NumPy Reference

Release 2.2.0

Written by the NumPy community

January 19, 2025

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Release
2.2

Date
January 19, 2025

This reference manual details functions, modules, and objects included in NumPy, describing what they are and what they do. For learning how to use NumPy, see the complete documentation.

CHAPTER

ONE

PYTHON API

1.1 NumPy's module structure

NumPy has a large number of submodules. Most regular usage of NumPy requires only the main namespace and a smaller set of submodules. The rest either either special-purpose or niche namespaces.

1.1.1 Main namespaces

Regular/recommended user-facing namespaces for general use:

- *numpy*
- *numpy.exceptions*
- *numpy.fft*
- *numpy.linalg*
- *numpy.polynomial*
- *numpy.random*
- *numpy.strings*
- *numpy.testing*
- *numpy.typing*

1.1.2 Special-purpose namespaces

- *numpy.ctypeslib* - interacting with NumPy objects with `ctypes`
- *numpy.dtypes* - dtype classes (typically not used directly by end users)
- *numpy.emath* - mathematical functions with automatic domain
- *numpy.lib* - utilities & functionality which do not fit the main namespace
- *numpy.rec* - record arrays (largely superseded by dataframe libraries)
- *numpy.version* - small module with more detailed version info

1.1.3 Legacy namespaces

Prefer not to use these namespaces for new code. There are better alternatives and/or this code is deprecated or isn't reliable.

- *numpy.char* - legacy string functionality, only for fixed-width strings
- *numpy.distutils* (deprecated) - build system support
- *numpy.f2py* - Fortran binding generation (usually used from the command line only)
- *numpy.ma* - masked arrays (not very reliable, needs an overhaul)
- *numpy.matlib* (pending deprecation) - functions supporting `matrix` instances

Exceptions and Warnings (`numpy.exceptions`)

General exceptions used by NumPy. Note that some exceptions may be module specific, such as linear algebra errors.

New in version NumPy: 1.25

The exceptions module is new in NumPy 1.25. Older exceptions remain available through the main NumPy namespace for compatibility.

Warnings

ComplexWarning	The warning raised when casting a complex dtype to a real dtype.
VisibleDeprecationWarning	Visible deprecation warning.
RankWarning	Matrix rank warning.

exception exceptions.**ComplexWarning**

The warning raised when casting a complex dtype to a real dtype.

As implemented, casting a complex number to a real discards its imaginary part, but this behavior may not be what the user actually wants.

exception exceptions.**VisibleDeprecationWarning**

Visible deprecation warning.

By default, python will not show deprecation warnings, so this class can be used when a very visible warning is helpful, for example because the usage is most likely a user bug.

exception exceptions.**RankWarning**

Matrix rank warning.

Issued by polynomial functions when the design matrix is rank deficient.

Exceptions

AxisError(axis[, ndim, msg_prefix])	Axis supplied was invalid.
DTypePromotionError	Multiple DTypes could not be converted to a common one.
TooHardError	max_work was exceeded.

exception exceptions.**AxisError**(*axis*, *ndim=None*, *msg_prefix=None*)

Axis supplied was invalid.

This is raised whenever an `axis` parameter is specified that is larger than the number of array dimensions. For compatibility with code written against older numpy versions, which raised a mixture of `ValueError` and `IndexError` for this situation, this exception subclasses both to ensure that `except ValueError` and `except IndexError` statements continue to catch `AxisError`.

Parameters

axis
[int or str] The out of bounds axis or a custom exception message. If an axis is provided, then *ndim* should be specified as well.

ndim
[int, optional] The number of array dimensions.

msg_prefix
[str, optional] A prefix for the exception message.

Examples

```
>>> import numpy as np
>>> array_1d = np.arange(10)
>>> np.cumsum(array_1d, axis=1)
Traceback (most recent call last):
  ...
numpy.exceptions.AxisError: axis 1 is out of bounds for array of dimension 1
```

Negative axes are preserved:

```
>>> np.cumsum(array_1d, axis=-2)
Traceback (most recent call last):
  ...
numpy.exceptions.AxisError: axis -2 is out of bounds for array of dimension 1
```

The class constructor generally takes the axis and arrays' dimensionality as arguments:

```
>>> print(np.exceptions.AxisError(2, 1, msg_prefix='error'))
error: axis 2 is out of bounds for array of dimension 1
```

Alternatively, a custom exception message can be passed:

```
>>> print(np.exceptions.AxisError('Custom error message'))
Custom error message
```

Attributes

axis
: [int, optional] The out of bounds axis or `None` if a custom exception message was provided. This should be the axis as passed by the user, before any normalization to resolve negative indices.

  New in version 1.22.

ndim
: [int, optional] The number of array dimensions or `None` if a custom exception message was provided.

  New in version 1.22.

exception exceptions.**DTypePromotionError**

Multiple DTypes could not be converted to a common one.

This exception derives from `TypeError` and is raised whenever dtypes cannot be converted to a single common one. This can be because they are of a different category/class or incompatible instances of the same one (see Examples).

Notes

Many functions will use promotion to find the correct result and implementation. For these functions the error will typically be chained with a more specific error indicating that no implementation was found for the input dtypes.

Typically promotion should be considered "invalid" between the dtypes of two arrays when *arr1 == arr2* can safely return all `False` because the dtypes are fundamentally different.

Examples

Datetimes and complex numbers are incompatible classes and cannot be promoted:

```
>>> import numpy as np
>>> np.result_type(np.dtype("M8[s]"), np.complex128)
Traceback (most recent call last):
 ...
DTypePromotionError: The DType <class 'numpy.dtype[datetime64]'> could not
be promoted by <class 'numpy.dtype[complex128]'>. This means that no common
DType exists for the given inputs. For example they cannot be stored in a
single array unless the dtype is `object`. The full list of DTypes is:
(<class 'numpy.dtype[datetime64]'>, <class 'numpy.dtype[complex128]'>)
```

For example for structured dtypes, the structure can mismatch and the same `DTypePromotionError` is given when two structured dtypes with a mismatch in their number of fields is given:

```
>>> dtype1 = np.dtype([("field1", np.float64), ("field2", np.int64)])
>>> dtype2 = np.dtype([("field1", np.float64)])
>>> np.promote_types(dtype1, dtype2)
Traceback (most recent call last):
 ...
DTypePromotionError: field names `('field1', 'field2')` and `('field1',)`
mismatch.
```

exception exceptions.**TooHardError**

max_work was exceeded.

This is raised whenever the maximum number of candidate solutions to consider specified by the `max_work` parameter is exceeded. Assigning a finite number to max_work may have caused the operation to fail.

Discrete Fourier Transform (`numpy.fft`)

The SciPy module `scipy.fft` is a more comprehensive superset of `numpy.fft`, which includes only a basic set of routines.

Standard FFTs

fft(a[, n, axis, norm, out])	Compute the one-dimensional discrete Fourier Transform.
ifft(a[, n, axis, norm, out])	Compute the one-dimensional inverse discrete Fourier Transform.
fft2(a[, s, axes, norm, out])	Compute the 2-dimensional discrete Fourier Transform.
ifft2(a[, s, axes, norm, out])	Compute the 2-dimensional inverse discrete Fourier Transform.
fftn(a[, s, axes, norm, out])	Compute the N-dimensional discrete Fourier Transform.
ifftn(a[, s, axes, norm, out])	Compute the N-dimensional inverse discrete Fourier Transform.

`fft.`**`fft`**(*a*, *n=None*, *axis=-1*, *norm=None*, *out=None*)

Compute the one-dimensional discrete Fourier Transform.

This function computes the one-dimensional *n*-point discrete Fourier Transform (DFT) with the efficient Fast Fourier Transform (FFT) algorithm [CT].

Parameters

a
[array_like] Input array, can be complex.

n
[int, optional] Length of the transformed axis of the output. If *n* is smaller than the length of the input, the input is cropped. If it is larger, the input is padded with zeros. If *n* is not given, the length of the input along the axis specified by *axis* is used.

axis
[int, optional] Axis over which to compute the FFT. If not given, the last axis is used.

norm
[{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The "backward", "forward" values were added.

out
[complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype.

New in version 2.0.0.

Returns

out
[complex ndarray] The truncated or zero-padded input, transformed along the axis indicated by *axis*, or the last one if *axis* is not specified.

Raises

IndexError
If *axis* is not a valid axis of *a*.

See also:

numpy.fft
for definition of the DFT and conventions used.

ifft
The inverse of *fft*.

fft2
The two-dimensional FFT.

fftn
The *n*-dimensional FFT.

rfftn
The *n*-dimensional FFT of real input.

fftfreq
Frequency bins for given FFT parameters.

Notes

FFT (Fast Fourier Transform) refers to a way the discrete Fourier Transform (DFT) can be calculated efficiently, by using symmetries in the calculated terms. The symmetry is highest when *n* is a power of 2, and the transform is therefore most efficient for these sizes.

The DFT is defined, with the conventions used in this implementation, in the documentation for the *numpy.fft* module.

References

[CT]

Examples

```
>>> import numpy as np
>>> np.fft.fft(np.exp(2j * np.pi * np.arange(8) / 8))
array([-2.33486982e-16+1.14423775e-17j,  8.00000000e+00-1.25557246e-15j,
        2.33486982e-16+2.33486982e-16j,  0.00000000e+00+1.22464680e-16j,
       -1.14423775e-17+2.33486982e-16j,  0.00000000e+00+5.20784380e-16j,
        1.14423775e-17+1.14423775e-17j,  0.00000000e+00+1.22464680e-16j])
```

In this example, real input has an FFT which is Hermitian, i.e., symmetric in the real part and anti-symmetric in the imaginary part, as described in the *numpy.fft* documentation:

```
>>> import matplotlib.pyplot as plt
>>> t = np.arange(256)
>>> sp = np.fft.fft(np.sin(t))
>>> freq = np.fft.fftfreq(t.shape[-1])
>>> plt.plot(freq, sp.real, freq, sp.imag)
[<matplotlib.lines.Line2D object at 0x...>, <matplotlib.lines.Line2D object at 0x.
```

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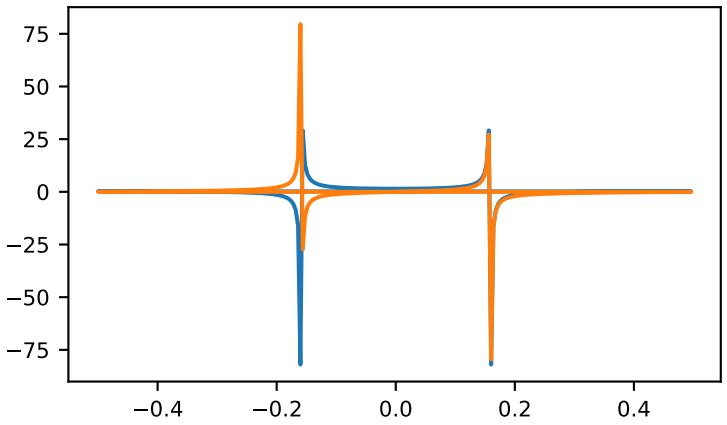
```
↪..>]
>>> plt.show()
```



`fft.`**`ifft`**(*a*, *n=None*, *axis=-1*, *norm=None*, *out=None*)

Compute the one-dimensional inverse discrete Fourier Transform.

This function computes the inverse of the one-dimensional *n*-point discrete Fourier transform computed by *fft*. In other words, `ifft(fft(a)) == a` to within numerical accuracy. For a general description of the algorithm and definitions, see *numpy.fft*.

The input should be ordered in the same way as is returned by *fft*, i.e.,

- `a[0]` should contain the zero frequency term,
- `a[1:n//2]` should contain the positive-frequency terms,
- `a[n//2 + 1:]` should contain the negative-frequency terms, in increasing order starting from the most negative frequency.

For an even number of input points, `A[n//2]` represents the sum of the values at the positive and negative Nyquist frequencies, as the two are aliased together. See *numpy.fft* for details.

Parameters

a
: [array_like] Input array, can be complex.

n
: [int, optional] Length of the transformed axis of the output. If *n* is smaller than the length of the input, the input is cropped. If it is larger, the input is padded with zeros. If *n* is not given, the length of the input along the axis specified by *axis* is used. See notes about padding issues.

axis
: [int, optional] Axis over which to compute the inverse DFT. If not given, the last axis is used.

norm
: [{“backward”, “ortho”, “forward”}, optional] Normalization mode (see *numpy.fft*). Default is “backward”. Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The “backward”, “forward” values were added.

out
[complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype.

New in version 2.0.0.

Returns

out
[complex ndarray] The truncated or zero-padded input, transformed along the axis indicated by *axis*, or the last one if *axis* is not specified.

Raises

IndexError
If *axis* is not a valid axis of *a*.

See also:

numpy.fft
An introduction, with definitions and general explanations.

fft
The one-dimensional (forward) FFT, of which *ifft* is the inverse

ifft2
The two-dimensional inverse FFT.

ifftn
The n-dimensional inverse FFT.

Notes

If the input parameter *n* is larger than the size of the input, the input is padded by appending zeros at the end. Even though this is the common approach, it might lead to surprising results. If a different padding is desired, it must be performed before calling *ifft*.

Examples

```
>>> import numpy as np
>>> np.fft.ifft([0, 4, 0, 0])
array([ 1.+0.j,  0.+1.j, -1.+0.j,  0.-1.j]) # may vary
```

Create and plot a band-limited signal with random phases:

```
>>> import matplotlib.pyplot as plt
>>> t = np.arange(400)
>>> n = np.zeros((400,), dtype=complex)
>>> n[40:60] = np.exp(1j*np.random.uniform(0, 2*np.pi, (20,)))
>>> s = np.fft.ifft(n)
>>> plt.plot(t, s.real, label='real')
[<matplotlib.lines.Line2D object at ...>]
>>> plt.plot(t, s.imag, '--', label='imaginary')
[<matplotlib.lines.Line2D object at ...>]
>>> plt.legend()
```

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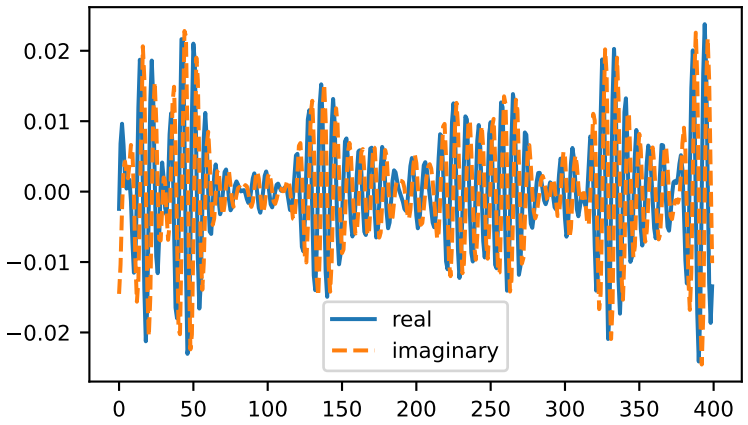
```
<matplotlib.legend.Legend object at ...>
>>> plt.show()
```



`fft.`**`fft2`**(*a*, *s=None*, *axes=(-2, -1)*, *norm=None*, *out=None*)

Compute the 2-dimensional discrete Fourier Transform.

This function computes the *n*-dimensional discrete Fourier Transform over any axes in an *M*-dimensional array by means of the Fast Fourier Transform (FFT). By default, the transform is computed over the last two axes of the input array, i.e., a 2-dimensional FFT.

Parameters

a

[array_like] Input array, can be complex

s

[sequence of ints, optional] Shape (length of each transformed axis) of the output (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). This corresponds to `n` for `fft(x, n)`. Along each axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros.

Changed in version 2.0: If it is `-1`, the whole input is used (no padding/trimming).

If *s* is not given, the shape of the input along the axes specified by *axes* is used.

Deprecated since version 2.0: If *s* is not `None`, *axes* must not be `None` either.

Deprecated since version 2.0: *s* must contain only `int` s, not `None` values. `None` values currently mean that the default value for `n` is used in the corresponding 1-D transform, but this behaviour is deprecated.

axes

[sequence of ints, optional] Axes over which to compute the FFT. If not given, the last two axes are used. A repeated index in *axes* means the transform over that axis is performed multiple times. A one-element sequence means that a one-dimensional FFT is performed. Default: `(-2, -1)`.

Deprecated since version 2.0: If *s* is specified, the corresponding *axes* to be transformed must not be `None`.

norm
[{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The "backward", "forward" values were added.

out
[complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype for all axes (and hence only the last axis can have `s` not equal to the shape at that axis).

New in version 2.0.0.

Returns

out
[complex ndarray] The truncated or zero-padded input, transformed along the axes indicated by *axes*, or the last two axes if *axes* is not given.

Raises

ValueError
If *s* and *axes* have different length, or *axes* not given and `len(s) != 2`.

IndexError
If an element of *axes* is larger than than the number of axes of *a*.

See also:

numpy.fft
Overall view of discrete Fourier transforms, with definitions and conventions used.

ifft2
The inverse two-dimensional FFT.

fft
The one-dimensional FFT.

fftn
The *n*-dimensional FFT.

fftshift
Shifts zero-frequency terms to the center of the array. For two-dimensional input, swaps first and third quadrants, and second and fourth quadrants.

Notes

fft2 is just *fftn* with a different default for *axes*.

The output, analogously to *fft*, contains the term for zero frequency in the low-order corner of the transformed axes, the positive frequency terms in the first half of these axes, the term for the Nyquist frequency in the middle of the axes and the negative frequency terms in the second half of the axes, in order of decreasingly negative frequency.

See *fftn* for details and a plotting example, and *numpy.fft* for definitions and conventions used.

Examples

```
>>> import numpy as np
>>> a = np.mgrid[:5, :5][0]
>>> np.fft.fft2(a)
array([[ 50.  +0.j        ,   0.  +0.j        ,   0.  +0.j        , # may vary
          0.  +0.j        ,   0.  +0.j        ],
       [-12.5+17.20477401j,   0.  +0.j        ,   0.  +0.j        ,
          0.  +0.j        ,   0.  +0.j        ],
       [-12.5 +4.0614962j ,   0.  +0.j        ,   0.  +0.j        ,
          0.  +0.j        ,   0.  +0.j        ],
       [-12.5 -4.0614962j ,   0.  +0.j        ,   0.  +0.j        ,
          0.  +0.j        ,   0.  +0.j        ],
       [-12.5-17.20477401j,   0.  +0.j        ,   0.  +0.j        ,
          0.  +0.j        ,   0.  +0.j        ]])
```

`fft.`**`ifft2`**(*a*, *s=None*, *axes=(-2, -1)*, *norm=None*, *out=None*)

Compute the 2-dimensional inverse discrete Fourier Transform.

This function computes the inverse of the 2-dimensional discrete Fourier Transform over any number of axes in an M-dimensional array by means of the Fast Fourier Transform (FFT). In other words, `ifft2(fft2(a)) == a` to within numerical accuracy. By default, the inverse transform is computed over the last two axes of the input array.

The input, analogously to *ifft*, should be ordered in the same way as is returned by *fft2*, i.e. it should have the term for zero frequency in the low-order corner of the two axes, the positive frequency terms in the first half of these axes, the term for the Nyquist frequency in the middle of the axes and the negative frequency terms in the second half of both axes, in order of decreasingly negative frequency.

Parameters

a
: [array_like] Input array, can be complex.

s
: [sequence of ints, optional] Shape (length of each axis) of the output (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). This corresponds to *n* for `ifft(x, n)`. Along each axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros.

  Changed in version 2.0: If it is `-1`, the whole input is used (no padding/trimming).

  If *s* is not given, the shape of the input along the axes specified by *axes* is used. See notes for issue on *ifft* zero padding.

  Deprecated since version 2.0: If *s* is not `None`, *axes* must not be `None` either.

  Deprecated since version 2.0: *s* must contain only `int` s, not `None` values. `None` values currently mean that the default value for `n` is used in the corresponding 1-D transform, but this behaviour is deprecated.

axes
: [sequence of ints, optional] Axes over which to compute the FFT. If not given, the last two axes are used. A repeated index in *axes* means the transform over that axis is performed multiple times. A one-element sequence means that a one-dimensional FFT is performed. Default: `(-2, -1)`.

  Deprecated since version 2.0: If *s* is specified, the corresponding *axes* to be transformed must not be `None`.

norm
: [{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

  New in version 1.20.0: The "backward", "forward" values were added.

out
: [complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype for all axes (and hence is incompatible with passing in all but the trivial `s`).

  New in version 2.0.0.

Returns

out
: [complex ndarray] The truncated or zero-padded input, transformed along the axes indicated by *axes*, or the last two axes if *axes* is not given.

Raises

ValueError
: If *s* and *axes* have different length, or *axes* not given and `len(s) != 2`.

IndexError
: If an element of *axes* is larger than than the number of axes of *a*.

See also:

numpy.fft
: Overall view of discrete Fourier transforms, with definitions and conventions used.

fft2
: The forward 2-dimensional FFT, of which *ifft2* is the inverse.

ifftn
: The inverse of the *n*-dimensional FFT.

fft
: The one-dimensional FFT.

ifft
: The one-dimensional inverse FFT.

Notes

ifft2 is just *ifftn* with a different default for *axes*.

See *ifftn* for details and a plotting example, and *numpy.fft* for definition and conventions used.

Zero-padding, analogously with *ifft*, is performed by appending zeros to the input along the specified dimension. Although this is the common approach, it might lead to surprising results. If another form of zero padding is desired, it must be performed before *ifft2* is called.

Examples

```
>>> import numpy as np
>>> a = 4 * np.eye(4)
>>> np.fft.ifft2(a)
array([[1.+0.j,  0.+0.j,  0.+0.j,  0.+0.j], # may vary
       [0.+0.j,  0.+0.j,  0.+0.j,  1.+0.j],
       [0.+0.j,  0.+0.j,  1.+0.j,  0.+0.j],
       [0.+0.j,  1.+0.j,  0.+0.j,  0.+0.j]])
```

`fft.`**`fftn`**(*a*, *s=None*, *axes=None*, *norm=None*, *out=None*)

Compute the N-dimensional discrete Fourier Transform.

This function computes the *N*-dimensional discrete Fourier Transform over any number of axes in an *M*-dimensional array by means of the Fast Fourier Transform (FFT).

Parameters

a
: [array_like] Input array, can be complex.

s
: [sequence of ints, optional] Shape (length of each transformed axis) of the output (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). This corresponds to `n` for `fft(x, n)`. Along any axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros.

  Changed in version 2.0: If it is `-1`, the whole input is used (no padding/trimming).

  If *s* is not given, the shape of the input along the axes specified by *axes* is used.

  Deprecated since version 2.0: If *s* is not `None`, *axes* must not be `None` either.

  Deprecated since version 2.0: *s* must contain only `int` s, not `None` values. `None` values currently mean that the default value for `n` is used in the corresponding 1-D transform, but this behaviour is deprecated.

axes
: [sequence of ints, optional] Axes over which to compute the FFT. If not given, the last `len(s)` axes are used, or all axes if *s* is also not specified. Repeated indices in *axes* means that the transform over that axis is performed multiple times.

  Deprecated since version 2.0: If *s* is specified, the corresponding *axes* to be transformed must be explicitly specified too.

norm
: [{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

  New in version 1.20.0: The "backward", "forward" values were added.

out
: [complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype for all axes (and hence is incompatible with passing in all but the trivial `s`).

  New in version 2.0.0.

Returns

out
[complex ndarray] The truncated or zero-padded input, transformed along the axes indicated by *axes*, or by a combination of *s* and *a*, as explained in the parameters section above.

Raises

ValueError
If *s* and *axes* have different length.

IndexError
If an element of *axes* is larger than than the number of axes of *a*.

See also:

numpy.fft
Overall view of discrete Fourier transforms, with definitions and conventions used.

ifftn
The inverse of `fftn`, the inverse *n*-dimensional FFT.

fft
The one-dimensional FFT, with definitions and conventions used.

rfftn
The *n*-dimensional FFT of real input.

fft2
The two-dimensional FFT.

fftshift
Shifts zero-frequency terms to centre of array

Notes

The output, analogously to `fft`, contains the term for zero frequency in the low-order corner of all axes, the positive frequency terms in the first half of all axes, the term for the Nyquist frequency in the middle of all axes and the negative frequency terms in the second half of all axes, in order of decreasingly negative frequency.

See `numpy.fft` for details, definitions and conventions used.

Examples

```
>>> import numpy as np
>>> a = np.mgrid[:3, :3, :3][0]
>>> np.fft.fftn(a, axes=(1, 2))
array([[[ 0.+0.j,   0.+0.j,   0.+0.j], # may vary
        [ 0.+0.j,   0.+0.j,   0.+0.j],
        [ 0.+0.j,   0.+0.j,   0.+0.j]],
       [[ 9.+0.j,   0.+0.j,   0.+0.j],
        [ 0.+0.j,   0.+0.j,   0.+0.j],
        [ 0.+0.j,   0.+0.j,   0.+0.j]],
       [[18.+0.j,   0.+0.j,   0.+0.j],
        [ 0.+0.j,   0.+0.j,   0.+0.j],
        [ 0.+0.j,   0.+0.j,   0.+0.j]]])
>>> np.fft.fftn(a, (2, 2), axes=(0, 1))
array([[[ 2.+0.j,  2.+0.j,  2.+0.j], # may vary
        [ 0.+0.j,  0.+0.j,  0.+0.j]],
```

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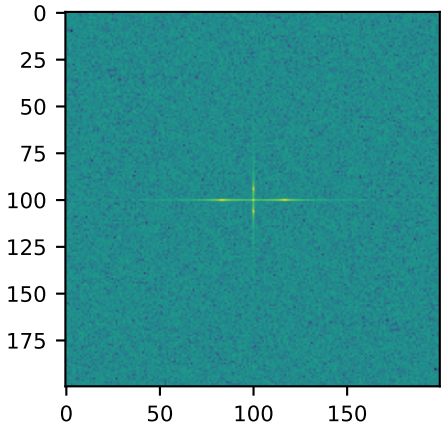
```
       [[-2.+0.j, -2.+0.j, -2.+0.j],
        [ 0.+0.j,  0.+0.j,  0.+0.j]]])
```

```
>>> import matplotlib.pyplot as plt
>>> [X, Y] = np.meshgrid(2 * np.pi * np.arange(200) / 12,
...                      2 * np.pi * np.arange(200) / 34)
>>> S = np.sin(X) + np.cos(Y) + np.random.uniform(0, 1, X.shape)
>>> FS = np.fft.fftn(S)
>>> plt.imshow(np.log(np.abs(np.fft.fftshift(FS))**2))
<matplotlib.image.AxesImage object at 0x...>
>>> plt.show()
```



`fft.`**`ifftn`**(*a*, *s=None*, *axes=None*, *norm=None*, *out=None*)

Compute the N-dimensional inverse discrete Fourier Transform.

This function computes the inverse of the N-dimensional discrete Fourier Transform over any number of axes in an M-dimensional array by means of the Fast Fourier Transform (FFT). In other words, `ifftn(fftn(a)) == a` to within numerical accuracy. For a description of the definitions and conventions used, see *numpy.fft*.

The input, analogously to *ifft*, should be ordered in the same way as is returned by *fftn*, i.e. it should have the term for zero frequency in all axes in the low-order corner, the positive frequency terms in the first half of all axes, the term for the Nyquist frequency in the middle of all axes and the negative frequency terms in the second half of all axes, in order of decreasingly negative frequency.

Parameters

a

[array_like] Input array, can be complex.

s

[sequence of ints, optional] Shape (length of each transformed axis) of the output (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). This corresponds to `n` for `ifft(x, n)`. Along any axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros.

Changed in version 2.0: If it is `-1`, the whole input is used (no padding/trimming).

If *s* is not given, the shape of the input along the axes specified by *axes* is used. See notes for issue on `ifft` zero padding.

Deprecated since version 2.0: If *s* is not `None`, *axes* must not be `None` either.

Deprecated since version 2.0: *s* must contain only `int` s, not `None` values. `None` values currently mean that the default value for `n` is used in the corresponding 1-D transform, but this behaviour is deprecated.

axes
[sequence of ints, optional] Axes over which to compute the IFFT. If not given, the last `len(s)` axes are used, or all axes if *s* is also not specified. Repeated indices in *axes* means that the inverse transform over that axis is performed multiple times.

Deprecated since version 2.0: If *s* is specified, the corresponding *axes* to be transformed must be explicitly specified too.

norm
[{"backward", "ortho", "forward"}, optional] Normalization mode (see `numpy.fft`). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The "backward", "forward" values were added.

out
[complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype for all axes (and hence is incompatible with passing in all but the trivial `s`).

New in version 2.0.0.

Returns

out
[complex ndarray] The truncated or zero-padded input, transformed along the axes indicated by *axes*, or by a combination of *s* or *a*, as explained in the parameters section above.

Raises

ValueError
If *s* and *axes* have different length.

IndexError
If an element of *axes* is larger than than the number of axes of *a*.

See also:

numpy.fft
Overall view of discrete Fourier transforms, with definitions and conventions used.

fftn
The forward *n*-dimensional FFT, of which `ifftn` is the inverse.

ifft
The one-dimensional inverse FFT.

ifft2
The two-dimensional inverse FFT.

ifftshift
Undoes `fftshift`, shifts zero-frequency terms to beginning of array.

Notes

See *numpy.fft* for definitions and conventions used.

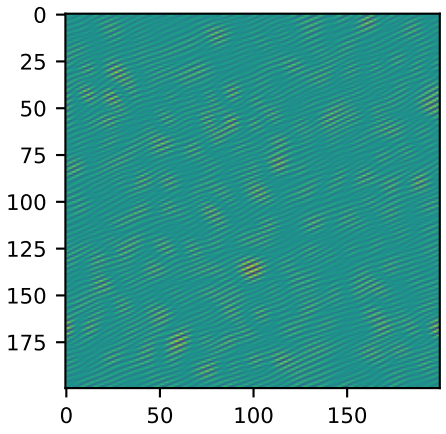
Zero-padding, analogously with *ifft*, is performed by appending zeros to the input along the specified dimension. Although this is the common approach, it might lead to surprising results. If another form of zero padding is desired, it must be performed before *ifftn* is called.

Examples

```
>>> import numpy as np
>>> a = np.eye(4)
>>> np.fft.ifftn(np.fft.fftn(a, axes=(0,)), axes=(1,))
array([[1.+0.j,  0.+0.j,  0.+0.j,  0.+0.j], # may vary
       [0.+0.j,  1.+0.j,  0.+0.j,  0.+0.j],
       [0.+0.j,  0.+0.j,  1.+0.j,  0.+0.j],
       [0.+0.j,  0.+0.j,  0.+0.j,  1.+0.j]])
```

Create and plot an image with band-limited frequency content:

```
>>> import matplotlib.pyplot as plt
>>> n = np.zeros((200,200), dtype=complex)
>>> n[60:80, 20:40] = np.exp(1j*np.random.uniform(0, 2*np.pi, (20, 20)))
>>> im = np.fft.ifftn(n).real
>>> plt.imshow(im)
<matplotlib.image.AxesImage object at 0x...>
>>> plt.show()
```



Real FFTs

rfft(a[, n, axis, norm, out])	Compute the one-dimensional discrete Fourier Transform for real input.
irfft(a[, n, axis, norm, out])	Computes the inverse of *rfft*.
rfft2(a[, s, axes, norm, out])	Compute the 2-dimensional FFT of a real array.
irfft2(a[, s, axes, norm, out])	Computes the inverse of *rfft2*.
rfftn(a[, s, axes, norm, out])	Compute the N-dimensional discrete Fourier Transform for real input.
irfftn(a[, s, axes, norm, out])	Computes the inverse of *rfftn*.

fft.**rfft**(*a*, *n=None*, *axis=-1*, *norm=None*, *out=None*)

Compute the one-dimensional discrete Fourier Transform for real input.

This function computes the one-dimensional *n*-point discrete Fourier Transform (DFT) of a real-valued array by means of an efficient algorithm called the Fast Fourier Transform (FFT).

Parameters

a
[array_like] Input array

n
[int, optional] Number of points along transformation axis in the input to use. If *n* is smaller than the length of the input, the input is cropped. If it is larger, the input is padded with zeros. If *n* is not given, the length of the input along the axis specified by *axis* is used.

axis
[int, optional] Axis over which to compute the FFT. If not given, the last axis is used.

norm
[{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The "backward", "forward" values were added.

out
[complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype.

New in version 2.0.0.

Returns

out
[complex ndarray] The truncated or zero-padded input, transformed along the axis indicated by *axis*, or the last one if *axis* is not specified. If *n* is even, the length of the transformed axis is `(n/2)+1`. If *n* is odd, the length is `(n+1)/2`.

Raises

IndexError
If *axis* is not a valid axis of *a*.

See also:

numpy.fft
For definition of the DFT and conventions used.

irfft
The inverse of *rfft*.

fft
The one-dimensional FFT of general (complex) input.

fftn
The *n*-dimensional FFT.

rfftn
The *n*-dimensional FFT of real input.

Notes

When the DFT is computed for purely real input, the output is Hermitian-symmetric, i.e. the negative frequency terms are just the complex conjugates of the corresponding positive-frequency terms, and the negative-frequency terms are therefore redundant. This function does not compute the negative frequency terms, and the length of the transformed axis of the output is therefore `n//2 + 1`.

When `A = rfft(a)` and fs is the sampling frequency, `A[0]` contains the zero-frequency term 0*fs, which is real due to Hermitian symmetry.

If *n* is even, `A[-1]` contains the term representing both positive and negative Nyquist frequency (+fs/2 and -fs/2), and must also be purely real. If *n* is odd, there is no term at fs/2; `A[-1]` contains the largest positive frequency (fs/2*(n-1)/n), and is complex in the general case.

If the input *a* contains an imaginary part, it is silently discarded.

Examples

```
>>> import numpy as np
>>> np.fft.fft([0, 1, 0, 0])
array([ 1.+0.j,  0.-1.j, -1.+0.j,  0.+1.j]) # may vary
>>> np.fft.rfft([0, 1, 0, 0])
array([ 1.+0.j,  0.-1.j, -1.+0.j]) # may vary
```

Notice how the final element of the *fft* output is the complex conjugate of the second element, for real input. For *rfft*, this symmetry is exploited to compute only the non-negative frequency terms.

`fft.`**`irfft`**(*a*, *n=None*, *axis=-1*, *norm=None*, *out=None*)

Computes the inverse of *rfft*.

This function computes the inverse of the one-dimensional *n*-point discrete Fourier Transform of real input computed by *rfft*. In other words, `irfft(rfft(a), len(a)) == a` to within numerical accuracy. (See Notes below for why `len(a)` is necessary here.)

The input is expected to be in the form returned by *rfft*, i.e. the real zero-frequency term followed by the complex positive frequency terms in order of increasing frequency. Since the discrete Fourier Transform of real input is Hermitian-symmetric, the negative frequency terms are taken to be the complex conjugates of the corresponding positive frequency terms.

Parameters

a
[array_like] The input array.

n
[int, optional] Length of the transformed axis of the output. For *n* output points, `n//2+1`

input points are necessary. If the input is longer than this, it is cropped. If it is shorter than this, it is padded with zeros. If *n* is not given, it is taken to be `2*(m-1)` where `m` is the length of the input along the axis specified by *axis*.

axis
[int, optional] Axis over which to compute the inverse FFT. If not given, the last axis is used.

norm
[{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The "backward", "forward" values were added.

out
[ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype.

New in version 2.0.0.

Returns

out
[ndarray] The truncated or zero-padded input, transformed along the axis indicated by *axis*, or the last one if *axis* is not specified. The length of the transformed axis is *n*, or, if *n* is not given, `2*(m-1)` where `m` is the length of the transformed axis of the input. To get an odd number of output points, *n* must be specified.

Raises

IndexError
If *axis* is not a valid axis of *a*.

See also:

numpy.fft
For definition of the DFT and conventions used.

rfft
The one-dimensional FFT of real input, of which *irfft* is inverse.

fft
The one-dimensional FFT.

irfft2
The inverse of the two-dimensional FFT of real input.

irfftn
The inverse of the *n*-dimensional FFT of real input.

Notes

Returns the real valued *n*-point inverse discrete Fourier transform of *a*, where *a* contains the non-negative frequency terms of a Hermitian-symmetric sequence. *n* is the length of the result, not the input.

If you specify an *n* such that *a* must be zero-padded or truncated, the extra/removed values will be added/removed at high frequencies. One can thus resample a series to *m* points via Fourier interpolation by: `a_resamp = irfft(rfft(a), m)`.

The correct interpretation of the hermitian input depends on the length of the original data, as given by *n*. This is because each input shape could correspond to either an odd or even length signal. By default, *irfft* assumes an

even output length which puts the last entry at the Nyquist frequency; aliasing with its symmetric counterpart. By Hermitian symmetry, the value is thus treated as purely real. To avoid losing information, the correct length of the real input **must** be given.

Examples

```
>>> import numpy as np
>>> np.fft.ifft([1, -1j, -1, 1j])
array([0.+0.j,  1.+0.j,  0.+0.j,  0.+0.j]) # may vary
>>> np.fft.irfft([1, -1j, -1])
array([0.,  1.,  0.,  0.])
```

Notice how the last term in the input to the ordinary *ifft* is the complex conjugate of the second term, and the output has zero imaginary part everywhere. When calling *irfft*, the negative frequencies are not specified, and the output array is purely real.

fft.**rfft2**(*a*, *s=None*, *axes=(-2, -1)*, *norm=None*, *out=None*)

Compute the 2-dimensional FFT of a real array.

Parameters

a
[array] Input array, taken to be real.

s
[sequence of ints, optional] Shape of the FFT.

Changed in version 2.0: If it is `-1`, the whole input is used (no padding/trimming).

Deprecated since version 2.0: If *s* is not `None`, *axes* must not be `None` either.

Deprecated since version 2.0: *s* must contain only `int` s, not `None` values. `None` values currently mean that the default value for `n` is used in the corresponding 1-D transform, but this behaviour is deprecated.

axes
[sequence of ints, optional] Axes over which to compute the FFT. Default: `(-2, -1)`.

Deprecated since version 2.0: If *s* is specified, the corresponding *axes* to be transformed must not be `None`.

norm
[{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The "backward", "forward" values were added.

out
[complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype for the last inverse transform. incompatible with passing in all but the trivial `s`).

New in version 2.0.0.

Returns

out
[ndarray] The result of the real 2-D FFT.

See also:

rfftn
Compute the N-dimensional discrete Fourier Transform for real input.

Notes

This is really just *rfftn* with different default behavior. For more details see *rfftn*.

Examples

```
>>> import numpy as np
>>> a = np.mgrid[:5, :5][0]
>>> np.fft.rfft2(a)
array([[ 50.  +0.j        ,   0.  +0.j        ,   0.  +0.j        ],
       [-12.5+17.20477401j,   0.  +0.j        ,   0.  +0.j        ],
       [-12.5 +4.0614962j ,   0.  +0.j        ,   0.  +0.j        ],
       [-12.5 -4.0614962j ,   0.  +0.j        ,   0.  +0.j        ],
       [-12.5-17.20477401j,   0.  +0.j        ,   0.  +0.j        ]])
```

`fft.`**`irfft2`**(*a*, *s=None*, *axes=(-2, -1)*, *norm=None*, *out=None*)
Computes the inverse of *rfft2*.

Parameters

a
[array_like] The input array

s
[sequence of ints, optional] Shape of the real output to the inverse FFT.

Changed in version 2.0: If it is `-1`, the whole input is used (no padding/trimming).

Deprecated since version 2.0: If *s* is not `None`, *axes* must not be `None` either.

Deprecated since version 2.0: *s* must contain only `int` s, not `None` values. `None` values currently mean that the default value for `n` is used in the corresponding 1-D transform, but this behaviour is deprecated.

axes
[sequence of ints, optional] The axes over which to compute the inverse fft. Default: `(-2, -1)`, the last two axes.

Deprecated since version 2.0: If *s* is specified, the corresponding *axes* to be transformed must not be `None`.

norm
[{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The "backward", "forward" values were added.

out
[ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype for the last transformation.

New in version 2.0.0.

Returns

out
[ndarray] The result of the inverse real 2-D FFT.

See also:

rfft2
The forward two-dimensional FFT of real input, of which *irfft2* is the inverse.

rfft
The one-dimensional FFT for real input.

irfft
The inverse of the one-dimensional FFT of real input.

irfftn
Compute the inverse of the N-dimensional FFT of real input.

Notes

This is really *irfftn* with different defaults. For more details see *irfftn*.

Examples

```
>>> import numpy as np
>>> a = np.mgrid[:5, :5][0]
>>> A = np.fft.rfft2(a)
>>> np.fft.irfft2(A, s=a.shape)
array([[0., 0., 0., 0., 0.],
       [1., 1., 1., 1., 1.],
       [2., 2., 2., 2., 2.],
       [3., 3., 3., 3., 3.],
       [4., 4., 4., 4., 4.]])
```

fft.**rfftn**(*a*, *s=None*, *axes=None*, *norm=None*, *out=None*)

Compute the N-dimensional discrete Fourier Transform for real input.

This function computes the N-dimensional discrete Fourier Transform over any number of axes in an M-dimensional real array by means of the Fast Fourier Transform (FFT). By default, all axes are transformed, with the real transform performed over the last axis, while the remaining transforms are complex.

Parameters

a
[array_like] Input array, taken to be real.

s
[sequence of ints, optional] Shape (length along each transformed axis) to use from the input. (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). The final element of *s* corresponds to *n* for `rfft(x, n)`, while for the remaining axes, it corresponds to *n* for `fft(x, n)`. Along any axis, if the given shape is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros.

Changed in version 2.0: If it is `-1`, the whole input is used (no padding/trimming).

If *s* is not given, the shape of the input along the axes specified by *axes* is used.

Deprecated since version 2.0: If *s* is not `None`, *axes* must not be `None` either.

Deprecated since version 2.0: *s* must contain only `int` s, not `None` values. `None` values currently mean that the default value for `n` is used in the corresponding 1-D transform, but this behaviour is deprecated.

axes
[sequence of ints, optional] Axes over which to compute the FFT. If not given, the last `len(s)` axes are used, or all axes if *s* is also not specified.

Deprecated since version 2.0: If *s* is specified, the corresponding *axes* to be transformed must be explicitly specified too.

norm
[{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The "backward", "forward" values were added.

out
[complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype for all axes (and hence is incompatible with passing in all but the trivial `s`).

New in version 2.0.0.

Returns

out
[complex ndarray] The truncated or zero-padded input, transformed along the axes indicated by *axes*, or by a combination of *s* and *a*, as explained in the parameters section above. The length of the last axis transformed will be `s[-1]//2+1`, while the remaining transformed axes will have lengths according to *s*, or unchanged from the input.

Raises

ValueError
If *s* and *axes* have different length.

IndexError
If an element of *axes* is larger than than the number of axes of *a*.

See also:

irfftn
The inverse of *rfftn*, i.e. the inverse of the n-dimensional FFT of real input.

fft
The one-dimensional FFT, with definitions and conventions used.

rfft
The one-dimensional FFT of real input.

fftn
The n-dimensional FFT.

rfft2
The two-dimensional FFT of real input.

Notes

The transform for real input is performed over the last transformation axis, as by *rfft*, then the transform over the remaining axes is performed as by *fftn*. The order of the output is as for *rfft* for the final transformation axis, and as for *fftn* for the remaining transformation axes.

See *fft* for details, definitions and conventions used.

Examples

```
>>> import numpy as np
>>> a = np.ones((2, 2, 2))
>>> np.fft.rfftn(a)
array([[[8.+0.j,  0.+0.j], # may vary
        [0.+0.j,  0.+0.j]],
       [[0.+0.j,  0.+0.j],
        [0.+0.j,  0.+0.j]]])
```

```
>>> np.fft.rfftn(a, axes=(2, 0))
array([[[4.+0.j,  0.+0.j], # may vary
        [4.+0.j,  0.+0.j]],
       [[0.+0.j,  0.+0.j],
        [0.+0.j,  0.+0.j]]])
```

fft.**irfftn**(*a*, *s=None*, *axes=None*, *norm=None*, *out=None*)

Computes the inverse of *rfftn*.

This function computes the inverse of the N-dimensional discrete Fourier Transform for real input over any number of axes in an M-dimensional array by means of the Fast Fourier Transform (FFT). In other words, `irfftn(rfftn(a), a.shape) == a` to within numerical accuracy. (The `a.shape` is necessary like `len(a)` is for *irfft*, and for the same reason.)

The input should be ordered in the same way as is returned by *rfftn*, i.e. as for *irfft* for the final transformation axis, and as for *ifftn* along all the other axes.

Parameters

a

[array_like] Input array.

s

[sequence of ints, optional] Shape (length of each transformed axis) of the output (`s[0]` refers to axis 0, `s[1]` to axis 1, etc.). *s* is also the number of input points used along this axis, except for the last axis, where `s[-1]//2+1` points of the input are used. Along any axis, if the shape indicated by *s* is smaller than that of the input, the input is cropped. If it is larger, the input is padded with zeros.

Changed in version 2.0: If it is `-1`, the whole input is used (no padding/trimming).

If *s* is not given, the shape of the input along the axes specified by axes is used. Except for the last axis which is taken to be `2*(m-1)` where `m` is the length of the input along that axis.

Deprecated since version 2.0: If *s* is not `None`, *axes* must not be `None` either.

Deprecated since version 2.0: *s* must contain only `int` s, not `None` values. `None` values currently mean that the default value for `n` is used in the corresponding 1-D transform, but this behaviour is deprecated.

axes
: [sequence of ints, optional] Axes over which to compute the inverse FFT. If not given, the last *len(s)* axes are used, or all axes if *s* is also not specified. Repeated indices in *axes* means that the inverse transform over that axis is performed multiple times.

  Deprecated since version 2.0: If *s* is specified, the corresponding *axes* to be transformed must be explicitly specified too.

norm
: [{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

  New in version 1.20.0: The "backward", "forward" values were added.

out
: [ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype for the last transformation.

  New in version 2.0.0.

Returns

out
: [ndarray] The truncated or zero-padded input, transformed along the axes indicated by *axes*, or by a combination of *s* or *a*, as explained in the parameters section above. The length of each transformed axis is as given by the corresponding element of *s*, or the length of the input in every axis except for the last one if *s* is not given. In the final transformed axis the length of the output when *s* is not given is `2*(m-1)` where `m` is the length of the final transformed axis of the input. To get an odd number of output points in the final axis, *s* must be specified.

Raises

ValueError
: If *s* and *axes* have different length.

IndexError
: If an element of *axes* is larger than than the number of axes of *a*.

See also:

rfftn
: The forward n-dimensional FFT of real input, of which *ifftn* is the inverse.

fft
: The one-dimensional FFT, with definitions and conventions used.

irfft
: The inverse of the one-dimensional FFT of real input.

irfft2
: The inverse of the two-dimensional FFT of real input.

Notes

See *fft* for definitions and conventions used.

See *rfft* for definitions and conventions used for real input.

The correct interpretation of the hermitian input depends on the shape of the original data, as given by *s*. This is because each input shape could correspond to either an odd or even length signal. By default, *irfftn* assumes an even output length which puts the last entry at the Nyquist frequency; aliasing with its symmetric counterpart. When performing the final complex to real transform, the last value is thus treated as purely real. To avoid losing information, the correct shape of the real input **must** be given.

Examples

```
>>> import numpy as np
>>> a = np.zeros((3, 2, 2))
>>> a[0, 0, 0] = 3 * 2 * 2
>>> np.fft.irfftn(a)
array([[[1.,  1.],
        [1.,  1.]],
       [[1.,  1.],
        [1.,  1.]],
       [[1.,  1.],
        [1.,  1.]]])
```

Hermitian FFTs

hfft(a[, n, axis, norm, out])	Compute the FFT of a signal that has Hermitian symmetry, i.e., a real spectrum.
ihfft(a[, n, axis, norm, out])	Compute the inverse FFT of a signal that has Hermitian symmetry.

`fft.`**`hfft`**(*a*, *n=None*, *axis=-1*, *norm=None*, *out=None*)

Compute the FFT of a signal that has Hermitian symmetry, i.e., a real spectrum.

Parameters

a
[array_like] The input array.

n
[int, optional] Length of the transformed axis of the output. For *n* output points, `n//2 + 1` input points are necessary. If the input is longer than this, it is cropped. If it is shorter than this, it is padded with zeros. If *n* is not given, it is taken to be `2*(m-1)` where `m` is the length of the input along the axis specified by *axis*.

axis
[int, optional] Axis over which to compute the FFT. If not given, the last axis is used.

norm
[{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

New in version 1.20.0: The "backward", "forward" values were added.

out
: [ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype.

  New in version 2.0.0.

Returns

out
: [ndarray] The truncated or zero-padded input, transformed along the axis indicated by *axis*, or the last one if *axis* is not specified. The length of the transformed axis is *n*, or, if *n* is not given, `2*m - 2` where `m` is the length of the transformed axis of the input. To get an odd number of output points, *n* must be specified, for instance as `2*m - 1` in the typical case,

Raises

IndexError
: If *axis* is not a valid axis of *a*.

See also:

rfft
: Compute the one-dimensional FFT for real input.

ihfft
: The inverse of *hfft*.

Notes

hfft/*ihfft* are a pair analogous to *rfft*/*irfft*, but for the opposite case: here the signal has Hermitian symmetry in the time domain and is real in the frequency domain. So here it's *hfft* for which you must supply the length of the result if it is to be odd.

- even: `ihfft(hfft(a, 2*len(a) - 2)) == a`, within roundoff error,
- odd: `ihfft(hfft(a, 2*len(a) - 1)) == a`, within roundoff error.

The correct interpretation of the hermitian input depends on the length of the original data, as given by *n*. This is because each input shape could correspond to either an odd or even length signal. By default, *hfft* assumes an even output length which puts the last entry at the Nyquist frequency; aliasing with its symmetric counterpart. By Hermitian symmetry, the value is thus treated as purely real. To avoid losing information, the shape of the full signal **must** be given.

Examples

```
>>> import numpy as np
>>> signal = np.array([1, 2, 3, 4, 3, 2])
>>> np.fft.fft(signal)
array([15.+0.j,  -4.+0.j,   0.+0.j,  -1.-0.j,   0.+0.j,  -4.+0.j]) # may vary
>>> np.fft.hfft(signal[:4]) # Input first half of signal
array([15.,  -4.,   0.,  -1.,   0.,  -4.])
>>> np.fft.hfft(signal, 6)  # Input entire signal and truncate
array([15.,  -4.,   0.,  -1.,   0.,  -4.])
```

```
>>> signal = np.array([[1, 1.j], [-1.j, 2]])
>>> np.conj(signal.T) - signal   # check Hermitian symmetry
array([[ 0.-0.j,  -0.+0.j], # may vary
```

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```
       [ 0.+0.j,  0.-0.j]])
>>> freq_spectrum = np.fft.hfft(signal)
>>> freq_spectrum
array([[ 1.,  1.],
       [ 2., -2.]])
```

fft.**ihfft**(*a*, *n=None*, *axis=-1*, *norm=None*, *out=None*)

Compute the inverse FFT of a signal that has Hermitian symmetry.

Parameters

a
: [array_like] Input array.

n
: [int, optional] Length of the inverse FFT, the number of points along transformation axis in the input to use. If *n* is smaller than the length of the input, the input is cropped. If it is larger, the input is padded with zeros. If *n* is not given, the length of the input along the axis specified by *axis* is used.

axis
: [int, optional] Axis over which to compute the inverse FFT. If not given, the last axis is used.

norm
: [{"backward", "ortho", "forward"}, optional] Normalization mode (see *numpy.fft*). Default is "backward". Indicates which direction of the forward/backward pair of transforms is scaled and with what normalization factor.

  New in version 1.20.0: The "backward", "forward" values were added.

out
: [complex ndarray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype.

  New in version 2.0.0.

Returns

out
: [complex ndarray] The truncated or zero-padded input, transformed along the axis indicated by *axis*, or the last one if *axis* is not specified. The length of the transformed axis is `n//2 + 1`.

See also:

hfft*, *irfft

Notes

hfft/*ihfft* are a pair analogous to *rfft*/*irfft*, but for the opposite case: here the signal has Hermitian symmetry in the time domain and is real in the frequency domain. So here it's *hfft* for which you must supply the length of the result if it is to be odd:

- even: `ihfft(hfft(a, 2*len(a) - 2)) == a`, within roundoff error,
- odd: `ihfft(hfft(a, 2*len(a) - 1)) == a`, within roundoff error.

Examples

```
>>> import numpy as np
>>> spectrum = np.array([ 15, -4, 0, -1, 0, -4])
>>> np.fft.ifft(spectrum)
array([1.+0.j,  2.+0.j,  3.+0.j,  4.+0.j,  3.+0.j,  2.+0.j]) # may vary
>>> np.fft.ihfft(spectrum)
array([ 1.-0.j,  2.-0.j,  3.-0.j,  4.-0.j]) # may vary
```

Helper routines

fftfreq(n[, d, device])	Return the Discrete Fourier Transform sample frequencies.
rfftfreq(n[, d, device])	Return the Discrete Fourier Transform sample frequencies (for usage with rfft, irfft).
fftshift(x[, axes])	Shift the zero-frequency component to the center of the spectrum.
ifftshift(x[, axes])	The inverse of *fftshift*.

fft.**fftfreq**(*n*, *d=1.0*, *device=None*)

Return the Discrete Fourier Transform sample frequencies.

The returned float array f contains the frequency bin centers in cycles per unit of the sample spacing (with zero at the start). For instance, if the sample spacing is in seconds, then the frequency unit is cycles/second.

Given a window length n and a sample spacing d:

```
f = [0, 1, ...,   n/2-1,     -n/2, ..., -1] / (d*n)   if n is even
f = [0, 1, ..., (n-1)/2, -(n-1)/2, ..., -1] / (d*n)   if n is odd
```

Parameters

n
: [int] Window length.

d
: [scalar, optional] Sample spacing (inverse of the sampling rate). Defaults to 1.

device
: [str, optional] The device on which to place the created array. Default: `None`. For Array-API interoperability only, so must be `"cpu"` if passed.

  New in version 2.0.0.

Returns

f
: [ndarray] Array of length n containing the sample frequencies.

Examples

```
>>> import numpy as np
>>> signal = np.array([-2, 8, 6, 4, 1, 0, 3, 5], dtype=float)
>>> fourier = np.fft.fft(signal)
>>> n = signal.size
>>> timestep = 0.1
>>> freq = np.fft.fftfreq(n, d=timestep)
>>> freq
array([ 0.  ,  1.25,  2.5 , ..., -3.75, -2.5 , -1.25])
```

fft.**rfftfreq**(*n*, *d=1.0*, *device=None*)

Return the Discrete Fourier Transform sample frequencies (for usage with rfft, irfft).

The returned float array *f* contains the frequency bin centers in cycles per unit of the sample spacing (with zero at the start). For instance, if the sample spacing is in seconds, then the frequency unit is cycles/second.

Given a window length *n* and a sample spacing *d*:

```
f = [0, 1, ...,     n/2-1,     n/2] / (d*n)   if n is even
f = [0, 1, ..., (n-1)/2-1, (n-1)/2] / (d*n)   if n is odd
```

Unlike *fftfreq* (but like `scipy.fftpack.rfftfreq`) the Nyquist frequency component is considered to be positive.

Parameters

n
: [int] Window length.

d
: [scalar, optional] Sample spacing (inverse of the sampling rate). Defaults to 1.

device
: [str, optional] The device on which to place the created array. Default: `None`. For Array-API interoperability only, so must be `"cpu"` if passed.

  New in version 2.0.0.

Returns

f
: [ndarray] Array of length `n//2 + 1` containing the sample frequencies.

Examples

```
>>> import numpy as np
>>> signal = np.array([-2, 8, 6, 4, 1, 0, 3, 5, -3, 4], dtype=float)
>>> fourier = np.fft.rfft(signal)
>>> n = signal.size
>>> sample_rate = 100
>>> freq = np.fft.fftfreq(n, d=1./sample_rate)
>>> freq
array([  0.,  10.,  20., ..., -30., -20., -10.])
>>> freq = np.fft.rfftfreq(n, d=1./sample_rate)
>>> freq
array([  0.,  10.,  20.,  30.,  40.,  50.])
```

fft.**fftshift**(*x*, *axes=None*)

Shift the zero-frequency component to the center of the spectrum.

This function swaps half-spaces for all axes listed (defaults to all). Note that `y[0]` is the Nyquist component only if `len(x)` is even.

Parameters

x
[array_like] Input array.

axes
[int or shape tuple, optional] Axes over which to shift. Default is None, which shifts all axes.

Returns

y
[ndarray] The shifted array.

See also:

ifftshift
The inverse of *fftshift*.

Examples

```
>>> import numpy as np
>>> freqs = np.fft.fftfreq(10, 0.1)
>>> freqs
array([ 0.,  1.,  2., ..., -3., -2., -1.])
>>> np.fft.fftshift(freqs)
array([-5., -4., -3., -2., -1.,  0.,  1.,  2.,  3.,  4.])
```

Shift the zero-frequency component only along the second axis:

```
>>> freqs = np.fft.fftfreq(9, d=1./9).reshape(3, 3)
>>> freqs
array([[ 0.,  1.,  2.],
       [ 3.,  4., -4.],
       [-3., -2., -1.]])
>>> np.fft.fftshift(freqs, axes=(1,))
array([[ 2.,  0.,  1.],
       [-4.,  3.,  4.],
       [-1., -3., -2.]])
```

fft.**ifftshift**(*x*, *axes=None*)

The inverse of *fftshift*. Although identical for even-length *x*, the functions differ by one sample for odd-length *x*.

Parameters

x
[array_like] Input array.

axes
[int or shape tuple, optional] Axes over which to calculate. Defaults to None, which shifts all axes.

Returns

y
[ndarray] The shifted array.

See also:

fftshift
Shift zero-frequency component to the center of the spectrum.

Examples

```
>>> import numpy as np
>>> freqs = np.fft.fftfreq(9, d=1./9).reshape(3, 3)
>>> freqs
array([[ 0.,  1.,  2.],
       [ 3.,  4., -4.],
       [-3., -2., -1.]])
>>> np.fft.ifftshift(np.fft.fftshift(freqs))
array([[ 0.,  1.,  2.],
       [ 3.,  4., -4.],
       [-3., -2., -1.]])
```

Background information

Fourier analysis is fundamentally a method for expressing a function as a sum of periodic components, and for recovering the function from those components. When both the function and its Fourier transform are replaced with discretized counterparts, it is called the discrete Fourier transform (DFT). The DFT has become a mainstay of numerical computing in part because of a very fast algorithm for computing it, called the Fast Fourier Transform (FFT), which was known to Gauss (1805) and was brought to light in its current form by Cooley and Tukey [CT]. Press et al. [NR] provide an accessible introduction to Fourier analysis and its applications.

Because the discrete Fourier transform separates its input into components that contribute at discrete frequencies, it has a great number of applications in digital signal processing, e.g., for filtering, and in this context the discretized input to the transform is customarily referred to as a *signal*, which exists in the *time domain*. The output is called a *spectrum* or *transform* and exists in the *frequency domain*.

Implementation details

There are many ways to define the DFT, varying in the sign of the exponent, normalization, etc. In this implementation, the DFT is defined as

$$A_k = \sum_{m=0}^{n-1} a_m \exp\left\{-2\pi i \frac{mk}{n}\right\} \qquad k = 0, \ldots, n-1.$$

The DFT is in general defined for complex inputs and outputs, and a single-frequency component at linear frequency f is represented by a complex exponential $a_m = \exp\{2\pi i\, f m \Delta t\}$, where Δt is the sampling interval.

The values in the result follow so-called "standard" order: If `A = fft(a, n)`, then `A[0]` contains the zero-frequency term (the sum of the signal), which is always purely real for real inputs. Then `A[1:n/2]` contains the positive-frequency terms, and `A[n/2+1:]` contains the negative-frequency terms, in order of decreasingly negative frequency. For an even number of input points, `A[n/2]` represents both positive and negative Nyquist frequency, and is also purely real for real input. For an odd number of input points, `A[(n-1)/2]` contains the largest positive frequency, while `A[(n+1)/2]` contains the largest negative frequency. The routine `np.fft.fftfreq(n)` returns an array giving the frequencies of corresponding elements in the output. The routine `np.fft.fftshift(A)` shifts transforms and their frequencies to put the zero-frequency components in the middle, and `np.fft.ifftshift(A)` undoes that shift.

When the input *a* is a time-domain signal and `A = fft(a)`, `np.abs(A)` is its amplitude spectrum and `np.abs(A)**2` is its power spectrum. The phase spectrum is obtained by `np.angle(A)`.

The inverse DFT is defined as

$$a_m = \frac{1}{n}\sum_{k=0}^{n-1} A_k \exp\left\{2\pi i \frac{mk}{n}\right\} \qquad m = 0, \ldots, n-1.$$

It differs from the forward transform by the sign of the exponential argument and the default normalization by $1/n$.

Type Promotion

numpy.fft promotes `float32` and `complex64` arrays to `float64` and `complex128` arrays respectively. For an FFT implementation that does not promote input arrays, see `scipy.fftpack`.

Normalization

The argument `norm` indicates which direction of the pair of direct/inverse transforms is scaled and with what normalization factor. The default normalization (`"backward"`) has the direct (forward) transforms unscaled and the inverse (backward) transforms scaled by $1/n$. It is possible to obtain unitary transforms by setting the keyword argument `norm` to `"ortho"` so that both direct and inverse transforms are scaled by $1/\sqrt{n}$. Finally, setting the keyword argument `norm` to `"forward"` has the direct transforms scaled by $1/n$ and the inverse transforms unscaled (i.e. exactly opposite to the default `"backward"`). *None* is an alias of the default option `"backward"` for backward compatibility.

Real and Hermitian transforms

When the input is purely real, its transform is Hermitian, i.e., the component at frequency f_k is the complex conjugate of the component at frequency $-f_k$, which means that for real inputs there is no information in the negative frequency components that is not already available from the positive frequency components. The family of *rfft* functions is designed to operate on real inputs, and exploits this symmetry by computing only the positive frequency components, up to and including the Nyquist frequency. Thus, `n` input points produce `n/2+1` complex output points. The inverses of this family assumes the same symmetry of its input, and for an output of `n` points uses `n/2+1` input points.

Correspondingly, when the spectrum is purely real, the signal is Hermitian. The *hfft* family of functions exploits this symmetry by using `n/2+1` complex points in the input (time) domain for `n` real points in the frequency domain.

In higher dimensions, FFTs are used, e.g., for image analysis and filtering. The computational efficiency of the FFT means that it can also be a faster way to compute large convolutions, using the property that a convolution in the time domain is equivalent to a point-by-point multiplication in the frequency domain.

Higher dimensions

In two dimensions, the DFT is defined as

$$A_{kl} = \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} a_{mn} \exp\left\{-2\pi i \left(\frac{mk}{M} + \frac{nl}{N}\right)\right\} \qquad k = 0, \ldots, M-1; \quad l = 0, \ldots, N-1,$$

which extends in the obvious way to higher dimensions, and the inverses in higher dimensions also extend in the same way.

References

Examples

For examples, see the various functions.

Linear algebra (`numpy.linalg`)

The NumPy linear algebra functions rely on BLAS and LAPACK to provide efficient low level implementations of standard linear algebra algorithms. Those libraries may be provided by NumPy itself using C versions of a subset of their reference implementations but, when possible, highly optimized libraries that take advantage of specialized processor functionality are preferred. Examples of such libraries are OpenBLAS, MKL (TM), and ATLAS. Because those libraries are multithreaded and processor dependent, environmental variables and external packages such as threadpoolctl may be needed to control the number of threads or specify the processor architecture.

The SciPy library also contains a `linalg` submodule, and there is overlap in the functionality provided by the SciPy and NumPy submodules. SciPy contains functions not found in *numpy.linalg*, such as functions related to LU decomposition and the Schur decomposition, multiple ways of calculating the pseudoinverse, and matrix transcendentals such as the matrix logarithm. Some functions that exist in both have augmented functionality in `scipy.linalg`. For example, `scipy.linalg.eig` can take a second matrix argument for solving generalized eigenvalue problems. Some functions in NumPy, however, have more flexible broadcasting options. For example, *numpy.linalg.solve* can handle "stacked" arrays, while `scipy.linalg.solve` accepts only a single square array as its first argument.

Note: The term *matrix* as it is used on this page indicates a 2d *numpy.array* object, and *not* a *numpy.matrix* object. The latter is no longer recommended, even for linear algebra. See *the matrix object documentation* for more information.

The `@` operator

Introduced in NumPy 1.10.0, the `@` operator is preferable to other methods when computing the matrix product between 2d arrays. The *numpy.matmul* function implements the `@` operator.

Matrix and vector products

dot(a, b[, out])	Dot product of two arrays.
linalg.multi_dot(arrays, *[, out])	Compute the dot product of two or more arrays in a single function call, while automatically selecting the fastest evaluation order.
vdot(a, b, /)	Return the dot product of two vectors.
vecdot(x1, x2, /[, out, casting, order, ...])	Vector dot product of two arrays.
linalg.vecdot(x1, x2, /, *[, axis])	Computes the vector dot product.
inner(a, b, /)	Inner product of two arrays.
outer(a, b[, out])	Compute the outer product of two vectors.
matmul(x1, x2, /[, out, casting, order, ...])	Matrix product of two arrays.
linalg.matmul(x1, x2, /)	Computes the matrix product.
matvec(x1, x2, /[, out, casting, order, ...])	Matrix-vector dot product of two arrays.
vecmat(x1, x2, /[, out, casting, order, ...])	Vector-matrix dot product of two arrays.
tensordot(a, b[, axes])	Compute tensor dot product along specified axes.
linalg.tensordot(x1, x2, /, *[, axes])	Compute tensor dot product along specified axes.
einsum(subscripts, *operands[, out, dtype, ...])	Evaluates the Einstein summation convention on the operands.
einsum_path(subscripts, *operands[, optimize])	Evaluates the lowest cost contraction order for an einsum expression by considering the creation of intermediate arrays.
linalg.matrix_power(a, n)	Raise a square matrix to the (integer) power *n*.
kron(a, b)	Kronecker product of two arrays.
linalg.cross(x1, x2, /, *[, axis])	Returns the cross product of 3-element vectors.

numpy.**dot**(*a*, *b*, *out=None*)

Dot product of two arrays. Specifically,

- If both *a* and *b* are 1-D arrays, it is inner product of vectors (without complex conjugation).
- If both *a* and *b* are 2-D arrays, it is matrix multiplication, but using *matmul* or `a @ b` is preferred.
- If either *a* or *b* is 0-D (scalar), it is equivalent to *multiply* and using `numpy.multiply(a, b)` or `a * b` is preferred.
- If *a* is an N-D array and *b* is a 1-D array, it is a sum product over the last axis of *a* and *b*.
- If *a* is an N-D array and *b* is an M-D array (where `M>=2`), it is a sum product over the last axis of *a* and the second-to-last axis of *b*:

```
dot(a, b)[i,j,k,m] = sum(a[i,j,:] * b[k,:,m])
```

It uses an optimized BLAS library when possible (see *numpy.linalg*).

Parameters

a
: [array_like] First argument.

b
: [array_like] Second argument.

out
: [ndarray, optional] Output argument. This must have the exact kind that would be returned if it was not used. In particular, it must have the right type, must be C-contiguous, and its dtype must be the dtype that would be returned for *dot(a,b)*. This is a performance feature. Therefore, if these conditions are not met, an exception is raised, instead of attempting to be flexible.

Returns

output
: [ndarray] Returns the dot product of *a* and *b*. If *a* and *b* are both scalars or both 1-D arrays then a scalar is returned; otherwise an array is returned. If *out* is given, then it is returned.

Raises

ValueError
: If the last dimension of *a* is not the same size as the second-to-last dimension of *b*.

See also:

vdot
: Complex-conjugating dot product.

vecdot
: Vector dot product of two arrays.

tensordot
: Sum products over arbitrary axes.

einsum
: Einstein summation convention.

matmul
: '@' operator as method with out parameter.

linalg.multi_dot
: Chained dot product.

Examples

```
>>> import numpy as np
>>> np.dot(3, 4)
12
```

Neither argument is complex-conjugated:

```
>>> np.dot([2j, 3j], [2j, 3j])
(-13+0j)
```

For 2-D arrays it is the matrix product:

```
>>> a = [[1, 0], [0, 1]]
>>> b = [[4, 1], [2, 2]]
>>> np.dot(a, b)
array([[4, 1],
       [2, 2]])
```

```
>>> a = np.arange(3*4*5*6).reshape((3,4,5,6))
>>> b = np.arange(3*4*5*6)[::-1].reshape((5,4,6,3))
>>> np.dot(a, b)[2,3,2,1,2,2]
499128
>>> sum(a[2,3,2,:] * b[1,2,:,2])
499128
```

linalg.**multi_dot**(*arrays*, *, *out=None*)

Compute the dot product of two or more arrays in a single function call, while automatically selecting the fastest evaluation order.

multi_dot chains *numpy.dot* and uses optimal parenthesization of the matrices [1] [2]. Depending on the shapes of the matrices, this can speed up the multiplication a lot.

If the first argument is 1-D it is treated as a row vector. If the last argument is 1-D it is treated as a column vector. The other arguments must be 2-D.

Think of *multi_dot* as:

```
def multi_dot(arrays): return functools.reduce(np.dot, arrays)
```

Parameters

arrays
[sequence of array_like] If the first argument is 1-D it is treated as row vector. If the last argument is 1-D it is treated as column vector. The other arguments must be 2-D.

out
[ndarray, optional] Output argument. This must have the exact kind that would be returned if it was not used. In particular, it must have the right type, must be C-contiguous, and its dtype must be the dtype that would be returned for *dot(a, b)*. This is a performance feature. Therefore, if these conditions are not met, an exception is raised, instead of attempting to be flexible.

Returns

output
[ndarray] Returns the dot product of the supplied arrays.

See also:

numpy.dot
dot multiplication with two arguments.

Notes

The cost for a matrix multiplication can be calculated with the following function:

```
def cost(A, B):
    return A.shape[0] * A.shape[1] * B.shape[1]
```

Assume we have three matrices $A_{10x100}, B_{100x5}, C_{5x50}$.

The costs for the two different parenthesizations are as follows:

```
cost((AB)C) = 10*100*5 + 10*5*50   = 5000 + 2500   = 7500
cost(A(BC)) = 10*100*50 + 100*5*50 = 50000 + 25000 = 75000
```

References

[1], [2]

Examples

multi_dot allows you to write:

```
>>> import numpy as np
>>> from numpy.linalg import multi_dot
>>> # Prepare some data
>>> A = np.random.random((10000, 100))
>>> B = np.random.random((100, 1000))
>>> C = np.random.random((1000, 5))
>>> D = np.random.random((5, 333))
>>> # the actual dot multiplication
>>> _ = multi_dot([A, B, C, D])
```

instead of:

```
>>> _ = np.dot(np.dot(np.dot(A, B), C), D)
>>> # or
>>> _ = A.dot(B).dot(C).dot(D)
```

numpy.**vdot**(*a*, *b*, */*)

Return the dot product of two vectors.

The *vdot* function handles complex numbers differently than *dot*: if the first argument is complex, it is replaced by its complex conjugate in the dot product calculation. *vdot* also handles multidimensional arrays differently than *dot*: it does not perform a matrix product, but flattens the arguments to 1-D arrays before taking a vector dot product.

Consequently, when the arguments are 2-D arrays of the same shape, this function effectively returns their Frobenius inner product (also known as the *trace inner product* or the *standard inner product* on a vector space of matrices).

Parameters

a
: [array_like] If *a* is complex the complex conjugate is taken before calculation of the dot product.

b
: [array_like] Second argument to the dot product.

Returns

output
: [ndarray] Dot product of *a* and *b*. Can be an int, float, or complex depending on the types of *a* and *b*.

See also:

dot
: Return the dot product without using the complex conjugate of the first argument.

Examples

```
>>> import numpy as np
>>> a = np.array([1+2j,3+4j])
>>> b = np.array([5+6j,7+8j])
>>> np.vdot(a, b)
(70-8j)
>>> np.vdot(b, a)
(70+8j)
```

Note that higher-dimensional arrays are flattened!

```
>>> a = np.array([[1, 4], [5, 6]])
>>> b = np.array([[4, 1], [2, 2]])
>>> np.vdot(a, b)
30
>>> np.vdot(b, a)
30
>>> 1*4 + 4*1 + 5*2 + 6*2
30
```

numpy.**vecdot**(*x1*, *x2*, */*, *out=None*, ***, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*, *axes*, *axis*]) **= <ufunc 'vecdot'>**

Vector dot product of two arrays.

Let **a** be a vector in *x1* and **b** be a corresponding vector in *x2*. The dot product is defined as:

$$\mathbf{a} \cdot \mathbf{b} = \sum_{i=0}^{n-1} \overline{a_i} b_i$$

where the sum is over the last dimension (unless *axis* is specified) and where $\overline{a_i}$ denotes the complex conjugate if a_i is complex and the identity otherwise.

New in version 2.0.0.

Parameters

x1, x2
: [array_like] Input arrays, scalars not allowed.

out
: [ndarray, optional] A location into which the result is stored. If provided, it must have the broadcasted shape of *x1* and *x2* with the last axis removed. If not provided or None, a freshly-allocated array is used.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] The vector dot product of the inputs. This is a scalar only when both x1, x2 are 1-d vectors.

Raises

ValueError
: If the last dimension of *x1* is not the same size as the last dimension of *x2*.

: If a scalar value is passed in.

See also:

vdot
: same but flattens arguments first

matmul
: Matrix-matrix product.

vecmat
: Vector-matrix product.

matvec
: Matrix-vector product.

einsum
: Einstein summation convention.

Examples

```
>>> import numpy as np
```

Get the projected size along a given normal for an array of vectors.

```
>>> v = np.array([[0., 5., 0.], [0., 0., 10.], [0., 6., 8.]])
>>> n = np.array([0., 0.6, 0.8])
>>> np.vecdot(v, n)
array([ 3.,  8., 10.])
```

`linalg.`**`vecdot`**(*x1*, *x2*, */*, ***, *axis=-1*)

Computes the vector dot product.

This function is restricted to arguments compatible with the Array API, contrary to *`numpy.vecdot`*.

Let **a** be a vector in `x1` and **b** be a corresponding vector in `x2`. The dot product is defined as:

$$\mathbf{a} \cdot \mathbf{b} = \sum_{i=0}^{n-1} \overline{a_i} b_i$$

over the dimension specified by `axis` and where $\overline{a_i}$ denotes the complex conjugate if a_i is complex and the identity otherwise.

Parameters

x1
[array_like] First input array.

x2
[array_like] Second input array.

axis
[int, optional] Axis over which to compute the dot product. Default: `-1`.

Returns

output
[ndarray] The vector dot product of the input.

See also:

numpy.vecdot

Examples

Get the projected size along a given normal for an array of vectors.

```
>>> v = np.array([[0., 5., 0.], [0., 0., 10.], [0., 6., 8.]])
>>> n = np.array([0., 0.6, 0.8])
>>> np.linalg.vecdot(v, n)
array([ 3.,  8., 10.])
```

numpy.**inner**(*a*, *b*, */*)

Inner product of two arrays.

Ordinary inner product of vectors for 1-D arrays (without complex conjugation), in higher dimensions a sum product over the last axes.

Parameters

a, b
[array_like] If *a* and *b* are nonscalar, their last dimensions must match.

Returns

out
[ndarray] If *a* and *b* are both scalars or both 1-D arrays then a scalar is returned; otherwise an array is returned. `out.shape = (*a.shape[:-1], *b.shape[:-1])`

Raises

ValueError
If both *a* and *b* are nonscalar and their last dimensions have different sizes.

See also:

tensordot
Sum products over arbitrary axes.

dot
Generalised matrix product, using second last dimension of *b*.

vecdot
Vector dot product of two arrays.

einsum
Einstein summation convention.

Notes

For vectors (1-D arrays) it computes the ordinary inner-product:

```
np.inner(a, b) = sum(a[:]*b[:])
```

More generally, if `ndim(a) = r > 0` and `ndim(b) = s > 0`:

```
np.inner(a, b) = np.tensordot(a, b, axes=(-1,-1))
```

or explicitly:

```
np.inner(a, b)[i0,...,ir-2,j0,...,js-2]
     = sum(a[i0,...,ir-2,:]*b[j0,...,js-2,:])
```

In addition *a* or *b* may be scalars, in which case:

```
np.inner(a,b) = a*b
```

Examples

Ordinary inner product for vectors:

```
>>> import numpy as np
>>> a = np.array([1,2,3])
>>> b = np.array([0,1,0])
>>> np.inner(a, b)
2
```

Some multidimensional examples:

```
>>> a = np.arange(24).reshape((2,3,4))
>>> b = np.arange(4)
>>> c = np.inner(a, b)
>>> c.shape
(2, 3)
>>> c
array([[ 14,  38,  62],
       [ 86, 110, 134]])
```

```
>>> a = np.arange(2).reshape((1,1,2))
>>> b = np.arange(6).reshape((3,2))
>>> c = np.inner(a, b)
>>> c.shape
(1, 1, 3)
>>> c
array([[[1, 3, 5]]])
```

An example where *b* is a scalar:

```
>>> np.inner(np.eye(2), 7)
array([[7., 0.],
       [0., 7.]])
```

numpy.**outer**(*a*, *b*, *out=None*)

Compute the outer product of two vectors.

Given two vectors *a* and *b* of length `M` and `N`, respectively, the outer product [1] is:

```
[[a_0*b_0  a_0*b_1 ... a_0*b_{N-1} ]
 [a_1*b_0    .
 [ ...          .
 [a_{M-1}*b_0            a_{M-1}*b_{N-1} ]]
```

Parameters

a
: [(M,) array_like] First input vector. Input is flattened if not already 1-dimensional.

b
: [(N,) array_like] Second input vector. Input is flattened if not already 1-dimensional.

out
: [(M, N) ndarray, optional] A location where the result is stored

Returns

out
: [(M, N) ndarray] `out[i, j] = a[i] * b[j]`

See also:

inner

einsum
: `einsum('i,j->ij', a.ravel(), b.ravel())` is the equivalent.

ufunc.outer
: A generalization to dimensions other than 1D and other operations. `np.multiply.outer(a.ravel(), b.ravel())` is the equivalent.

linalg.outer
: An Array API compatible variation of `np.outer`, which accepts 1-dimensional inputs only.

tensordot
: `np.tensordot(a.ravel(), b.ravel(), axes=((), ()))` is the equivalent.

References

[1]

Examples

Make a (*very* coarse) grid for computing a Mandelbrot set:

```
>>> import numpy as np
>>> rl = np.outer(np.ones((5,)), np.linspace(-2, 2, 5))
>>> rl
array([[-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.]])
>>> im = np.outer(1j*np.linspace(2, -2, 5), np.ones((5,)))
>>> im
array([[0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j],
       [0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j],
       [0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j],
       [0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j],
       [0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j]])
>>> grid = rl + im
>>> grid
array([[-2.+2.j, -1.+2.j,  0.+2.j,  1.+2.j,  2.+2.j],
       [-2.+1.j, -1.+1.j,  0.+1.j,  1.+1.j,  2.+1.j],
       [-2.+0.j, -1.+0.j,  0.+0.j,  1.+0.j,  2.+0.j],
       [-2.-1.j, -1.-1.j,  0.-1.j,  1.-1.j,  2.-1.j],
       [-2.-2.j, -1.-2.j,  0.-2.j,  1.-2.j,  2.-2.j]])
```

An example using a “vector” of letters:

```
>>> x = np.array(['a', 'b', 'c'], dtype=object)
>>> np.outer(x, [1, 2, 3])
array([['a', 'aa', 'aaa'],
       ['b', 'bb', 'bbb'],
       ['c', 'cc', 'ccc']], dtype=object)
```

numpy.**matmul**(*x1*, *x2*, */*, *out=None*, ***, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*, *axes*, *axis*]) **= <ufunc 'matmul'>**

Matrix product of two arrays.

Parameters

x1, x2
: [array_like] Input arrays, scalars not allowed.

out
: [ndarray, optional] A location into which the result is stored. If provided, it must have a shape that matches the signature *(n,k),(k,m)->(n,m)*. If not provided or None, a freshly-allocated array is returned.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] The matrix product of the inputs. This is a scalar only when both x1, x2 are 1-d vectors.

Raises

ValueError
If the last dimension of *x1* is not the same size as the second-to-last dimension of *x2*.

If a scalar value is passed in.

See also:

vecdot
Complex-conjugating dot product for stacks of vectors.

matvec
Matrix-vector product for stacks of matrices and vectors.

vecmat
Vector-matrix product for stacks of vectors and matrices.

tensordot
Sum products over arbitrary axes.

einsum
Einstein summation convention.

dot
alternative matrix product with different broadcasting rules.

Notes

The behavior depends on the arguments in the following way.

- If both arguments are 2-D they are multiplied like conventional matrices.
- If either argument is N-D, N > 2, it is treated as a stack of matrices residing in the last two indexes and broadcast accordingly.
- If the first argument is 1-D, it is promoted to a matrix by prepending a 1 to its dimensions. After matrix multiplication the prepended 1 is removed. (For stacks of vectors, use `vecmat`.)
- If the second argument is 1-D, it is promoted to a matrix by appending a 1 to its dimensions. After matrix multiplication the appended 1 is removed. (For stacks of vectors, use `matvec`.)

`matmul` differs from `dot` in two important ways:

- Multiplication by scalars is not allowed, use `*` instead.
- Stacks of matrices are broadcast together as if the matrices were elements, respecting the signature `(n,k),(k,m)->(n,m)`:

```
>>> a = np.ones([9, 5, 7, 4])
>>> c = np.ones([9, 5, 4, 3])
>>> np.dot(a, c).shape
(9, 5, 7, 9, 5, 3)
>>> np.matmul(a, c).shape
(9, 5, 7, 3)
>>> # n is 7, k is 4, m is 3
```

The matmul function implements the semantics of the `@` operator introduced in Python 3.5 following **PEP 465**.

It uses an optimized BLAS library when possible (see *numpy.linalg*).

Examples

For 2-D arrays it is the matrix product:

```
>>> import numpy as np
```

```
>>> a = np.array([[1, 0],
...               [0, 1]])
>>> b = np.array([[4, 1],
...               [2, 2]])
>>> np.matmul(a, b)
array([[4, 1],
       [2, 2]])
```

For 2-D mixed with 1-D, the result is the usual.

```
>>> a = np.array([[1, 0],
...               [0, 1]])
>>> b = np.array([1, 2])
>>> np.matmul(a, b)
array([1, 2])
>>> np.matmul(b, a)
array([1, 2])
```

Broadcasting is conventional for stacks of arrays

```
>>> a = np.arange(2 * 2 * 4).reshape((2, 2, 4))
>>> b = np.arange(2 * 2 * 4).reshape((2, 4, 2))
>>> np.matmul(a,b).shape
(2, 2, 2)
>>> np.matmul(a, b)[0, 1, 1]
98
>>> sum(a[0, 1, :] * b[0 , :, 1])
98
```

Vector, vector returns the scalar inner product, but neither argument is complex-conjugated:

```
>>> np.matmul([2j, 3j], [2j, 3j])
(-13+0j)
```

Scalar multiplication raises an error.

```
>>> np.matmul([1,2], 3)
Traceback (most recent call last):
...
ValueError: matmul: Input operand 1 does not have enough dimensions ...
```

The `@` operator can be used as a shorthand for `np.matmul` on ndarrays.

```
>>> x1 = np.array([2j, 3j])
>>> x2 = np.array([2j, 3j])
>>> x1 @ x2
(-13+0j)
```

`linalg.`**`matmul`**(*x1*, *x2*, */*)

Computes the matrix product.

This function is Array API compatible, contrary to *`numpy.matmul`*.

Parameters

x1
[array_like] The first input array.

x2
[array_like] The second input array.

Returns

out
[ndarray] The matrix product of the inputs. This is a scalar only when both `x1`, `x2` are 1-d vectors.

Raises

ValueError
If the last dimension of `x1` is not the same size as the second-to-last dimension of `x2`.

If a scalar value is passed in.

See also:

numpy.matmul

Examples

For 2-D arrays it is the matrix product:

```
>>> a = np.array([[1, 0],
...               [0, 1]])
>>> b = np.array([[4, 1],
...               [2, 2]])
>>> np.linalg.matmul(a, b)
array([[4, 1],
       [2, 2]])
```

For 2-D mixed with 1-D, the result is the usual.

```
>>> a = np.array([[1, 0],
...               [0, 1]])
>>> b = np.array([1, 2])
>>> np.linalg.matmul(a, b)
array([1, 2])
>>> np.linalg.matmul(b, a)
array([1, 2])
```

Broadcasting is conventional for stacks of arrays

```
>>> a = np.arange(2 * 2 * 4).reshape((2, 2, 4))
>>> b = np.arange(2 * 2 * 4).reshape((2, 4, 2))
>>> np.linalg.matmul(a,b).shape
(2, 2, 2)
>>> np.linalg.matmul(a, b)[0, 1, 1]
98
>>> sum(a[0, 1, :] * b[0 , :, 1])
98
```

Vector, vector returns the scalar inner product, but neither argument is complex-conjugated:

```
>>> np.linalg.matmul([2j, 3j], [2j, 3j])
(-13+0j)
```

Scalar multiplication raises an error.

```
>>> np.linalg.matmul([1,2], 3)
Traceback (most recent call last):
...
ValueError: matmul: Input operand 1 does not have enough dimensions ...
```

numpy.**matvec**(*x1*, *x2*, */*, *out=None*, ***, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*, *axes*, *axis*]) **= <ufunc 'matvec'>**

Matrix-vector dot product of two arrays.

Given a matrix (or stack of matrices) **A** in `x1` and a vector (or stack of vectors) **v** in `x2`, the matrix-vector product is defined as:

$$\mathbf{A} \cdot \mathbf{b} = \sum_{j=0}^{n-1} A_{ij} v_j$$

where the sum is over the last dimensions in `x1` and `x2` (unless `axes` is specified). (For a matrix-vector product with the vector conjugated, use `np.vecmat(x2, x1.mT)`.)

New in version 2.2.0.

Parameters

x1, x2
[array_like] Input arrays, scalars not allowed.

out
[ndarray, optional] A location into which the result is stored. If provided, it must have the broadcasted shape of `x1` and `x2` with the summation axis removed. If not provided or None, a freshly-allocated array is used.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The matrix-vector product of the inputs.

Raises

ValueError
If the last dimensions of `x1` and `x2` are not the same size.

If a scalar value is passed in.

See also:

vecdot
Vector-vector product.

vecmat
Vector-matrix product.

matmul
Matrix-matrix product.

einsum
Einstein summation convention.

Examples

Rotate a set of vectors from Y to X along Z.

```
>>> a = np.array([[0., 1., 0.],
...               [-1., 0., 0.],
...               [0., 0., 1.]])
>>> v = np.array([[1., 0., 0.],
...               [0., 1., 0.],
...               [0., 0., 1.],
...               [0., 6., 8.]])
>>> np.matvec(a, v)
array([[ 0., -1.,  0.],
       [ 1.,  0.,  0.],
       [ 0.,  0.,  1.],
       [ 6.,  0.,  8.]])
```

numpy.**vecmat** (*x1*, *x2*, */*, *out=None*, ***, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*, *axes*, *axis*]) **= <ufunc 'vecmat'>**

Vector-matrix dot product of two arrays.

Given a vector (or stack of vector) **v** in `x1` and a matrix (or stack of matrices) **A** in `x2`, the vector-matrix product is defined as:

$$\mathbf{b} \cdot \mathbf{A} = \sum_{i=0}^{n-1} \overline{v_i} A_{ij}$$

where the sum is over the last dimension of `x1` and the one-but-last dimensions in `x2` (unless *axes* is specified) and where $\overline{v_i}$ denotes the complex conjugate if v is complex and the identity otherwise. (For a non-conjugated vector-matrix product, use `np.matvec(x2.mT, x1)`.)

New in version 2.2.0.

Parameters

x1, x2
[array_like] Input arrays, scalars not allowed.

out
[ndarray, optional] A location into which the result is stored. If provided, it must have the broadcasted shape of `x1` and `x2` with the summation axis removed. If not provided or None, a freshly-allocated array is used.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The vector-matrix product of the inputs.

Raises

ValueError
If the last dimensions of `x1` and the one-but-last dimension of `x2` are not the same size.

If a scalar value is passed in.

See also:

vecdot
Vector-vector product.

matvec
Matrix-vector product.

matmul
Matrix-matrix product.

einsum
Einstein summation convention.

Examples

Project a vector along X and Y.

```
>>> v = np.array([0., 4., 2.])
>>> a = np.array([[1., 0., 0.],
...               [0., 1., 0.],
...               [0., 0., 0.]])
>>> np.vecmat(v, a)
array([ 0.,  4., 0.])
```

numpy.**tensordot**(*a*, *b*, *axes=2*)

Compute tensor dot product along specified axes.

Given two tensors, *a* and *b*, and an array_like object containing two array_like objects, `(a_axes, b_axes)`, sum the products of *a*'s and *b*'s elements (components) over the axes specified by `a_axes` and `b_axes`. The third argument can be a single non-negative integer_like scalar, `N`; if it is such, then the last `N` dimensions of *a* and the first `N` dimensions of *b* are summed over.

Parameters

a, b
[array_like] Tensors to "dot".

axes
[int or (2,) array_like]

- integer_like If an int N, sum over the last N axes of *a* and the first N axes of *b* in order. The sizes of the corresponding axes must match.
- (2,) array_like Or, a list of axes to be summed over, first sequence applying to *a*, second to *b*. Both elements array_like must be of the same length.

Returns

output
[ndarray] The tensor dot product of the input.

See also:

dot, ***einsum***

Notes

Three common use cases are:

- `axes = 0` : tensor product $a \otimes b$
- `axes = 1` : tensor dot product $a \cdot b$
- `axes = 2` : (default) tensor double contraction $a : b$

When *axes* is integer_like, the sequence of axes for evaluation will be: from the -Nth axis to the -1th axis in *a*, and from the 0th axis to (N-1)th axis in *b*. For example, `axes = 2` is the equal to `axes = [[-2, -1], [0, 1]]`. When N-1 is smaller than 0, or when -N is larger than -1, the element of *a* and *b* are defined as the *axes*.

When there is more than one axis to sum over - and they are not the last (first) axes of *a* (*b*) - the argument *axes* should consist of two sequences of the same length, with the first axis to sum over given first in both sequences, the second axis second, and so forth. The calculation can be referred to `numpy.einsum`.

The shape of the result consists of the non-contracted axes of the first tensor, followed by the non-contracted axes of the second.

Examples

An example on integer_like:

```
>>> a_0 = np.array([[1, 2], [3, 4]])
>>> b_0 = np.array([[5, 6], [7, 8]])
>>> c_0 = np.tensordot(a_0, b_0, axes=0)
>>> c_0.shape
(2, 2, 2, 2)
>>> c_0
array([[[[ 5,  6],
         [ 7,  8]],
        [[10, 12],
         [14, 16]]],
       [[[15, 18],
         [21, 24]],
        [[20, 24],
         [28, 32]]]])
```

An example on array_like:

```
>>> a = np.arange(60.).reshape(3,4,5)
>>> b = np.arange(24.).reshape(4,3,2)
>>> c = np.tensordot(a,b, axes=([1,0],[0,1]))
>>> c.shape
(5, 2)
>>> c
array([[4400., 4730.],
       [4532., 4874.],
       [4664., 5018.],
       [4796., 5162.],
       [4928., 5306.]])
```

A slower but equivalent way of computing the same…

```
>>> d = np.zeros((5,2))
>>> for i in range(5):
...   for j in range(2):
...     for k in range(3):
...       for n in range(4):
...         d[i,j] += a[k,n,i] * b[n,k,j]
>>> c == d
array([[ True,  True],
       [ True,  True],
       [ True,  True],
       [ True,  True],
       [ True,  True]])
```

An extended example taking advantage of the overloading of + and *:

```
>>> a = np.array(range(1, 9))
>>> a.shape = (2, 2, 2)
>>> A = np.array(('a', 'b', 'c', 'd'), dtype=object)
>>> A.shape = (2, 2)
>>> a; A
array([[[1, 2],
        [3, 4]],
       [[5, 6],
        [7, 8]]])
array([['a', 'b'],
       ['c', 'd']], dtype=object)
```

```
>>> np.tensordot(a, A) # third argument default is 2 for double-contraction
array(['abbcccdddd', 'aaaaabbbbbbccccccdddddddd'], dtype=object)
```

```
>>> np.tensordot(a, A, 1)
array([[['acc', 'bdd'],
        ['aaacccc', 'bbbdddd']],
       [['aaaaacccccc', 'bbbbbddddddd'],
        ['aaaaaaaccccccc', 'bbbbbbbddddddd']]], dtype=object)
```

```
>>> np.tensordot(a, A, 0) # tensor product (result too long to incl.)
array([[[[['a', 'b'],
          ['c', 'd']],
          ...
```

```
>>> np.tensordot(a, A, (0, 1))
array([[['abbbbb', 'cddddd'],
        ['aabbbbbb', 'ccdddddd']],
       [['aaabbbbbbb', 'cccddddddd'],
        ['aaaabbbbbbbb', 'ccccddddddd']]], dtype=object)
```

```
>>> np.tensordot(a, A, (2, 1))
array([[['abb', 'cdd'],
        ['aaabbbb', 'cccdddd']],
       [['aaaaabbbbbb', 'ccccdddddd'],
        ['aaaaaaabbbbbbbb', 'ccccccddddddd']]], dtype=object)
```

```
>>> np.tensordot(a, A, ((0, 1), (0, 1)))
array(['abbbcccccddddddd', 'aabbbbbccccccddddddddd'], dtype=object)
```

```
>>> np.tensordot(a, A, ((2, 1), (1, 0)))
array(['acccbbdddd', 'aaaaaccccccbbbbbbddddddddd'], dtype=object)
```

linalg.**tensordot**(*x1*, *x2*, */*, *, *axes=2*)

Compute tensor dot product along specified axes.

Given two tensors, *a* and *b*, and an array_like object containing two array_like objects, `(a_axes, b_axes)`, sum the products of *a*'s and *b*'s elements (components) over the axes specified by `a_axes` and `b_axes`. The third argument can be a single non-negative integer_like scalar, `N`; if it is such, then the last `N` dimensions of *a* and the first `N` dimensions of *b* are summed over.

Parameters

a, b
[array_like] Tensors to "dot".

axes
[int or (2,) array_like]

- integer_like If an int N, sum over the last N axes of *a* and the first N axes of *b* in order. The sizes of the corresponding axes must match.
- (2,) array_like Or, a list of axes to be summed over, first sequence applying to *a*, second to *b*. Both elements array_like must be of the same length.

Returns

output
[ndarray] The tensor dot product of the input.

See also:

dot*, *einsum

Notes

Three common use cases are:

- `axes = 0` : tensor product $a \otimes b$
- `axes = 1` : tensor dot product $a \cdot b$
- `axes = 2` : (default) tensor double contraction $a : b$

When *axes* is integer_like, the sequence of axes for evaluation will be: from the -Nth axis to the -1th axis in *a*, and from the 0th axis to (N-1)th axis in *b*. For example, `axes = 2` is the equal to `axes = [[-2, -1], [0, 1]]`. When N-1 is smaller than 0, or when -N is larger than -1, the element of *a* and *b* are defined as the *axes*.

When there is more than one axis to sum over - and they are not the last (first) axes of *a* (*b*) - the argument *axes* should consist of two sequences of the same length, with the first axis to sum over given first in both sequences, the second axis second, and so forth. The calculation can be referred to `numpy.einsum`.

The shape of the result consists of the non-contracted axes of the first tensor, followed by the non-contracted axes of the second.

Examples

An example on integer_like:

```
>>> a_0 = np.array([[1, 2], [3, 4]])
>>> b_0 = np.array([[5, 6], [7, 8]])
>>> c_0 = np.tensordot(a_0, b_0, axes=0)
>>> c_0.shape
(2, 2, 2, 2)
>>> c_0
array([[[[ 5,  6],
         [ 7,  8]],
        [[10, 12],
         [14, 16]]],
       [[[15, 18],
         [21, 24]],
        [[20, 24],
         [28, 32]]]])
```

An example on array_like:

```
>>> a = np.arange(60.).reshape(3,4,5)
>>> b = np.arange(24.).reshape(4,3,2)
>>> c = np.tensordot(a,b, axes=([1,0],[0,1]))
>>> c.shape
(5, 2)
>>> c
array([[4400., 4730.],
       [4532., 4874.],
       [4664., 5018.],
       [4796., 5162.],
       [4928., 5306.]])
```

A slower but equivalent way of computing the same…

```
>>> d = np.zeros((5,2))
>>> for i in range(5):
...   for j in range(2):
...     for k in range(3):
...       for n in range(4):
...         d[i,j] += a[k,n,i] * b[n,k,j]
>>> c == d
array([[ True,  True],
       [ True,  True],
       [ True,  True],
       [ True,  True],
       [ True,  True]])
```

An extended example taking advantage of the overloading of + and *:

```
>>> a = np.array(range(1, 9))
>>> a.shape = (2, 2, 2)
>>> A = np.array(('a', 'b', 'c', 'd'), dtype=object)
>>> A.shape = (2, 2)
>>> a; A
array([[[1, 2],
        [3, 4]],
       [[5, 6],
```

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```
        [7, 8]]])
array([['a', 'b'],
       ['c', 'd']], dtype=object)
```

```
>>> np.tensordot(a, A) # third argument default is 2 for double-contraction
array(['abbcccdddd', 'aaaaabbbbbbccccccdddddddd'], dtype=object)
```

```
>>> np.tensordot(a, A, 1)
array([[['acc', 'bdd'],
        ['aaacccc', 'bbbdddd']],
       [['aaaaacccccc', 'bbbbbddddddd'],
        ['aaaaaaaccccccc', 'bbbbbbbddddddd']]], dtype=object)
```

```
>>> np.tensordot(a, A, 0) # tensor product (result too long to incl.)
array([[[[[['a', 'b'],
           ['c', 'd']],
          ...
```

```
>>> np.tensordot(a, A, (0, 1))
array([[['abbbbb', 'cddddd'],
        ['aabbbbbb', 'ccdddddd']],
       [['aaabbbbbbb', 'cccddddddd'],
        ['aaaabbbbbbbb', 'ccccdddddddd']]], dtype=object)
```

```
>>> np.tensordot(a, A, (2, 1))
array([[['abb', 'cdd'],
        ['aaabbbb', 'cccdddd']],
       [['aaaaabbbbbb', 'cccccdddddd'],
        ['aaaaaaabbbbbbbb', 'ccccccdddddddd']]], dtype=object)
```

```
>>> np.tensordot(a, A, ((0, 1), (0, 1)))
array(['abbbcccccddddddd', 'aabbbbccccccdddddddd'], dtype=object)
```

```
>>> np.tensordot(a, A, ((2, 1), (1, 0)))
array(['acccbbdddd', 'aaaaacccccccbbbbbbddddddddd'], dtype=object)
```

numpy.**einsum**(*subscripts*, **operands*, *out=None*, *dtype=None*, *order='K'*, *casting='safe'*, *optimize=False*)

Evaluates the Einstein summation convention on the operands.

Using the Einstein summation convention, many common multi-dimensional, linear algebraic array operations can be represented in a simple fashion. In *implicit* mode `einsum` computes these values.

In *explicit* mode, `einsum` provides further flexibility to compute other array operations that might not be considered classical Einstein summation operations, by disabling, or forcing summation over specified subscript labels.

See the notes and examples for clarification.

Parameters

subscripts
: [str] Specifies the subscripts for summation as comma separated list of subscript labels. An implicit (classical Einstein summation) calculation is performed unless the explicit indicator '->' is included as well as subscript labels of the precise output form.

operands
: [list of array_like] These are the arrays for the operation.

out
[ndarray, optional] If provided, the calculation is done into this array.

dtype
[{data-type, None}, optional] If provided, forces the calculation to use the data type specified. Note that you may have to also give a more liberal *casting* parameter to allow the conversions. Default is None.

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout of the output. 'C' means it should be C contiguous. 'F' means it should be Fortran contiguous, 'A' means it should be 'F' if the inputs are all 'F', 'C' otherwise. 'K' means it should be as close to the layout as the inputs as is possible, including arbitrarily permuted axes. Default is 'K'.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Setting this to 'unsafe' is not recommended, as it can adversely affect accumulations.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.
- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

Default is 'safe'.

optimize
[{False, True, 'greedy', 'optimal'}, optional] Controls if intermediate optimization should occur. No optimization will occur if False and True will default to the 'greedy' algorithm. Also accepts an explicit contraction list from the `np.einsum_path` function. See `np.einsum_path` for more details. Defaults to False.

Returns

output
[ndarray] The calculation based on the Einstein summation convention.

See also:

einsum_path, ***dot***, ***inner***, ***outer***, ***tensordot***, ***linalg.multi_dot***
einsum
Similar verbose interface is provided by the einops package to cover additional operations: transpose, reshape/flatten, repeat/tile, squeeze/unsqueeze and reductions. The opt_einsum optimizes contraction order for einsum-like expressions in backend-agnostic manner.

Notes

The Einstein summation convention can be used to compute many multi-dimensional, linear algebraic array operations. *einsum* provides a succinct way of representing these.

A non-exhaustive list of these operations, which can be computed by *einsum*, is shown below along with examples:

- Trace of an array, *numpy.trace*.
- Return a diagonal, *numpy.diag*.
- Array axis summations, *numpy.sum*.

- Transpositions and permutations, *numpy.transpose*.
- **Matrix multiplication and dot product, *numpy.matmul***
  numpy.dot.
- **Vector inner and outer products, *numpy.inner***
  numpy.outer.
- **Broadcasting, element-wise and scalar multiplication,**
  numpy.multiply.
- Tensor contractions, *numpy.tensordot*.
- **Chained array operations, in efficient calculation order,**
  numpy.einsum_path.

The subscripts string is a comma-separated list of subscript labels, where each label refers to a dimension of the corresponding operand. Whenever a label is repeated it is summed, so `np.einsum('i,i', a, b)` is equivalent to *np.inner(a,b)*. If a label appears only once, it is not summed, so `np.einsum('i', a)` produces a view of `a` with no changes. A further example `np.einsum('ij,jk', a, b)` describes traditional matrix multiplication and is equivalent to *np.matmul(a,b)*. Repeated subscript labels in one operand take the diagonal. For example, `np.einsum('ii', a)` is equivalent to *np.trace(a)*.

In *implicit mode*, the chosen subscripts are important since the axes of the output are reordered alphabetically. This means that `np.einsum('ij', a)` doesn't affect a 2D array, while `np.einsum('ji', a)` takes its transpose. Additionally, `np.einsum('ij,jk', a, b)` returns a matrix multiplication, while, `np.einsum('ij,jh', a, b)` returns the transpose of the multiplication since subscript 'h' precedes subscript 'i'.

In *explicit mode* the output can be directly controlled by specifying output subscript labels. This requires the identifier '->' as well as the list of output subscript labels. This feature increases the flexibility of the function since summing can be disabled or forced when required. The call `np.einsum('i->', a)` is like *np.sum(a)* if `a` is a 1-D array, and `np.einsum('ii->i', a)` is like *np.diag(a)* if `a` is a square 2-D array. The difference is that *einsum* does not allow broadcasting by default. Additionally `np.einsum('ij,jh->ih', a, b)` directly specifies the order of the output subscript labels and therefore returns matrix multiplication, unlike the example above in implicit mode.

To enable and control broadcasting, use an ellipsis. Default NumPy-style broadcasting is done by adding an ellipsis to the left of each term, like `np.einsum('...ii->...i', a)`. `np.einsum('...i->...', a)` is like *np.sum(a, axis=-1)* for array `a` of any shape. To take the trace along the first and last axes, you can do `np.einsum('i...i', a)`, or to do a matrix-matrix product with the left-most indices instead of rightmost, one can do `np.einsum('ij...,jk...->ik...', a, b)`.

When there is only one operand, no axes are summed, and no output parameter is provided, a view into the operand is returned instead of a new array. Thus, taking the diagonal as `np.einsum('ii->i', a)` produces a view (changed in version 1.10.0).

einsum also provides an alternative way to provide the subscripts and operands as `einsum(op0, sublist0, op1, sublist1, ..., [sublistout])`. If the output shape is not provided in this format *einsum* will be calculated in implicit mode, otherwise it will be performed explicitly. The examples below have corresponding *einsum* calls with the two parameter methods.

Views returned from einsum are now writeable whenever the input array is writeable. For example, `np.einsum('ijk...->kji...', a)` will now have the same effect as *np.swapaxes(a, 0, 2)* and `np.einsum('ii->i', a)` will return a writeable view of the diagonal of a 2D array.

Added the `optimize` argument which will optimize the contraction order of an einsum expression. For a contraction with three or more operands this can greatly increase the computational efficiency at the cost of a larger memory footprint during computation.

Typically a 'greedy' algorithm is applied which empirical tests have shown returns the optimal path in the majority of cases. In some cases 'optimal' will return the superlative path through a more expensive, exhaustive search. For iterative calculations it may be advisable to calculate the optimal path once and reuse that path by supplying it as an argument. An example is given below.

See *numpy.einsum_path* for more details.

Examples

```
>>> a = np.arange(25).reshape(5,5)
>>> b = np.arange(5)
>>> c = np.arange(6).reshape(2,3)
```

Trace of a matrix:

```
>>> np.einsum('ii', a)
60
>>> np.einsum(a, [0,0])
60
>>> np.trace(a)
60
```

Extract the diagonal (requires explicit form):

```
>>> np.einsum('ii->i', a)
array([ 0,  6, 12, 18, 24])
>>> np.einsum(a, [0,0], [0])
array([ 0,  6, 12, 18, 24])
>>> np.diag(a)
array([ 0,  6, 12, 18, 24])
```

Sum over an axis (requires explicit form):

```
>>> np.einsum('ij->i', a)
array([ 10,  35,  60,  85, 110])
>>> np.einsum(a, [0,1], [0])
array([ 10,  35,  60,  85, 110])
>>> np.sum(a, axis=1)
array([ 10,  35,  60,  85, 110])
```

For higher dimensional arrays summing a single axis can be done with ellipsis:

```
>>> np.einsum('...j->...', a)
array([ 10,  35,  60,  85, 110])
>>> np.einsum(a, [Ellipsis,1], [Ellipsis])
array([ 10,  35,  60,  85, 110])
```

Compute a matrix transpose, or reorder any number of axes:

```
>>> np.einsum('ji', c)
array([[0, 3],
       [1, 4],
       [2, 5]])
>>> np.einsum('ij->ji', c)
array([[0, 3],
       [1, 4],
```

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```
       [2, 5]])
>>> np.einsum(c, [1,0])
array([[0, 3],
       [1, 4],
       [2, 5]])
>>> np.transpose(c)
array([[0, 3],
       [1, 4],
       [2, 5]])
```

Vector inner products:

```
>>> np.einsum('i,i', b, b)
30
>>> np.einsum(b, [0], b, [0])
30
>>> np.inner(b,b)
30
```

Matrix vector multiplication:

```
>>> np.einsum('ij,j', a, b)
array([ 30,  80, 130, 180, 230])
>>> np.einsum(a, [0,1], b, [1])
array([ 30,  80, 130, 180, 230])
>>> np.dot(a, b)
array([ 30,  80, 130, 180, 230])
>>> np.einsum('...j,j', a, b)
array([ 30,  80, 130, 180, 230])
```

Broadcasting and scalar multiplication:

```
>>> np.einsum('..., ...', 3, c)
array([[ 0,  3,  6],
       [ 9, 12, 15]])
>>> np.einsum(',ij', 3, c)
array([[ 0,  3,  6],
       [ 9, 12, 15]])
>>> np.einsum(3, [Ellipsis], c, [Ellipsis])
array([[ 0,  3,  6],
       [ 9, 12, 15]])
>>> np.multiply(3, c)
array([[ 0,  3,  6],
       [ 9, 12, 15]])
```

Vector outer product:

```
>>> np.einsum('i,j', np.arange(2)+1, b)
array([[0, 1, 2, 3, 4],
       [0, 2, 4, 6, 8]])
>>> np.einsum(np.arange(2)+1, [0], b, [1])
array([[0, 1, 2, 3, 4],
       [0, 2, 4, 6, 8]])
>>> np.outer(np.arange(2)+1, b)
array([[0, 1, 2, 3, 4],
       [0, 2, 4, 6, 8]])
```

Tensor contraction:

```
>>> a = np.arange(60.).reshape(3,4,5)
>>> b = np.arange(24.).reshape(4,3,2)
>>> np.einsum('ijk,jil->kl', a, b)
array([[4400., 4730.],
       [4532., 4874.],
       [4664., 5018.],
       [4796., 5162.],
       [4928., 5306.]])
>>> np.einsum(a, [0,1,2], b, [1,0,3], [2,3])
array([[4400., 4730.],
       [4532., 4874.],
       [4664., 5018.],
       [4796., 5162.],
       [4928., 5306.]])
>>> np.tensordot(a,b, axes=([1,0],[0,1]))
array([[4400., 4730.],
       [4532., 4874.],
       [4664., 5018.],
       [4796., 5162.],
       [4928., 5306.]])
```

Writeable returned arrays (since version 1.10.0):

```
>>> a = np.zeros((3, 3))
>>> np.einsum('ii->i', a)[:] = 1
>>> a
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
```

Example of ellipsis use:

```
>>> a = np.arange(6).reshape((3,2))
>>> b = np.arange(12).reshape((4,3))
>>> np.einsum('ki,jk->ij', a, b)
array([[10, 28, 46, 64],
       [13, 40, 67, 94]])
>>> np.einsum('ki,...k->i...', a, b)
array([[10, 28, 46, 64],
       [13, 40, 67, 94]])
>>> np.einsum('k...,jk', a, b)
array([[10, 28, 46, 64],
       [13, 40, 67, 94]])
```

Chained array operations. For more complicated contractions, speed ups might be achieved by repeatedly computing a 'greedy' path or pre-computing the 'optimal' path and repeatedly applying it, using an *einsum_path* insertion (since version 1.12.0). Performance improvements can be particularly significant with larger arrays:

```
>>> a = np.ones(64).reshape(2,4,8)
```

Basic *einsum*: ~1520ms (benchmarked on 3.1GHz Intel i5.)

```
>>> for iteration in range(500):
...     _ = np.einsum('ijk,ilm,njm,nlk,abc->',a,a,a,a,a)
```

Sub-optimal *einsum* (due to repeated path calculation time): ~330ms

```
>>> for iteration in range(500):
...     _ = np.einsum('ijk,ilm,njm,nlk,abc->',a,a,a,a,a,
...         optimize='optimal')
```

Greedy *einsum* (faster optimal path approximation): ~160ms

```
>>> for iteration in range(500):
...     _ = np.einsum('ijk,ilm,njm,nlk,abc->',a,a,a,a,a, optimize='greedy')
```

Optimal *einsum* (best usage pattern in some use cases): ~110ms

```
>>> path = np.einsum_path('ijk,ilm,njm,nlk,abc->',a,a,a,a,a,
...     optimize='optimal')[0]
>>> for iteration in range(500):
...     _ = np.einsum('ijk,ilm,njm,nlk,abc->',a,a,a,a,a, optimize=path)
```

numpy.**einsum_path**(*subscripts*, **operands*, *optimize='greedy'*)

Evaluates the lowest cost contraction order for an einsum expression by considering the creation of intermediate arrays.

Parameters

subscripts
[str] Specifies the subscripts for summation.

***operands**
[list of array_like] These are the arrays for the operation.

optimize
[{bool, list, tuple, 'greedy', 'optimal'}] Choose the type of path. If a tuple is provided, the second argument is assumed to be the maximum intermediate size created. If only a single argument is provided the largest input or output array size is used as a maximum intermediate size.

- if a list is given that starts with `einsum_path`, uses this as the contraction path
- if False no optimization is taken
- if True defaults to the 'greedy' algorithm
- 'optimal' An algorithm that combinatorially explores all possible ways of contracting the listed tensors and chooses the least costly path. Scales exponentially with the number of terms in the contraction.
- 'greedy' An algorithm that chooses the best pair contraction at each step. Effectively, this algorithm searches the largest inner, Hadamard, and then outer products at each step. Scales cubically with the number of terms in the contraction. Equivalent to the 'optimal' path for most contractions.

Default is 'greedy'.

Returns

path
[list of tuples] A list representation of the einsum path.

string_repr
[str] A printable representation of the einsum path.

See also:

einsum, *linalg.multi_dot*

Notes

The resulting path indicates which terms of the input contraction should be contracted first, the result of this contraction is then appended to the end of the contraction list. This list can then be iterated over until all intermediate contractions are complete.

Examples

We can begin with a chain dot example. In this case, it is optimal to contract the `b` and `c` tensors first as represented by the first element of the path `(1, 2)`. The resulting tensor is added to the end of the contraction and the remaining contraction `(0, 1)` is then completed.

```
>>> np.random.seed(123)
>>> a = np.random.rand(2, 2)
>>> b = np.random.rand(2, 5)
>>> c = np.random.rand(5, 2)
>>> path_info = np.einsum_path('ij,jk,kl->il', a, b, c, optimize='greedy')
>>> print(path_info[0])
['einsum_path', (1, 2), (0, 1)]
>>> print(path_info[1])
  Complete contraction:  ij,jk,kl->il # may vary
         Naive scaling:  4
     Optimized scaling:  3
      Naive FLOP count:  1.600e+02
  Optimized FLOP count:  5.600e+01
   Theoretical speedup:  2.857
  Largest intermediate:  4.000e+00 elements
-------------------------------------------------------------------------
scaling                  current                                remaining
-------------------------------------------------------------------------
   3                   kl,jk->jl                              ij,jl->il
   3                   jl,ij->il                                 il->il
```

A more complex index transformation example.

```
>>> I = np.random.rand(10, 10, 10, 10)
>>> C = np.random.rand(10, 10)
>>> path_info = np.einsum_path('ea,fb,abcd,gc,hd->efgh', C, C, I, C, C,
...                            optimize='greedy')
```

```
>>> print(path_info[0])
['einsum_path', (0, 2), (0, 3), (0, 2), (0, 1)]
>>> print(path_info[1])
  Complete contraction:  ea,fb,abcd,gc,hd->efgh # may vary
         Naive scaling:  8
     Optimized scaling:  5
      Naive FLOP count:  8.000e+08
  Optimized FLOP count:  8.000e+05
   Theoretical speedup:  1000.000
  Largest intermediate:  1.000e+04 elements
--------------------------------------------------------------------------
scaling                  current                                remaining
--------------------------------------------------------------------------
```

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```
  5               abcd,ea->bcde                    fb,gc,hd,bcde->efgh
  5               bcde,fb->cdef                       gc,hd,cdef->efgh
  5               cdef,gc->defg                          hd,defg->efgh
  5               defg,hd->efgh                             efgh->efgh
```

linalg.**matrix_power**(*a*, *n*)

Raise a square matrix to the (integer) power *n*.

For positive integers *n*, the power is computed by repeated matrix squarings and matrix multiplications. If `n == 0`, the identity matrix of the same shape as M is returned. If `n < 0`, the inverse is computed and then raised to the `abs(n)`.

Note: Stacks of object matrices are not currently supported.

Parameters

a
[(…, M, M) array_like] Matrix to be "powered".

n
[int] The exponent can be any integer or long integer, positive, negative, or zero.

Returns

an**
[(…, M, M) ndarray or matrix object] The return value is the same shape and type as *M*; if the exponent is positive or zero then the type of the elements is the same as those of *M*. If the exponent is negative the elements are floating-point.

Raises

LinAlgError
For matrices that are not square or that (for negative powers) cannot be inverted numerically.

Examples

```
>>> import numpy as np
>>> from numpy.linalg import matrix_power
>>> i = np.array([[0, 1], [-1, 0]]) # matrix equiv. of the imaginary unit
>>> matrix_power(i, 3) # should = -i
array([[ 0, -1],
       [ 1,  0]])
>>> matrix_power(i, 0)
array([[1, 0],
       [0, 1]])
>>> matrix_power(i, -3) # should = 1/(-i) = i, but w/ f.p. elements
array([[ 0.,  1.],
       [-1.,  0.]])
```

Somewhat more sophisticated example

```
>>> q = np.zeros((4, 4))
>>> q[0:2, 0:2] = -i
>>> q[2:4, 2:4] = i
```

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```
>>> q # one of the three quaternion units not equal to 1
array([[ 0., -1.,  0.,  0.],
       [ 1.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  1.],
       [ 0.,  0., -1.,  0.]])
>>> matrix_power(q, 2) # = -np.eye(4)
array([[-1.,  0.,  0.,  0.],
       [ 0., -1.,  0.,  0.],
       [ 0.,  0., -1.,  0.],
       [ 0.,  0.,  0., -1.]])
```

numpy.**kron**(*a*, *b*)

Kronecker product of two arrays.

Computes the Kronecker product, a composite array made of blocks of the second array scaled by the first.

Parameters

a, b
[array_like]

Returns

out
[ndarray]

See also:

outer
The outer product

Notes

The function assumes that the number of dimensions of *a* and *b* are the same, if necessary prepending the smallest with ones. If `a.shape = (r0,r1,..,rN)` and `b.shape = (s0,s1,...,sN)`, the Kronecker product has shape `(r0*s0, r1*s1, ..., rN*SN)`. The elements are products of elements from *a* and *b*, organized explicitly by:

```
kron(a,b)[k0,k1,...,kN] = a[i0,i1,...,iN] * b[j0,j1,...,jN]
```

where:

```
kt = it * st + jt,  t = 0,...,N
```

In the common 2-D case (N=1), the block structure can be visualized:

```
[[ a[0,0]*b,   a[0,1]*b,  ... , a[0,-1]*b  ],
 [  ...                              ...   ],
 [ a[-1,0]*b,  a[-1,1]*b, ... , a[-1,-1]*b ]]
```

Examples

```
>>> import numpy as np
>>> np.kron([1,10,100], [5,6,7])
array([  5,   6,   7, ..., 500, 600, 700])
>>> np.kron([5,6,7], [1,10,100])
array([  5,  50, 500, ...,   7,  70, 700])
```

```
>>> np.kron(np.eye(2), np.ones((2,2)))
array([[1.,  1.,  0.,  0.],
       [1.,  1.,  0.,  0.],
       [0.,  0.,  1.,  1.],
       [0.,  0.,  1.,  1.]])
```

```
>>> a = np.arange(100).reshape((2,5,2,5))
>>> b = np.arange(24).reshape((2,3,4))
>>> c = np.kron(a,b)
>>> c.shape
(2, 10, 6, 20)
>>> I = (1,3,0,2)
>>> J = (0,2,1)
>>> J1 = (0,) + J             # extend to ndim=4
>>> S1 = (1,) + b.shape
>>> K = tuple(np.array(I) * np.array(S1) + np.array(J1))
>>> c[K] == a[I]*b[J]
True
```

linalg.**cross**(*x1*, *x2*, */*, ***, *axis=-1*)

Returns the cross product of 3-element vectors.

If `x1` and/or `x2` are multi-dimensional arrays, then the cross-product of each pair of corresponding 3-element vectors is independently computed.

This function is Array API compatible, contrary to *numpy.cross*.

Parameters

x1
: [array_like] The first input array.

x2
: [array_like] The second input array. Must be compatible with `x1` for all non-compute axes. The size of the axis over which to compute the cross-product must be the same size as the respective axis in `x1`.

axis
: [int, optional] The axis (dimension) of `x1` and `x2` containing the vectors for which to compute the cross-product. Default: `-1`.

Returns

out
: [ndarray] An array containing the cross products.

See also:

numpy.cross

Examples

Vector cross-product.

```
>>> x = np.array([1, 2, 3])
>>> y = np.array([4, 5, 6])
>>> np.linalg.cross(x, y)
array([-3,  6, -3])
```

Multiple vector cross-products. Note that the direction of the cross product vector is defined by the *right-hand rule*.

```
>>> x = np.array([[1,2,3], [4,5,6]])
>>> y = np.array([[4,5,6], [1,2,3]])
>>> np.linalg.cross(x, y)
array([[-3,  6, -3],
       [ 3, -6,  3]])
```

```
>>> x = np.array([[1, 2], [3, 4], [5, 6]])
>>> y = np.array([[4, 5], [6, 1], [2, 3]])
>>> np.linalg.cross(x, y, axis=0)
array([[-24,  6],
       [ 18, 24],
       [-6,  -18]])
```

Decompositions

linalg.cholesky(a, /, *[, upper])	Cholesky decomposition.
linalg.outer(x1, x2, /)	Compute the outer product of two vectors.
linalg.qr(a[, mode])	Compute the qr factorization of a matrix.
linalg.svd(a[, full_matrices, compute_uv, ...])	Singular Value Decomposition.
linalg.svdvals(x, /)	Returns the singular values of a matrix (or a stack of matrices) `x`.

linalg.**cholesky**(*a*, */*, ***, *upper=False*)

Cholesky decomposition.

Return the lower or upper Cholesky decomposition, `L * L.H` or `U.H * U`, of the square matrix `a`, where `L` is lower-triangular, `U` is upper-triangular, and `.H` is the conjugate transpose operator (which is the ordinary transpose if `a` is real-valued). `a` must be Hermitian (symmetric if real-valued) and positive-definite. No checking is performed to verify whether `a` is Hermitian or not. In addition, only the lower or upper-triangular and diagonal elements of `a` are used. Only `L` or `U` is actually returned.

Parameters

a
: [(…, M, M) array_like] Hermitian (symmetric if all elements are real), positive-definite input matrix.

upper
: [bool] If `True`, the result must be the upper-triangular Cholesky factor. If `False`, the result must be the lower-triangular Cholesky factor. Default: `False`.

Returns

L
: [(…, M, M) array_like] Lower or upper-triangular Cholesky factor of *a*. Returns a matrix object if *a* is a matrix object.

Raises

LinAlgError
If the decomposition fails, for example, if a is not positive-definite.

See also:

scipy.linalg.cholesky
Similar function in SciPy.

scipy.linalg.cholesky_banded
Cholesky decompose a banded Hermitian positive-definite matrix.

scipy.linalg.cho_factor
Cholesky decomposition of a matrix, to use in `scipy.linalg.cho_solve`.

Notes

Broadcasting rules apply, see the *numpy.linalg* documentation for details.

The Cholesky decomposition is often used as a fast way of solving

$$A\mathbf{x} = \mathbf{b}$$

(when A is both Hermitian/symmetric and positive-definite).

First, we solve for $\mathbf{y}$ in

$$L\mathbf{y} = \mathbf{b},$$

and then for $\mathbf{x}$ in

$$L^H\mathbf{x} = \mathbf{y}.$$

Examples

```
>>> import numpy as np
>>> A = np.array([[1,-2j],[2j,5]])
>>> A
array([[ 1.+0.j, -0.-2.j],
       [ 0.+2.j,  5.+0.j]])
>>> L = np.linalg.cholesky(A)
>>> L
array([[1.+0.j, 0.+0.j],
       [0.+2.j, 1.+0.j]])
>>> np.dot(L, L.T.conj()) # verify that L * L.H = A
array([[1.+0.j, 0.-2.j],
       [0.+2.j, 5.+0.j]])
>>> A = [[1,-2j],[2j,5]] # what happens if A is only array_like?
>>> np.linalg.cholesky(A) # an ndarray object is returned
array([[1.+0.j, 0.+0.j],
       [0.+2.j, 1.+0.j]])
>>> # But a matrix object is returned if A is a matrix object
>>> np.linalg.cholesky(np.matrix(A))
matrix([[ 1.+0.j,  0.+0.j],
        [ 0.+2.j,  1.+0.j]])
```

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```
>>> # The upper-triangular Cholesky factor can also be obtained.
>>> np.linalg.cholesky(A, upper=True)
array([[1.-0.j, 0.-2.j],
       [0.-0.j, 1.-0.j]])
```

linalg.**outer**(*x1*, *x2*, */*)

Compute the outer product of two vectors.

This function is Array API compatible. Compared to `np.outer` it accepts 1-dimensional inputs only.

Parameters

x1
[(M,) array_like] One-dimensional input array of size `N`. Must have a numeric data type.

x2
[(N,) array_like] One-dimensional input array of size `M`. Must have a numeric data type.

Returns

out
[(M, N) ndarray] `out[i, j] = a[i] * b[j]`

See also:

outer

Examples

Make a (*very* coarse) grid for computing a Mandelbrot set:

```
>>> rl = np.linalg.outer(np.ones((5,)), np.linspace(-2, 2, 5))
>>> rl
array([[-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.]])
>>> im = np.linalg.outer(1j*np.linspace(2, -2, 5), np.ones((5,)))
>>> im
array([[0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j],
       [0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j],
       [0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j],
       [0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j],
       [0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j]])
>>> grid = rl + im
>>> grid
array([[-2.+2.j, -1.+2.j,  0.+2.j,  1.+2.j,  2.+2.j],
       [-2.+1.j, -1.+1.j,  0.+1.j,  1.+1.j,  2.+1.j],
       [-2.+0.j, -1.+0.j,  0.+0.j,  1.+0.j,  2.+0.j],
       [-2.-1.j, -1.-1.j,  0.-1.j,  1.-1.j,  2.-1.j],
       [-2.-2.j, -1.-2.j,  0.-2.j,  1.-2.j,  2.-2.j]])
```

An example using a “vector” of letters:

```
>>> x = np.array(['a', 'b', 'c'], dtype=object)
>>> np.linalg.outer(x, [1, 2, 3])
```

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```
array([['a', 'aa', 'aaa'],
       ['b', 'bb', 'bbb'],
       ['c', 'cc', 'ccc']], dtype=object)
```

linalg.**qr**(*a*, *mode='reduced'*)

Compute the qr factorization of a matrix.

Factor the matrix *a* as *qr*, where *q* is orthonormal and *r* is upper-triangular.

Parameters

a
[array_like, shape (…, M, N)] An array-like object with the dimensionality of at least 2.

mode
[{'reduced', 'complete', 'r', 'raw'}, optional, default: 'reduced'] If K = min(M, N), then

- 'reduced' : returns Q, R with dimensions (…, M, K), (…, K, N)
- 'complete' : returns Q, R with dimensions (…, M, M), (…, M, N)
- 'r' : returns R only with dimensions (…, K, N)
- 'raw' : returns h, tau with dimensions (…, N, M), (…, K,)

The options 'reduced', 'complete, and 'raw' are new in numpy 1.8, see the notes for more information. The default is 'reduced', and to maintain backward compatibility with earlier versions of numpy both it and the old default 'full' can be omitted. Note that array h returned in 'raw' mode is transposed for calling Fortran. The 'economic' mode is deprecated. The modes 'full' and 'economic' may be passed using only the first letter for backwards compatibility, but all others must be spelled out. See the Notes for more explanation.

Returns

When mode is 'reduced' or 'complete', the result will be a namedtuple with the attributes *Q* and *R*.

Q
[ndarray of float or complex, optional] A matrix with orthonormal columns. When mode = 'complete' the result is an orthogonal/unitary matrix depending on whether or not a is real/complex. The determinant may be either +/- 1 in that case. In case the number of dimensions in the input array is greater than 2 then a stack of the matrices with above properties is returned.

R
[ndarray of float or complex, optional] The upper-triangular matrix or a stack of upper-triangular matrices if the number of dimensions in the input array is greater than 2.

(h, tau)
[ndarrays of np.double or np.cdouble, optional] The array h contains the Householder reflectors that generate q along with r. The tau array contains scaling factors for the reflectors. In the deprecated 'economic' mode only h is returned.

Raises

LinAlgError
If factoring fails.

See also:

scipy.linalg.qr
Similar function in SciPy.

scipy.linalg.rq
Compute RQ decomposition of a matrix.

Notes

This is an interface to the LAPACK routines `dgeqrf`, `zgeqrf`, `dorgqr`, and `zungqr`.

For more information on the qr factorization, see for example: https://en.wikipedia.org/wiki/QR_factorization

Subclasses of *ndarray* are preserved except for the 'raw' mode. So if *a* is of type *matrix*, all the return values will be matrices too.

New 'reduced', 'complete', and 'raw' options for mode were added in NumPy 1.8.0 and the old option 'full' was made an alias of 'reduced'. In addition the options 'full' and 'economic' were deprecated. Because 'full' was the previous default and 'reduced' is the new default, backward compatibility can be maintained by letting *mode* default. The 'raw' option was added so that LAPACK routines that can multiply arrays by q using the Householder reflectors can be used. Note that in this case the returned arrays are of type np.double or np.cdouble and the h array is transposed to be FORTRAN compatible. No routines using the 'raw' return are currently exposed by numpy, but some are available in lapack_lite and just await the necessary work.

Examples

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> a = rng.normal(size=(9, 6))
>>> Q, R = np.linalg.qr(a)
>>> np.allclose(a, np.dot(Q, R))  # a does equal QR
True
>>> R2 = np.linalg.qr(a, mode='r')
>>> np.allclose(R, R2)  # mode='r' returns the same R as mode='full'
True
>>> a = np.random.normal(size=(3, 2, 2)) # Stack of 2 x 2 matrices as input
>>> Q, R = np.linalg.qr(a)
>>> Q.shape
(3, 2, 2)
>>> R.shape
(3, 2, 2)
>>> np.allclose(a, np.matmul(Q, R))
True
```

Example illustrating a common use of *qr*: solving of least squares problems

What are the least-squares-best *m* and *y0* in `y = y0 + mx` for the following data: {(0,1), (1,0), (1,2), (2,1)}. (Graph the points and you'll see that it should be y0 = 0, m = 1.) The answer is provided by solving the over-determined matrix equation `Ax = b`, where:

```
A = array([[0, 1], [1, 1], [1, 1], [2, 1]])
x = array([[y0], [m]])
b = array([[1], [0], [2], [1]])
```

If A = QR such that Q is orthonormal (which is always possible via Gram-Schmidt), then `x = inv(R) * (Q.T) * b`. (In numpy practice, however, we simply use *lstsq*.)

```
>>> A = np.array([[0, 1], [1, 1], [1, 1], [2, 1]])
>>> A
array([[0, 1],
```

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```
       [1, 1],
       [1, 1],
       [2, 1]])
>>> b = np.array([1, 2, 2, 3])
>>> Q, R = np.linalg.qr(A)
>>> p = np.dot(Q.T, b)
>>> np.dot(np.linalg.inv(R), p)
array([  1.,   1.])
```

linalg.**svd**(*a*, *full_matrices=True*, *compute_uv=True*, *hermitian=False*)

Singular Value Decomposition.

When *a* is a 2D array, and `full_matrices=False`, then it is factorized as `u @ np.diag(s) @ vh = (u * s) @ vh`, where *u* and the Hermitian transpose of *vh* are 2D arrays with orthonormal columns and *s* is a 1D array of *a*'s singular values. When *a* is higher-dimensional, SVD is applied in stacked mode as explained below.

Parameters

a
[(…, M, N) array_like] A real or complex array with `a.ndim >= 2`.

full_matrices
[bool, optional] If True (default), *u* and *vh* have the shapes `(..., M, M)` and `(..., N, N)`, respectively. Otherwise, the shapes are `(..., M, K)` and `(..., K, N)`, respectively, where `K = min(M, N)`.

compute_uv
[bool, optional] Whether or not to compute *u* and *vh* in addition to *s*. True by default.

hermitian
[bool, optional] If True, *a* is assumed to be Hermitian (symmetric if real-valued), enabling a more efficient method for finding singular values. Defaults to False.

Returns

When *compute_uv* is True, the result is a namedtuple with the following attribute names:

U
[{ (…, M, M), (…, M, K) } array] Unitary array(s). The first `a.ndim - 2` dimensions have the same size as those of the input *a*. The size of the last two dimensions depends on the value of *full_matrices*. Only returned when *compute_uv* is True.

S
[(…, K) array] Vector(s) with the singular values, within each vector sorted in descending order. The first `a.ndim - 2` dimensions have the same size as those of the input *a*.

Vh
[{ (…, N, N), (…, K, N) } array] Unitary array(s). The first `a.ndim - 2` dimensions have the same size as those of the input *a*. The size of the last two dimensions depends on the value of *full_matrices*. Only returned when *compute_uv* is True.

Raises

LinAlgError
If SVD computation does not converge.

See also:

scipy.linalg.svd
Similar function in SciPy.

scipy.linalg.svdvals
Compute singular values of a matrix.

Notes

The decomposition is performed using LAPACK routine _gesdd.

SVD is usually described for the factorization of a 2D matrix A. The higher-dimensional case will be discussed below. In the 2D case, SVD is written as $A = USV^H$, where $A = a$, $U = u$, $S = \mathtt{np.diag}(s)$ and $V^H = vh$. The 1D array *s* contains the singular values of *a* and *u* and *vh* are unitary. The rows of *vh* are the eigenvectors of $A^H A$ and the columns of *u* are the eigenvectors of AA^H. In both cases the corresponding (possibly non-zero) eigenvalues are given by `s**2`.

If *a* has more than two dimensions, then broadcasting rules apply, as explained in *Linear algebra on several matrices at once*. This means that SVD is working in "stacked" mode: it iterates over all indices of the first `a.ndim - 2` dimensions and for each combination SVD is applied to the last two indices. The matrix *a* can be reconstructed from the decomposition with either `(u * s[..., None, :]) @ vh` or `u @ (s[..., None] * vh)`. (The `@` operator can be replaced by the function `np.matmul` for python versions below 3.5.)

If *a* is a `matrix` object (as opposed to an `ndarray`), then so are all the return values.

Examples

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> a = rng.normal(size=(9, 6)) + 1j*rng.normal(size=(9, 6))
>>> b = rng.normal(size=(2, 7, 8, 3)) + 1j*rng.normal(size=(2, 7, 8, 3))
```

Reconstruction based on full SVD, 2D case:

```
>>> U, S, Vh = np.linalg.svd(a, full_matrices=True)
>>> U.shape, S.shape, Vh.shape
((9, 9), (6,), (6, 6))
>>> np.allclose(a, np.dot(U[:, :6] * S, Vh))
True
>>> smat = np.zeros((9, 6), dtype=complex)
>>> smat[:6, :6] = np.diag(S)
>>> np.allclose(a, np.dot(U, np.dot(smat, Vh)))
True
```

Reconstruction based on reduced SVD, 2D case:

```
>>> U, S, Vh = np.linalg.svd(a, full_matrices=False)
>>> U.shape, S.shape, Vh.shape
((9, 6), (6,), (6, 6))
>>> np.allclose(a, np.dot(U * S, Vh))
True
>>> smat = np.diag(S)
>>> np.allclose(a, np.dot(U, np.dot(smat, Vh)))
True
```

Reconstruction based on full SVD, 4D case:

```
>>> U, S, Vh = np.linalg.svd(b, full_matrices=True)
>>> U.shape, S.shape, Vh.shape
```

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```
((2, 7, 8, 8), (2, 7, 3), (2, 7, 3, 3))
>>> np.allclose(b, np.matmul(U[..., :3] * S[..., None, :], Vh))
True
>>> np.allclose(b, np.matmul(U[..., :3], S[..., None] * Vh))
True
```

Reconstruction based on reduced SVD, 4D case:

```
>>> U, S, Vh = np.linalg.svd(b, full_matrices=False)
>>> U.shape, S.shape, Vh.shape
((2, 7, 8, 3), (2, 7, 3), (2, 7, 3, 3))
>>> np.allclose(b, np.matmul(U * S[..., None, :], Vh))
True
>>> np.allclose(b, np.matmul(U, S[..., None] * Vh))
True
```

`linalg.`**`svdvals`**`(x, /)`

Returns the singular values of a matrix (or a stack of matrices) `x`. When x is a stack of matrices, the function will compute the singular values for each matrix in the stack.

This function is Array API compatible.

Calling `np.svdvals(x)` to get singular values is the same as `np.svd(x, compute_uv=False, hermitian=False)`.

Parameters

x
: [(…, M, N) array_like] Input array having shape (…, M, N) and whose last two dimensions form matrices on which to perform singular value decomposition. Should have a floating-point data type.

Returns

out
: [ndarray] An array with shape (…, K) that contains the vector(s) of singular values of length K, where K = min(M, N).

See also:

`scipy.linalg.svdvals`
: Compute singular values of a matrix.

Examples

```
>>> np.linalg.svdvals([[1, 2, 3, 4, 5],
...                    [1, 4, 9, 16, 25],
...                    [1, 8, 27, 64, 125]])
array([146.68862757,   5.57510612,   0.60393245])
```

Determine the rank of a matrix using singular values:

```
>>> s = np.linalg.svdvals([[1, 2, 3],
...                        [2, 4, 6],
...                        [-1, 1, -1]]); s
array([8.38434191e+00, 1.64402274e+00, 2.31534378e-16])
```

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```
>>> np.count_nonzero(s > 1e-10)  # Matrix of rank 2
2
```

Matrix eigenvalues

linalg.eig(a)	Compute the eigenvalues and right eigenvectors of a square array.
linalg.eigh(a[, UPLO])	Return the eigenvalues and eigenvectors of a complex Hermitian (conjugate symmetric) or a real symmetric matrix.
linalg.eigvals(a)	Compute the eigenvalues of a general matrix.
linalg.eigvalsh(a[, UPLO])	Compute the eigenvalues of a complex Hermitian or real symmetric matrix.

linalg.**eig**(*a*)

Compute the eigenvalues and right eigenvectors of a square array.

Parameters

a
[(…, M, M) array] Matrices for which the eigenvalues and right eigenvectors will be computed

Returns

A namedtuple with the following attributes:
eigenvalues
[(…, M) array] The eigenvalues, each repeated according to its multiplicity. The eigenvalues are not necessarily ordered. The resulting array will be of complex type, unless the imaginary part is zero in which case it will be cast to a real type. When *a* is real the resulting eigenvalues will be real (0 imaginary part) or occur in conjugate pairs

eigenvectors
[(…, M, M) array] The normalized (unit "length") eigenvectors, such that the column `eigenvectors[:,i]` is the eigenvector corresponding to the eigenvalue `eigenvalues[i]`.

Raises

LinAlgError
If the eigenvalue computation does not converge.

See also:

eigvals
eigenvalues of a non-symmetric array.

eigh
eigenvalues and eigenvectors of a real symmetric or complex Hermitian (conjugate symmetric) array.

eigvalsh
eigenvalues of a real symmetric or complex Hermitian (conjugate symmetric) array.

scipy.linalg.eig
Similar function in SciPy that also solves the generalized eigenvalue problem.

scipy.linalg.schur
Best choice for unitary and other non-Hermitian normal matrices.

Notes

Broadcasting rules apply, see the *numpy.linalg* documentation for details.

This is implemented using the _geev LAPACK routines which compute the eigenvalues and eigenvectors of general square arrays.

The number *w* is an eigenvalue of *a* if there exists a vector *v* such that `a @ v = w * v`. Thus, the arrays *a*, *eigenvalues*, and *eigenvectors* satisfy the equations `a @ eigenvectors[:,i] = eigenvalues[i] * eigenvectors[:,i]` for $i \in \{0, ..., M-1\}$.

The array *eigenvectors* may not be of maximum rank, that is, some of the columns may be linearly dependent, although round-off error may obscure that fact. If the eigenvalues are all different, then theoretically the eigenvectors are linearly independent and *a* can be diagonalized by a similarity transformation using *eigenvectors*, i.e, `inv(eigenvectors) @ a @ eigenvectors` is diagonal.

For non-Hermitian normal matrices the SciPy function `scipy.linalg.schur` is preferred because the matrix *eigenvectors* is guaranteed to be unitary, which is not the case when using *eig*. The Schur factorization produces an upper triangular matrix rather than a diagonal matrix, but for normal matrices only the diagonal of the upper triangular matrix is needed, the rest is roundoff error.

Finally, it is emphasized that *eigenvectors* consists of the *right* (as in right-hand side) eigenvectors of *a*. A vector *y* satisfying `y.T @ a = z * y.T` for some number *z* is called a *left* eigenvector of *a*, and, in general, the left and right eigenvectors of a matrix are not necessarily the (perhaps conjugate) transposes of each other.

References

G. Strang, *Linear Algebra and Its Applications*, 2nd Ed., Orlando, FL, Academic Press, Inc., 1980, Various pp.

Examples

```
>>> import numpy as np
>>> from numpy import linalg as LA
```

(Almost) trivial example with real eigenvalues and eigenvectors.

```
>>> eigenvalues, eigenvectors = LA.eig(np.diag((1, 2, 3)))
>>> eigenvalues
array([1., 2., 3.])
>>> eigenvectors
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
```

Real matrix possessing complex eigenvalues and eigenvectors; note that the eigenvalues are complex conjugates of each other.

```
>>> eigenvalues, eigenvectors = LA.eig(np.array([[1, -1], [1, 1]]))
>>> eigenvalues
array([1.+1.j, 1.-1.j])
>>> eigenvectors
array([[0.70710678+0.j        , 0.70710678-0.j        ],
       [0.        -0.70710678j, 0.        +0.70710678j]])
```

Complex-valued matrix with real eigenvalues (but complex-valued eigenvectors); note that `a.conj().T == a`, i.e., *a* is Hermitian.

```
>>> a = np.array([[1, 1j], [-1j, 1]])
>>> eigenvalues, eigenvectors = LA.eig(a)
>>> eigenvalues
array([2.+0.j, 0.+0.j])
>>> eigenvectors
array([[ 0.        +0.70710678j,  0.70710678+0.j        ], # may vary
       [ 0.70710678+0.j        , -0.        +0.70710678j]])
```

Be careful about round-off error!

```
>>> a = np.array([[1 + 1e-9, 0], [0, 1 - 1e-9]])
>>> # Theor. eigenvalues are 1 +/- 1e-9
>>> eigenvalues, eigenvectors = LA.eig(a)
>>> eigenvalues
array([1., 1.])
>>> eigenvectors
array([[1., 0.],
       [0., 1.]])
```

linalg.**eigh**(*a*, *UPLO='L'*)

Return the eigenvalues and eigenvectors of a complex Hermitian (conjugate symmetric) or a real symmetric matrix.

Returns two objects, a 1-D array containing the eigenvalues of *a*, and a 2-D square array or matrix (depending on the input type) of the corresponding eigenvectors (in columns).

Parameters

a
: [(…, M, M) array] Hermitian or real symmetric matrices whose eigenvalues and eigenvectors are to be computed.

UPLO
: [{'L', 'U'}, optional] Specifies whether the calculation is done with the lower triangular part of *a* ('L', default) or the upper triangular part ('U'). Irrespective of this value only the real parts of the diagonal will be considered in the computation to preserve the notion of a Hermitian matrix. It therefore follows that the imaginary part of the diagonal will always be treated as zero.

Returns

A namedtuple with the following attributes:
eigenvalues
: [(…, M) ndarray] The eigenvalues in ascending order, each repeated according to its multiplicity.

eigenvectors
: [{(…, M, M) ndarray, (…, M, M) matrix}] The column `eigenvectors[:, i]` is the normalized eigenvector corresponding to the eigenvalue `eigenvalues[i]`. Will return a matrix object if *a* is a matrix object.

Raises

LinAlgError
: If the eigenvalue computation does not converge.

See also:

eigvalsh
: eigenvalues of real symmetric or complex Hermitian (conjugate symmetric) arrays.

eig
: eigenvalues and right eigenvectors for non-symmetric arrays.

eigvals
: eigenvalues of non-symmetric arrays.

scipy.linalg.eigh
: Similar function in SciPy (but also solves the generalized eigenvalue problem).

Notes

Broadcasting rules apply, see the *numpy.linalg* documentation for details.

The eigenvalues/eigenvectors are computed using LAPACK routines _syevd, _heevd.

The eigenvalues of real symmetric or complex Hermitian matrices are always real. [1] The array *eigenvalues* of (column) eigenvectors is unitary and *a*, *eigenvalues*, and *eigenvectors* satisfy the equations `dot(a, eigenvectors[:, i]) = eigenvalues[i] * eigenvectors[:, i]`.

References

[1]

Examples

```
>>> import numpy as np
>>> from numpy import linalg as LA
>>> a = np.array([[1, -2j], [2j, 5]])
>>> a
array([[ 1.+0.j, -0.-2.j],
       [ 0.+2.j,  5.+0.j]])
>>> eigenvalues, eigenvectors = LA.eigh(a)
>>> eigenvalues
array([0.17157288, 5.82842712])
>>> eigenvectors
array([[-0.92387953+0.j        , -0.38268343+0.j        ], # may vary
       [ 0.        +0.38268343j,  0.        -0.92387953j]])
```

```
>>> (np.dot(a, eigenvectors[:, 0]) -
... eigenvalues[0] * eigenvectors[:, 0])  # verify 1st eigenval/vec pair
array([5.55111512e-17+0.0000000e+00j, 0.00000000e+00+1.2490009e-16j])
>>> (np.dot(a, eigenvectors[:, 1]) -
... eigenvalues[1] * eigenvectors[:, 1])  # verify 2nd eigenval/vec pair
array([0.+0.j, 0.+0.j])
```

```
>>> A = np.matrix(a) # what happens if input is a matrix object
>>> A
matrix([[ 1.+0.j, -0.-2.j],
        [ 0.+2.j,  5.+0.j]])
>>> eigenvalues, eigenvectors = LA.eigh(A)
>>> eigenvalues
array([0.17157288, 5.82842712])
>>> eigenvectors
matrix([[-0.92387953+0.j        , -0.38268343+0.j        ], # may vary
        [ 0.        +0.38268343j,  0.        -0.92387953j]])
```

```
>>> # demonstrate the treatment of the imaginary part of the diagonal
>>> a = np.array([[5+2j, 9-2j], [0+2j, 2-1j]])
>>> a
array([[5.+2.j, 9.-2.j],
       [0.+2.j, 2.-1.j]])
>>> # with UPLO='L' this is numerically equivalent to using LA.eig() with:
>>> b = np.array([[5.+0.j, 0.-2.j], [0.+2.j, 2.-0.j]])
>>> b
array([[5.+0.j, 0.-2.j],
       [0.+2.j, 2.+0.j]])
>>> wa, va = LA.eigh(a)
>>> wb, vb = LA.eig(b)
>>> wa
array([1., 6.])
>>> wb
array([6.+0.j, 1.+0.j])
>>> va
array([[-0.4472136 +0.j        , -0.89442719+0.j        ], # may vary
       [ 0.        +0.89442719j,  0.        -0.4472136j ]])
>>> vb
array([[ 0.89442719+0.j       , -0.        +0.4472136j],
       [-0.        +0.4472136j,  0.89442719+0.j       ]])
```

linalg.**eigvals**(*a*)

Compute the eigenvalues of a general matrix.

Main difference between *eigvals* and *eig*: the eigenvectors aren't returned.

Parameters

a
: [(…, M, M) array_like] A complex- or real-valued matrix whose eigenvalues will be computed.

Returns

w
: [(…, M,) ndarray] The eigenvalues, each repeated according to its multiplicity. They are not necessarily ordered, nor are they necessarily real for real matrices.

Raises

LinAlgError
: If the eigenvalue computation does not converge.

See also:

eig
: eigenvalues and right eigenvectors of general arrays

eigvalsh
: eigenvalues of real symmetric or complex Hermitian (conjugate symmetric) arrays.

eigh
: eigenvalues and eigenvectors of real symmetric or complex Hermitian (conjugate symmetric) arrays.

scipy.linalg.eigvals
: Similar function in SciPy.

Notes

Broadcasting rules apply, see the *numpy.linalg* documentation for details.

This is implemented using the _geev LAPACK routines which compute the eigenvalues and eigenvectors of general square arrays.

Examples

Illustration, using the fact that the eigenvalues of a diagonal matrix are its diagonal elements, that multiplying a matrix on the left by an orthogonal matrix, *Q*, and on the right by *Q.T* (the transpose of *Q*), preserves the eigenvalues of the "middle" matrix. In other words, if *Q* is orthogonal, then `Q * A * Q.T` has the same eigenvalues as `A`:

```
>>> import numpy as np
>>> from numpy import linalg as LA
>>> x = np.random.random()
>>> Q = np.array([[np.cos(x), -np.sin(x)], [np.sin(x), np.cos(x)]])
>>> LA.norm(Q[0, :]), LA.norm(Q[1, :]), np.dot(Q[0, :],Q[1, :])
(1.0, 1.0, 0.0)
```

Now multiply a diagonal matrix by `Q` on one side and by `Q.T` on the other:

```
>>> D = np.diag((-1,1))
>>> LA.eigvals(D)
array([-1.,  1.])
>>> A = np.dot(Q, D)
>>> A = np.dot(A, Q.T)
>>> LA.eigvals(A)
array([ 1., -1.]) # random
```

linalg.**eigvalsh**(*a*, *UPLO='L'*)

Compute the eigenvalues of a complex Hermitian or real symmetric matrix.

Main difference from eigh: the eigenvectors are not computed.

Parameters

a
: [(…, M, M) array_like] A complex- or real-valued matrix whose eigenvalues are to be computed.

UPLO
: [{'L', 'U'}, optional] Specifies whether the calculation is done with the lower triangular part of *a* ('L', default) or the upper triangular part ('U'). Irrespective of this value only the real parts of the diagonal will be considered in the computation to preserve the notion of a Hermitian matrix. It therefore follows that the imaginary part of the diagonal will always be treated as zero.

Returns

w
: [(…, M,) ndarray] The eigenvalues in ascending order, each repeated according to its multiplicity.

Raises

LinAlgError
: If the eigenvalue computation does not converge.

See also:

eigh
: eigenvalues and eigenvectors of real symmetric or complex Hermitian (conjugate symmetric) arrays.

eigvals
: eigenvalues of general real or complex arrays.

eig
: eigenvalues and right eigenvectors of general real or complex arrays.

scipy.linalg.eigvalsh
: Similar function in SciPy.

Notes

Broadcasting rules apply, see the *numpy.linalg* documentation for details.

The eigenvalues are computed using LAPACK routines _syevd, _heevd.

Examples

```
>>> import numpy as np
>>> from numpy import linalg as LA
>>> a = np.array([[1, -2j], [2j, 5]])
>>> LA.eigvalsh(a)
array([ 0.17157288,  5.82842712]) # may vary
```

```
>>> # demonstrate the treatment of the imaginary part of the diagonal
>>> a = np.array([[5+2j, 9-2j], [0+2j, 2-1j]])
>>> a
array([[5.+2.j, 9.-2.j],
       [0.+2.j, 2.-1.j]])
>>> # with UPLO='L' this is numerically equivalent to using LA.eigvals()
>>> # with:
>>> b = np.array([[5.+0.j, 0.-2.j], [0.+2.j, 2.-0.j]])
>>> b
array([[5.+0.j, 0.-2.j],
       [0.+2.j, 2.+0.j]])
>>> wa = LA.eigvalsh(a)
>>> wb = LA.eigvals(b)
>>> wa; wb
array([1., 6.])
array([6.+0.j, 1.+0.j])
```

Norms and other numbers

linalg.norm(x[, ord, axis, keepdims])	Matrix or vector norm.
linalg.matrix_norm(x, /, *[, keepdims, ord])	Computes the matrix norm of a matrix (or a stack of matrices) `x`.
linalg.vector_norm(x, /, *[, axis, ...])	Computes the vector norm of a vector (or batch of vectors) `x`.
linalg.cond(x[, p])	Compute the condition number of a matrix.
linalg.det(a)	Compute the determinant of an array.
linalg.matrix_rank(A[, tol, hermitian, rtol])	Return matrix rank of array using SVD method
linalg.slogdet(a)	Compute the sign and (natural) logarithm of the determinant of an array.
trace(a[, offset, axis1, axis2, dtype, out])	Return the sum along diagonals of the array.
linalg.trace(x, /, *[, offset, dtype])	Returns the sum along the specified diagonals of a matrix (or a stack of matrices) `x`.

`linalg.`**`norm`**(*x*, *ord=None*, *axis=None*, *keepdims=False*)

Matrix or vector norm.

This function is able to return one of eight different matrix norms, or one of an infinite number of vector norms (described below), depending on the value of the `ord` parameter.

Parameters

x
: [array_like] Input array. If *axis* is None, *x* must be 1-D or 2-D, unless *ord* is None. If both *axis* and *ord* are None, the 2-norm of `x.ravel` will be returned.

ord
: [{int, float, inf, -inf, 'fro', 'nuc'}, optional] Order of the norm (see table under `Notes` for what values are supported for matrices and vectors respectively). inf means numpy's *inf* object. The default is None.

axis
: [{None, int, 2-tuple of ints}, optional.] If *axis* is an integer, it specifies the axis of *x* along which to compute the vector norms. If *axis* is a 2-tuple, it specifies the axes that hold 2-D matrices, and the matrix norms of these matrices are computed. If *axis* is None then either a vector norm (when *x* is 1-D) or a matrix norm (when *x* is 2-D) is returned. The default is None.

keepdims
: [bool, optional] If this is set to True, the axes which are normed over are left in the result as dimensions with size one. With this option the result will broadcast correctly against the original *x*.

Returns

n
: [float or ndarray] Norm of the matrix or vector(s).

See also:

scipy.linalg.norm
: Similar function in SciPy.

Notes

For values of `ord < 1`, the result is, strictly speaking, not a mathematical 'norm', but it may still be useful for various numerical purposes.

The following norms can be calculated:

ord	norm for matrices	norm for vectors
None	Frobenius norm	2-norm
'fro'	Frobenius norm	–
'nuc'	nuclear norm	–
inf	max(sum(abs(x), axis=1))	max(abs(x))
-inf	min(sum(abs(x), axis=1))	min(abs(x))
0	–	sum(x != 0)
1	max(sum(abs(x), axis=0))	as below
-1	min(sum(abs(x), axis=0))	as below
2	2-norm (largest sing. value)	as below
-2	smallest singular value	as below
other	–	sum(abs(x)**ord)**(1./ord)

The Frobenius norm is given by [1]:

$||A||_F = [\sum_{i,j} abs(a_{i,j})^2]^{1/2}$

The nuclear norm is the sum of the singular values.

Both the Frobenius and nuclear norm orders are only defined for matrices and raise a ValueError when `x.ndim != 2`.

References

[1]

Examples

```
>>> import numpy as np
>>> from numpy import linalg as LA
>>> a = np.arange(9) - 4
>>> a
array([-4, -3, -2, ...,  2,  3,  4])
>>> b = a.reshape((3, 3))
>>> b
array([[-4, -3, -2],
       [-1,  0,  1],
       [ 2,  3,  4]])
```

```
>>> LA.norm(a)
7.745966692414834
>>> LA.norm(b)
7.745966692414834
>>> LA.norm(b, 'fro')
7.745966692414834
>>> LA.norm(a, np.inf)
```

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```
4.0
>>> LA.norm(b, np.inf)
9.0
>>> LA.norm(a, -np.inf)
0.0
>>> LA.norm(b, -np.inf)
2.0
```

```
>>> LA.norm(a, 1)
20.0
>>> LA.norm(b, 1)
7.0
>>> LA.norm(a, -1)
-4.6566128774142013e-010
>>> LA.norm(b, -1)
6.0
>>> LA.norm(a, 2)
7.745966692414834
>>> LA.norm(b, 2)
7.3484692283495345
```

```
>>> LA.norm(a, -2)
0.0
>>> LA.norm(b, -2)
1.8570331885190563e-016 # may vary
>>> LA.norm(a, 3)
5.8480354764257312 # may vary
>>> LA.norm(a, -3)
0.0
```

Using the *axis* argument to compute vector norms:

```
>>> c = np.array([[ 1, 2, 3],
...               [-1, 1, 4]])
>>> LA.norm(c, axis=0)
array([ 1.41421356,  2.23606798,  5.        ])
>>> LA.norm(c, axis=1)
array([ 3.74165739,  4.24264069])
>>> LA.norm(c, ord=1, axis=1)
array([ 6.,  6.])
```

Using the *axis* argument to compute matrix norms:

```
>>> m = np.arange(8).reshape(2,2,2)
>>> LA.norm(m, axis=(1,2))
array([  3.74165739,  11.22497216])
>>> LA.norm(m[0, :, :]), LA.norm(m[1, :, :])
(3.7416573867739413, 11.224972160321824)
```

linalg.**matrix_norm**(*x*, */*, ***, *keepdims=False*, *ord='fro'*)

Computes the matrix norm of a matrix (or a stack of matrices) `x`.

This function is Array API compatible.

Parameters

x

[array_like] Input array having shape (…, M, N) and whose two innermost dimensions form `MxN` matrices.

keepdims
[bool, optional] If this is set to True, the axes which are normed over are left in the result as dimensions with size one. Default: False.

ord
[{1, -1, 2, -2, inf, -inf, 'fro', 'nuc'}, optional] The order of the norm. For details see the table under `Notes` in *numpy.linalg.norm*.

See also:

numpy.linalg.norm
Generic norm function

Examples

```
>>> from numpy import linalg as LA
>>> a = np.arange(9) - 4
>>> a
array([-4, -3, -2, ...,  2,  3,  4])
>>> b = a.reshape((3, 3))
>>> b
array([[-4, -3, -2],
       [-1,  0,  1],
       [ 2,  3,  4]])
```

```
>>> LA.matrix_norm(b)
7.745966692414834
>>> LA.matrix_norm(b, ord='fro')
7.745966692414834
>>> LA.matrix_norm(b, ord=np.inf)
9.0
>>> LA.matrix_norm(b, ord=-np.inf)
2.0
```

```
>>> LA.matrix_norm(b, ord=1)
7.0
>>> LA.matrix_norm(b, ord=-1)
6.0
>>> LA.matrix_norm(b, ord=2)
7.3484692283495345
>>> LA.matrix_norm(b, ord=-2)
1.8570331885190563e-016 # may vary
```

`linalg.`**`vector_norm`**(*x*, */*, ***, *axis=None*, *keepdims=False*, *ord=2*)

Computes the vector norm of a vector (or batch of vectors) `x`.

This function is Array API compatible.

Parameters

x
[array_like] Input array.

axis
[{None, int, 2-tuple of ints}, optional] If an integer, `axis` specifies the axis (dimension) along

which to compute vector norms. If an n-tuple, `axis` specifies the axes (dimensions) along which to compute batched vector norms. If `None`, the vector norm must be computed over all array values (i.e., equivalent to computing the vector norm of a flattened array). Default: `None`.

keepdims
[bool, optional] If this is set to True, the axes which are normed over are left in the result as dimensions with size one. Default: False.

ord
[{int, float, inf, -inf}, optional] The order of the norm. For details see the table under `Notes` in *numpy.linalg.norm*.

See also:

numpy.linalg.norm
Generic norm function

Examples

```
>>> from numpy import linalg as LA
>>> a = np.arange(9) + 1
>>> a
array([1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> b = a.reshape((3, 3))
>>> b
array([[1, 2, 3],
       [4, 5, 6],
       [7, 8, 9]])
```

```
>>> LA.vector_norm(b)
16.881943016134134
>>> LA.vector_norm(b, ord=np.inf)
9.0
>>> LA.vector_norm(b, ord=-np.inf)
1.0
```

```
>>> LA.vector_norm(b, ord=0)
9.0
>>> LA.vector_norm(b, ord=1)
45.0
>>> LA.vector_norm(b, ord=-1)
0.3534857623790153
>>> LA.vector_norm(b, ord=2)
16.881943016134134
>>> LA.vector_norm(b, ord=-2)
0.8058837395885292
```

`linalg.`**`cond`**(*x*, *p=None*)

Compute the condition number of a matrix.

This function is capable of returning the condition number using one of seven different norms, depending on the value of *p* (see Parameters below).

Parameters

x

[(…, M, N) array_like] The matrix whose condition number is sought.

p

[{None, 1, -1, 2, -2, inf, -inf, 'fro'}, optional] Order of the norm used in the condition number computation:

p	norm for matrices
None	2-norm, computed directly using the `SVD`
'fro'	Frobenius norm
inf	max(sum(abs(x), axis=1))
-inf	min(sum(abs(x), axis=1))
1	max(sum(abs(x), axis=0))
-1	min(sum(abs(x), axis=0))
2	2-norm (largest sing. value)
-2	smallest singular value

inf means the *numpy.inf* object, and the Frobenius norm is the root-of-sum-of-squares norm.

Returns

c

[{float, inf}] The condition number of the matrix. May be infinite.

See also:

numpy.linalg.norm

Notes

The condition number of x is defined as the norm of x times the norm of the inverse of x [1]; the norm can be the usual L2-norm (root-of-sum-of-squares) or one of a number of other matrix norms.

References

[1]

Examples

```
>>> import numpy as np
>>> from numpy import linalg as LA
>>> a = np.array([[1, 0, -1], [0, 1, 0], [1, 0, 1]])
>>> a
array([[ 1,  0, -1],
       [ 0,  1,  0],
       [ 1,  0,  1]])
>>> LA.cond(a)
1.4142135623730951
>>> LA.cond(a, 'fro')
3.1622776601683795
>>> LA.cond(a, np.inf)
```

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```
2.0
>>> LA.cond(a, -np.inf)
1.0
>>> LA.cond(a, 1)
2.0
>>> LA.cond(a, -1)
1.0
>>> LA.cond(a, 2)
1.4142135623730951
>>> LA.cond(a, -2)
0.70710678118654746 # may vary
>>> (min(LA.svd(a, compute_uv=False)) *
... min(LA.svd(LA.inv(a), compute_uv=False)))
0.70710678118654746 # may vary
```

linalg.**det**(*a*)

Compute the determinant of an array.

Parameters

a
[(…, M, M) array_like] Input array to compute determinants for.

Returns

det
[(…) array_like] Determinant of *a*.

See also:

slogdet
Another way to represent the determinant, more suitable for large matrices where underflow/overflow may occur.

scipy.linalg.det
Similar function in SciPy.

Notes

Broadcasting rules apply, see the *numpy.linalg* documentation for details.

The determinant is computed via LU factorization using the LAPACK routine `z/dgetrf`.

Examples

The determinant of a 2-D array [[a, b], [c, d]] is ad - bc:

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> np.linalg.det(a)
-2.0 # may vary
```

Computing determinants for a stack of matrices:

```
>>> a = np.array([ [[1, 2], [3, 4]], [[1, 2], [2, 1]], [[1, 3], [3, 1]] ])
>>> a.shape
(3, 2, 2)
>>> np.linalg.det(a)
array([-2., -3., -8.])
```

linalg.**matrix_rank**(*A*, *tol=None*, *hermitian=False*, *, *rtol=None*)

Return matrix rank of array using SVD method

Rank of the array is the number of singular values of the array that are greater than *tol*.

Parameters

A
[{(M,), (…, M, N)} array_like] Input vector or stack of matrices.

tol
[(…) array_like, float, optional] Threshold below which SVD values are considered zero. If *tol* is None, and `S` is an array with singular values for *M*, and `eps` is the epsilon value for datatype of `S`, then *tol* is set to `S.max() * max(M, N) * eps`.

hermitian
[bool, optional] If True, *A* is assumed to be Hermitian (symmetric if real-valued), enabling a more efficient method for finding singular values. Defaults to False.

rtol
[(…) array_like, float, optional] Parameter for the relative tolerance component. Only `tol` or `rtol` can be set at a time. Defaults to `max(M, N) * eps`.

New in version 2.0.0.

Returns

rank
[(…) array_like] Rank of A.

Notes

The default threshold to detect rank deficiency is a test on the magnitude of the singular values of *A*. By default, we identify singular values less than `S.max() * max(M, N) * eps` as indicating rank deficiency (with the symbols defined above). This is the algorithm MATLAB uses [1]. It also appears in *Numerical recipes* in the discussion of SVD solutions for linear least squares [2].

This default threshold is designed to detect rank deficiency accounting for the numerical errors of the SVD computation. Imagine that there is a column in *A* that is an exact (in floating point) linear combination of other columns in *A*. Computing the SVD on *A* will not produce a singular value exactly equal to 0 in general: any difference of the smallest SVD value from 0 will be caused by numerical imprecision in the calculation of the SVD. Our threshold for small SVD values takes this numerical imprecision into account, and the default threshold will detect such numerical rank deficiency. The threshold may declare a matrix *A* rank deficient even if the linear combination of some columns of *A* is not exactly equal to another column of *A* but only numerically very close to another column of *A*.

We chose our default threshold because it is in wide use. Other thresholds are possible. For example, elsewhere in the 2007 edition of *Numerical recipes* there is an alternative threshold of `S.max() * np.finfo(A.dtype).eps / 2. * np.sqrt(m + n + 1.)`. The authors describe this threshold as being based on "expected roundoff error" (p 71).

The thresholds above deal with floating point roundoff error in the calculation of the SVD. However, you may have more information about the sources of error in *A* that would make you consider other tolerance values to detect

effective rank deficiency. The most useful measure of the tolerance depends on the operations you intend to use on your matrix. For example, if your data come from uncertain measurements with uncertainties greater than floating point epsilon, choosing a tolerance near that uncertainty may be preferable. The tolerance may be absolute if the uncertainties are absolute rather than relative.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> from numpy.linalg import matrix_rank
>>> matrix_rank(np.eye(4)) # Full rank matrix
4
>>> I=np.eye(4); I[-1,-1] = 0. # rank deficient matrix
>>> matrix_rank(I)
3
>>> matrix_rank(np.ones((4,))) # 1 dimension - rank 1 unless all 0
1
>>> matrix_rank(np.zeros((4,)))
0
```

linalg.**slogdet**(*a*)

Compute the sign and (natural) logarithm of the determinant of an array.

If an array has a very small or very large determinant, then a call to *det* may overflow or underflow. This routine is more robust against such issues, because it computes the logarithm of the determinant rather than the determinant itself.

Parameters

a
[(…, M, M) array_like] Input array, has to be a square 2-D array.

Returns

A namedtuple with the following attributes:
sign
[(…) array_like] A number representing the sign of the determinant. For a real matrix, this is 1, 0, or -1. For a complex matrix, this is a complex number with absolute value 1 (i.e., it is on the unit circle), or else 0.

logabsdet
[(…) array_like] The natural log of the absolute value of the determinant.

If the determinant is zero, then *sign* will be 0 and *logabsdet* will be -inf. In all cases, the determinant is equal to `sign * np.exp(logabsdet)`.

See also:

det

Notes

Broadcasting rules apply, see the *numpy.linalg* documentation for details.

The determinant is computed via LU factorization using the LAPACK routine `z/dgetrf`.

Examples

The determinant of a 2-D array `[[a, b], [c, d]]` is `ad - bc`:

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> (sign, logabsdet) = np.linalg.slogdet(a)
>>> (sign, logabsdet)
(-1, 0.69314718055994529) # may vary
>>> sign * np.exp(logabsdet)
-2.0
```

Computing log-determinants for a stack of matrices:

```
>>> a = np.array([ [[1, 2], [3, 4]], [[1, 2], [2, 1]], [[1, 3], [3, 1]] ])
>>> a.shape
(3, 2, 2)
>>> sign, logabsdet = np.linalg.slogdet(a)
>>> (sign, logabsdet)
(array([-1., -1., -1.]), array([ 0.69314718,  1.09861229,  2.07944154]))
>>> sign * np.exp(logabsdet)
array([-2., -3., -8.])
```

This routine succeeds where ordinary *det* does not:

```
>>> np.linalg.det(np.eye(500) * 0.1)
0.0
>>> np.linalg.slogdet(np.eye(500) * 0.1)
(1, -1151.2925464970228)
```

numpy.**trace**(*a*, *offset=0*, *axis1=0*, *axis2=1*, *dtype=None*, *out=None*)

Return the sum along diagonals of the array.

If *a* is 2-D, the sum along its diagonal with the given offset is returned, i.e., the sum of elements `a[i,i+offset]` for all i.

If *a* has more than two dimensions, then the axes specified by axis1 and axis2 are used to determine the 2-D sub-arrays whose traces are returned. The shape of the resulting array is the same as that of *a* with *axis1* and *axis2* removed.

Parameters

a
: [array_like] Input array, from which the diagonals are taken.

offset
: [int, optional] Offset of the diagonal from the main diagonal. Can be both positive and negative. Defaults to 0.

axis1, axis2
: [int, optional] Axes to be used as the first and second axis of the 2-D sub-arrays from which the diagonals should be taken. Defaults are the first two axes of *a*.

dtype
: [dtype, optional] Determines the data-type of the returned array and of the accumulator where the elements are summed. If dtype has the value None and *a* is of integer type of precision less than the default integer precision, then the default integer precision is used. Otherwise, the precision is the same as that of *a*.

out
: [ndarray, optional] Array into which the output is placed. Its type is preserved and it must be of the right shape to hold the output.

Returns

sum_along_diagonals
: [ndarray] If *a* is 2-D, the sum along the diagonal is returned. If *a* has larger dimensions, then an array of sums along diagonals is returned.

See also:

diag, *diagonal*, *diagflat*

Examples

```
>>> import numpy as np
>>> np.trace(np.eye(3))
3.0
>>> a = np.arange(8).reshape((2,2,2))
>>> np.trace(a)
array([6, 8])
```

```
>>> a = np.arange(24).reshape((2,2,2,3))
>>> np.trace(a).shape
(2, 3)
```

linalg.**trace**(*x*, */*, ***, *offset=0*, *dtype=None*)

Returns the sum along the specified diagonals of a matrix (or a stack of matrices) `x`.

This function is Array API compatible, contrary to *numpy.trace*.

Parameters

x
: [(…,M,N) array_like] Input array having shape (…, M, N) and whose innermost two dimensions form MxN matrices.

offset
: [int, optional] Offset specifying the off-diagonal relative to the main diagonal, where:

```
* offset = 0: the main diagonal.
* offset > 0: off-diagonal above the main diagonal.
* offset < 0: off-diagonal below the main diagonal.
```

dtype
: [dtype, optional] Data type of the returned array.

Returns

out
: [ndarray] An array containing the traces and whose shape is determined by removing the last two dimensions and storing the traces in the last array dimension. For example, if x has rank

k and shape: (I, J, K, …, L, M, N), then an output array has rank k-2 and shape: (I, J, K, …, L) where:

```
out[i, j, k, ..., l] = trace(a[i, j, k, ..., l, :, :])
```

The returned array must have a data type as described by the dtype parameter above.

See also:

numpy.trace

Examples

```
>>> np.linalg.trace(np.eye(3))
3.0
>>> a = np.arange(8).reshape((2, 2, 2))
>>> np.linalg.trace(a)
array([3, 11])
```

Trace is computed with the last two axes as the 2-d sub-arrays. This behavior differs from *numpy.trace* which uses the first two axes by default.

```
>>> a = np.arange(24).reshape((3, 2, 2, 2))
>>> np.linalg.trace(a).shape
(3, 2)
```

Traces adjacent to the main diagonal can be obtained by using the *offset* argument:

```
>>> a = np.arange(9).reshape((3, 3)); a
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
>>> np.linalg.trace(a, offset=1)  # First superdiagonal
6
>>> np.linalg.trace(a, offset=2)  # Second superdiagonal
2
>>> np.linalg.trace(a, offset=-1)  # First subdiagonal
10
>>> np.linalg.trace(a, offset=-2)  # Second subdiagonal
6
```

Solving equations and inverting matrices

linalg.solve(a, b)	Solve a linear matrix equation, or system of linear scalar equations.
linalg.tensorsolve(a, b[, axes])	Solve the tensor equation `a x = b` for x.
linalg.lstsq(a, b[, rcond])	Return the least-squares solution to a linear matrix equation.
linalg.inv(a)	Compute the inverse of a matrix.
linalg.pinv(a[, rcond, hermitian, rtol])	Compute the (Moore-Penrose) pseudo-inverse of a matrix.
linalg.tensorinv(a[, ind])	Compute the 'inverse' of an N-dimensional array.

linalg.**solve**(*a*, *b*)

Solve a linear matrix equation, or system of linear scalar equations.

Computes the "exact" solution, *x*, of the well-determined, i.e., full rank, linear matrix equation *ax* = *b*.

Parameters

a
[(…, M, M) array_like] Coefficient matrix.

b
[{(M,), (…, M, K)}, array_like] Ordinate or "dependent variable" values.

Returns

x
[{(…, M,), (…, M, K)} ndarray] Solution to the system a x = b. Returned shape is (…, M) if b is shape (M,) and (…, M, K) if b is (…, M, K), where the "…" part is broadcasted between a and b.

Raises

LinAlgError
If *a* is singular or not square.

See also:

scipy.linalg.solve
Similar function in SciPy.

Notes

Broadcasting rules apply, see the *numpy.linalg* documentation for details.

The solutions are computed using LAPACK routine _gesv.

a must be square and of full-rank, i.e., all rows (or, equivalently, columns) must be linearly independent; if either is not true, use *lstsq* for the least-squares best "solution" of the system/equation.

Changed in version 2.0: The b array is only treated as a shape (M,) column vector if it is exactly 1-dimensional. In all other instances it is treated as a stack of (M, K) matrices. Previously b would be treated as a stack of (M,) vectors if b.ndim was equal to a.ndim - 1.

References

[1]

Examples

Solve the system of equations: `x0 + 2 * x1 = 1` and `3 * x0 + 5 * x1 = 2`:

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 5]])
>>> b = np.array([1, 2])
>>> x = np.linalg.solve(a, b)
>>> x
array([-1.,  1.])
```

Check that the solution is correct:

```
>>> np.allclose(np.dot(a, x), b)
True
```

linalg.**tensorsolve**(*a*, *b*, *axes=None*)

Solve the tensor equation `a x = b` for x.

It is assumed that all indices of *x* are summed over in the product, together with the rightmost indices of *a*, as is done in, for example, `tensordot(a, x, axes=x.ndim)`.

Parameters

a
: [array_like] Coefficient tensor, of shape `b.shape + Q`. *Q*, a tuple, equals the shape of that sub-tensor of *a* consisting of the appropriate number of its rightmost indices, and must be such that `prod(Q) == prod(b.shape)` (in which sense *a* is said to be 'square').

b
: [array_like] Right-hand tensor, which can be of any shape.

axes
: [tuple of ints, optional] Axes in *a* to reorder to the right, before inversion. If None (default), no reordering is done.

Returns

x
: [ndarray, shape Q]

Raises

LinAlgError
: If *a* is singular or not 'square' (in the above sense).

See also:

numpy.tensordot*, *tensorinv*, *numpy.einsum

Examples

```
>>> import numpy as np
>>> a = np.eye(2*3*4)
>>> a.shape = (2*3, 4, 2, 3, 4)
>>> rng = np.random.default_rng()
>>> b = rng.normal(size=(2*3, 4))
>>> x = np.linalg.tensorsolve(a, b)
>>> x.shape
(2, 3, 4)
>>> np.allclose(np.tensordot(a, x, axes=3), b)
True
```

linalg.**lstsq**(*a*, *b*, *rcond=None*)

Return the least-squares solution to a linear matrix equation.

Computes the vector *x* that approximately solves the equation `a @ x = b`. The equation may be under-, well-, or over-determined (i.e., the number of linearly independent rows of *a* can be less than, equal to, or greater than its number of linearly independent columns). If *a* is square and of full rank, then *x* (but for round-off error) is

the "exact" solution of the equation. Else, x minimizes the Euclidean 2-norm $||b - ax||$. If there are multiple minimizing solutions, the one with the smallest 2-norm $||x||$ is returned.

Parameters

a
[(M, N) array_like] "Coefficient" matrix.

b
[{(M,), (M, K)} array_like] Ordinate or "dependent variable" values. If *b* is two-dimensional, the least-squares solution is calculated for each of the *K* columns of *b*.

rcond
[float, optional] Cut-off ratio for small singular values of *a*. For the purposes of rank determination, singular values are treated as zero if they are smaller than *rcond* times the largest singular value of *a*. The default uses the machine precision times `max(M, N)`. Passing `-1` will use machine precision.

Changed in version 2.0: Previously, the default was `-1`, but a warning was given that this would change.

Returns

x
[{(N,), (N, K)} ndarray] Least-squares solution. If *b* is two-dimensional, the solutions are in the *K* columns of *x*.

residuals
[{(1,), (K,), (0,)} ndarray] Sums of squared residuals: Squared Euclidean 2-norm for each column in `b - a @ x`. If the rank of *a* is < N or M <= N, this is an empty array. If *b* is 1-dimensional, this is a (1,) shape array. Otherwise the shape is (K,).

rank
[int] Rank of matrix *a*.

s
[(min(M, N),) ndarray] Singular values of *a*.

Raises

LinAlgError
If computation does not converge.

See also:

scipy.linalg.lstsq
Similar function in SciPy.

Notes

If *b* is a matrix, then all array results are returned as matrices.

Examples

Fit a line, `y = mx + c`, through some noisy data-points:

```
>>> import numpy as np
>>> x = np.array([0, 1, 2, 3])
>>> y = np.array([-1, 0.2, 0.9, 2.1])
```

By examining the coefficients, we see that the line should have a gradient of roughly 1 and cut the y-axis at, more or less, -1.

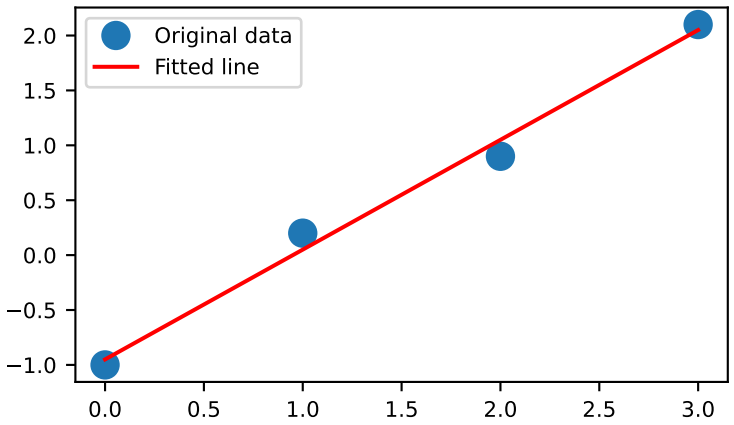
We can rewrite the line equation as `y = Ap`, where `A = [[x 1]]` and `p = [[m], [c]]`. Now use *`lstsq`* to solve for *p*:

```
>>> A = np.vstack([x, np.ones(len(x))]).T
>>> A
array([[ 0.,  1.],
       [ 1.,  1.],
       [ 2.,  1.],
       [ 3.,  1.]])
```

```
>>> m, c = np.linalg.lstsq(A, y)[0]
>>> m, c
(1.0 -0.95) # may vary
```

Plot the data along with the fitted line:

```
>>> import matplotlib.pyplot as plt
>>> _ = plt.plot(x, y, 'o', label='Original data', markersize=10)
>>> _ = plt.plot(x, m*x + c, 'r', label='Fitted line')
>>> _ = plt.legend()
>>> plt.show()
```



`linalg.`**`inv`**`(a)`

Compute the inverse of a matrix.

Given a square matrix *a*, return the matrix *ainv* satisfying `a @ ainv = ainv @ a = eye(a.shape[0])`.

Parameters

a
[(…, M, M) array_like] Matrix to be inverted.

Returns

ainv
[(…, M, M) ndarray or matrix] Inverse of the matrix *a*.

Raises

LinAlgError
If *a* is not square or inversion fails.

See also:

`scipy.linalg.inv`
Similar function in SciPy.

`numpy.linalg.cond`
Compute the condition number of a matrix.

`numpy.linalg.svd`
Compute the singular value decomposition of a matrix.

Notes

Broadcasting rules apply, see the *`numpy.linalg`* documentation for details.

If *a* is detected to be singular, a *`LinAlgError`* is raised. If *a* is ill-conditioned, a *`LinAlgError`* may or may not be raised, and results may be inaccurate due to floating-point errors.

References

[1]

Examples

```
>>> import numpy as np
>>> from numpy.linalg import inv
>>> a = np.array([[1., 2.], [3., 4.]])
>>> ainv = inv(a)
>>> np.allclose(a @ ainv, np.eye(2))
True
>>> np.allclose(ainv @ a, np.eye(2))
True
```

If a is a matrix object, then the return value is a matrix as well:

```
>>> ainv = inv(np.matrix(a))
>>> ainv
matrix([[-2. ,  1. ],
        [ 1.5, -0.5]])
```

Inverses of several matrices can be computed at once:

```
>>> a = np.array([[[1., 2.], [3., 4.]], [[1, 3], [3, 5]]])
>>> inv(a)
array([[[-2.  ,  1.  ],
        [ 1.5 , -0.5 ]],
       [[-1.25,  0.75],
        [ 0.75, -0.25]]])
```

If a matrix is close to singular, the computed inverse may not satisfy `a @ ainv = ainv @ a = eye(a.shape[0])` even if a *LinAlgError* is not raised:

```
>>> a = np.array([[2,4,6],[2,0,2],[6,8,14]])
>>> inv(a)  # No errors raised
array([[-1.12589991e+15, -5.62949953e+14,  5.62949953e+14],
   [-1.12589991e+15, -5.62949953e+14,  5.62949953e+14],
   [ 1.12589991e+15,  5.62949953e+14, -5.62949953e+14]])
>>> a @ inv(a)
array([[ 0.  , -0.5 ,  0.  ],  # may vary
       [-0.5 ,  0.625,  0.25 ],
       [ 0.  ,  0.  ,  1.  ]])
```

To detect ill-conditioned matrices, you can use *numpy.linalg.cond* to compute its *condition number* [1]. The larger the condition number, the more ill-conditioned the matrix is. As a rule of thumb, if the condition number `cond(a) = 10**k`, then you may lose up to `k` digits of accuracy on top of what would be lost to the numerical method due to loss of precision from arithmetic methods.

```
>>> from numpy.linalg import cond
>>> cond(a)
np.float64(8.659885634118668e+17)  # may vary
```

It is also possible to detect ill-conditioning by inspecting the matrix's singular values directly. The ratio between the largest and the smallest singular value is the condition number:

```
>>> from numpy.linalg import svd
>>> sigma = svd(a, compute_uv=False)  # Do not compute singular vectors
>>> sigma.max()/sigma.min()
8.659885634118668e+17  # may vary
```

`linalg.`**`pinv`**(*a*, *rcond=None*, *hermitian=False*, ***, *rtol=<no value>*)

Compute the (Moore-Penrose) pseudo-inverse of a matrix.

Calculate the generalized inverse of a matrix using its singular-value decomposition (SVD) and including all *large* singular values.

Parameters

a
: [(…, M, N) array_like] Matrix or stack of matrices to be pseudo-inverted.

rcond
: [(…) array_like of float, optional] Cutoff for small singular values. Singular values less than or equal to `rcond * largest_singular_value` are set to zero. Broadcasts against the stack of matrices. Default: `1e-15`.

hermitian
: [bool, optional] If True, *a* is assumed to be Hermitian (symmetric if real-valued), enabling a more efficient method for finding singular values. Defaults to False.

rtol
: [(…) array_like of float, optional] Same as *rcond*, but it's an Array API compatible parameter

name. Only *rcond* or *rtol* can be set at a time. If none of them are provided then NumPy's `1e-15` default is used. If `rtol=None` is passed then the API standard default is used.

New in version 2.0.0.

Returns

B
[(…, N, M) ndarray] The pseudo-inverse of *a*. If *a* is a *matrix* instance, then so is *B*.

Raises

LinAlgError
If the SVD computation does not converge.

See also:

scipy.linalg.pinv
Similar function in SciPy.

scipy.linalg.pinvh
Compute the (Moore-Penrose) pseudo-inverse of a Hermitian matrix.

Notes

The pseudo-inverse of a matrix A, denoted A^+, is defined as: "the matrix that 'solves' [the least-squares problem] $Ax = b$," i.e., if $\bar{x}$ is said solution, then A^+ is that matrix such that $\bar{x} = A^+b$.

It can be shown that if $Q_1\Sigma Q_2^T = A$ is the singular value decomposition of A, then $A^+ = Q_2\Sigma^+Q_1^T$, where $Q_{1,2}$ are orthogonal matrices, Σ is a diagonal matrix consisting of A's so-called singular values, (followed, typically, by zeros), and then Σ^+ is simply the diagonal matrix consisting of the reciprocals of A's singular values (again, followed by zeros). [1]

References

[1]

Examples

The following example checks that `a * a+ * a == a` and `a+ * a * a+ == a+`:

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> a = rng.normal(size=(9, 6))
>>> B = np.linalg.pinv(a)
>>> np.allclose(a, np.dot(a, np.dot(B, a)))
True
>>> np.allclose(B, np.dot(B, np.dot(a, B)))
True
```

linalg.**tensorinv**(*a*, *ind=2*)

Compute the 'inverse' of an N-dimensional array.

The result is an inverse for *a* relative to the tensordot operation `tensordot(a, b, ind)`, i. e., up to floating-point accuracy, `tensordot(tensorinv(a), a, ind)` is the "identity" tensor for the tensordot operation.

Parameters

a
: [array_like] Tensor to 'invert'. Its shape must be 'square', i. e., `prod(a.shape[:ind]) == prod(a.shape[ind:])`.

ind
: [int, optional] Number of first indices that are involved in the inverse sum. Must be a positive integer, default is 2.

Returns

b
: [ndarray] *a*'s tensordot inverse, shape `a.shape[ind:] + a.shape[:ind]`.

Raises

LinAlgError
: If *a* is singular or not 'square' (in the above sense).

See also:

numpy.tensordot, *tensorsolve*

Examples

```
>>> import numpy as np
>>> a = np.eye(4*6)
>>> a.shape = (4, 6, 8, 3)
>>> ainv = np.linalg.tensorinv(a, ind=2)
>>> ainv.shape
(8, 3, 4, 6)
>>> rng = np.random.default_rng()
>>> b = rng.normal(size=(4, 6))
>>> np.allclose(np.tensordot(ainv, b), np.linalg.tensorsolve(a, b))
True
```

```
>>> a = np.eye(4*6)
>>> a.shape = (24, 8, 3)
>>> ainv = np.linalg.tensorinv(a, ind=1)
>>> ainv.shape
(8, 3, 24)
>>> rng = np.random.default_rng()
>>> b = rng.normal(size=24)
>>> np.allclose(np.tensordot(ainv, b, 1), np.linalg.tensorsolve(a, b))
True
```

Other matrix operations

diagonal(a[, offset, axis1, axis2])	Return specified diagonals.
linalg.diagonal(x, /, *[, offset])	Returns specified diagonals of a matrix (or a stack of matrices) `x`.
linalg.matrix_transpose(x, /)	Transposes a matrix (or a stack of matrices) `x`.

numpy.**diagonal**(*a*, *offset=0*, *axis1=0*, *axis2=1*)

Return specified diagonals.

If *a* is 2-D, returns the diagonal of *a* with the given offset, i.e., the collection of elements of the form `a[i, i+offset]`. If *a* has more than two dimensions, then the axes specified by *axis1* and *axis2* are used to determine the 2-D sub-array whose diagonal is returned. The shape of the resulting array can be determined by removing *axis1* and *axis2* and appending an index to the right equal to the size of the resulting diagonals.

In versions of NumPy prior to 1.7, this function always returned a new, independent array containing a copy of the values in the diagonal.

In NumPy 1.7 and 1.8, it continues to return a copy of the diagonal, but depending on this fact is deprecated. Writing to the resulting array continues to work as it used to, but a FutureWarning is issued.

Starting in NumPy 1.9 it returns a read-only view on the original array. Attempting to write to the resulting array will produce an error.

In some future release, it will return a read/write view and writing to the returned array will alter your original array. The returned array will have the same type as the input array.

If you don't write to the array returned by this function, then you can just ignore all of the above.

If you depend on the current behavior, then we suggest copying the returned array explicitly, i.e., use `np.diagonal(a).copy()` instead of just `np.diagonal(a)`. This will work with both past and future versions of NumPy.

Parameters

a
: [array_like] Array from which the diagonals are taken.

offset
: [int, optional] Offset of the diagonal from the main diagonal. Can be positive or negative. Defaults to main diagonal (0).

axis1
: [int, optional] Axis to be used as the first axis of the 2-D sub-arrays from which the diagonals should be taken. Defaults to first axis (0).

axis2
: [int, optional] Axis to be used as the second axis of the 2-D sub-arrays from which the diagonals should be taken. Defaults to second axis (1).

Returns

array_of_diagonals
: [ndarray] If *a* is 2-D, then a 1-D array containing the diagonal and of the same type as *a* is returned unless *a* is a *matrix*, in which case a 1-D array rather than a (2-D) *matrix* is returned in order to maintain backward compatibility.

  If `a.ndim > 2`, then the dimensions specified by *axis1* and *axis2* are removed, and a new axis inserted at the end corresponding to the diagonal.

Raises

ValueError
: If the dimension of *a* is less than 2.

See also:

diag
: MATLAB work-a-like for 1-D and 2-D arrays.

diagflat
: Create diagonal arrays.

trace
Sum along diagonals.

Examples

```
>>> import numpy as np
>>> a = np.arange(4).reshape(2,2)
>>> a
array([[0, 1],
       [2, 3]])
>>> a.diagonal()
array([0, 3])
>>> a.diagonal(1)
array([1])
```

A 3-D example:

```
>>> a = np.arange(8).reshape(2,2,2); a
array([[[0, 1],
        [2, 3]],
       [[4, 5],
        [6, 7]]])
>>> a.diagonal(0,  # Main diagonals of two arrays created by skipping
...            0,  # across the outer(left)-most axis last and
...            1)  # the "middle" (row) axis first.
array([[0, 6],
       [1, 7]])
```

The sub-arrays whose main diagonals we just obtained; note that each corresponds to fixing the right-most (column) axis, and that the diagonals are "packed" in rows.

```
>>> a[:,:,0]  # main diagonal is [0 6]
array([[0, 2],
       [4, 6]])
>>> a[:,:,1]  # main diagonal is [1 7]
array([[1, 3],
       [5, 7]])
```

The anti-diagonal can be obtained by reversing the order of elements using either *numpy.flipud* or *numpy.fliplr*.

```
>>> a = np.arange(9).reshape(3, 3)
>>> a
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
>>> np.fliplr(a).diagonal()  # Horizontal flip
array([2, 4, 6])
>>> np.flipud(a).diagonal()  # Vertical flip
array([6, 4, 2])
```

Note that the order in which the diagonal is retrieved varies depending on the flip function.

linalg.**diagonal**(*x*, */*, ***, *offset=0*)

Returns specified diagonals of a matrix (or a stack of matrices) `x`.

This function is Array API compatible, contrary to *numpy.diagonal*, the matrix is assumed to be defined by the last two dimensions.

Parameters

x
[(…,M,N) array_like] Input array having shape (…, M, N) and whose innermost two dimensions form MxN matrices.

offset
[int, optional] Offset specifying the off-diagonal relative to the main diagonal, where:

```
* offset = 0: the main diagonal.
* offset > 0: off-diagonal above the main diagonal.
* offset < 0: off-diagonal below the main diagonal.
```

Returns

out
[(…,min(N,M)) ndarray] An array containing the diagonals and whose shape is determined by removing the last two dimensions and appending a dimension equal to the size of the resulting diagonals. The returned array must have the same data type as `x`.

See also:

numpy.diagonal

Examples

```
>>> a = np.arange(4).reshape(2, 2); a
array([[0, 1],
       [2, 3]])
>>> np.linalg.diagonal(a)
array([0, 3])
```

A 3-D example:

```
>>> a = np.arange(8).reshape(2, 2, 2); a
array([[[0, 1],
        [2, 3]],
       [[4, 5],
        [6, 7]]])
>>> np.linalg.diagonal(a)
array([[0, 3],
       [4, 7]])
```

Diagonals adjacent to the main diagonal can be obtained by using the *offset* argument:

```
>>> a = np.arange(9).reshape(3, 3)
>>> a
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
>>> np.linalg.diagonal(a, offset=1)  # First superdiagonal
array([1, 5])
>>> np.linalg.diagonal(a, offset=2)  # Second superdiagonal
array([2])
```

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```
>>> np.linalg.diagonal(a, offset=-1)  # First subdiagonal
array([3, 7])
>>> np.linalg.diagonal(a, offset=-2)  # Second subdiagonal
array([6])
```

The anti-diagonal can be obtained by reversing the order of elements using either *numpy.flipud* or *numpy.fliplr*.

```
>>> a = np.arange(9).reshape(3, 3)
>>> a
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
>>> np.linalg.diagonal(np.fliplr(a))  # Horizontal flip
array([2, 4, 6])
>>> np.linalg.diagonal(np.flipud(a))  # Vertical flip
array([6, 4, 2])
```

Note that the order in which the diagonal is retrieved varies depending on the flip function.

linalg.**matrix_transpose**(*x*, */*)

Transposes a matrix (or a stack of matrices) `x`.

This function is Array API compatible.

Parameters

x
[array_like] Input array having shape (…, M, N) and whose two innermost dimensions form `MxN` matrices.

Returns

out
[ndarray] An array containing the transpose for each matrix and having shape (…, N, M).

See also:

transpose
Generic transpose method.

Examples

```
>>> import numpy as np
>>> np.matrix_transpose([[1, 2], [3, 4]])
array([[1, 3],
       [2, 4]])
```

```
>>> np.matrix_transpose([[[1, 2], [3, 4]], [[5, 6], [7, 8]]])
array([[[1, 3],
        [2, 4]],
       [[5, 7],
        [6, 8]]])
```

Exceptions

linalg.LinAlgError	Generic Python-exception-derived object raised by linalg functions.

exception linalg.**LinAlgError**

Generic Python-exception-derived object raised by linalg functions.

General purpose exception class, derived from Python's ValueError class, programmatically raised in linalg functions when a Linear Algebra-related condition would prevent further correct execution of the function.

Parameters

None

Examples

```
>>> from numpy import linalg as LA
>>> LA.inv(np.zeros((2,2)))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "...linalg.py", line 350,
    in inv return wrap(solve(a, identity(a.shape[0], dtype=a.dtype)))
  File "...linalg.py", line 249,
    in solve
    raise LinAlgError('Singular matrix')
numpy.linalg.LinAlgError: Singular matrix
```

Linear algebra on several matrices at once

Several of the linear algebra routines listed above are able to compute results for several matrices at once, if they are stacked into the same array.

This is indicated in the documentation via input parameter specifications such as `a : (..., M, M) array_like`. This means that if for instance given an input array `a.shape == (N, M, M)`, it is interpreted as a "stack" of N matrices, each of size M-by-M. Similar specification applies to return values, for instance the determinant has `det : (...)` and will in this case return an array of shape `det(a).shape == (N,)`. This generalizes to linear algebra operations on higher-dimensional arrays: the last 1 or 2 dimensions of a multidimensional array are interpreted as vectors or matrices, as appropriate for each operation.

numpy.polynomial

A sub-package for efficiently dealing with polynomials.

Within the documentation for this sub-package, a "finite power series," i.e., a polynomial (also referred to simply as a "series") is represented by a 1-D numpy array of the polynomial's coefficients, ordered from lowest order term to highest. For example, array([1,2,3]) represents `P_0 + 2*P_1 + 3*P_2`, where P_n is the n-th order basis polynomial applicable to the specific module in question, e.g., *polynomial* (which "wraps" the "standard" basis) or *chebyshev*. For optimal performance, all operations on polynomials, including evaluation at an argument, are implemented as operations on the coefficients. Additional (module-specific) information can be found in the docstring for the module of interest.

This package provides *convenience classes* for each of six different kinds of polynomials:

Name	Provides
Polynomial	Power series
Chebyshev	Chebyshev series
Legendre	Legendre series
Laguerre	Laguerre series
Hermite	Hermite series
HermiteE	HermiteE series

These *convenience classes* provide a consistent interface for creating, manipulating, and fitting data with polynomials of different bases. The convenience classes are the preferred interface for the *polynomial* package, and are available from the `numpy.polynomial` namespace. This eliminates the need to navigate to the corresponding submodules, e.g. `np.polynomial.Polynomial` or `np.polynomial.Chebyshev` instead of `np.polynomial.polynomial.Polynomial` or `np.polynomial.chebyshev.Chebyshev`, respectively. The classes provide a more consistent and concise interface than the type-specific functions defined in the submodules for each type of polynomial. For example, to fit a Chebyshev polynomial with degree `1` to data given by arrays `xdata` and `ydata`, the *fit* class method:

```
>>> from numpy.polynomial import Chebyshev
>>> xdata = [1, 2, 3, 4]
>>> ydata = [1, 4, 9, 16]
>>> c = Chebyshev.fit(xdata, ydata, deg=1)
```

is preferred over the *chebyshev.chebfit* function from the `np.polynomial.chebyshev` module:

```
>>> from numpy.polynomial.chebyshev import chebfit
>>> c = chebfit(xdata, ydata, deg=1)
```

See *Using the convenience classes* for more details.

Convenience Classes

The following lists the various constants and methods common to all of the classes representing the various kinds of polynomials. In the following, the term `Poly` represents any one of the convenience classes (e.g. *Polynomial*, *Chebyshev*, *Hermite*, etc.) while the lowercase `p` represents an **instance** of a polynomial class.

Constants

- `Poly.domain` – Default domain
- `Poly.window` – Default window
- `Poly.basis_name` – String used to represent the basis
- `Poly.maxpower` – Maximum value `n` such that `p**n` is allowed
- `Poly.nickname` – String used in printing

Creation

Methods for creating polynomial instances.

- `Poly.basis(degree)` – Basis polynomial of given degree
- `Poly.identity()` – `p` where `p(x) = x` for all `x`
- `Poly.fit(x, y, deg)` – `p` of degree `deg` with coefficients determined by the least-squares fit to the data `x`, `y`
- `Poly.fromroots(roots)` – `p` with specified roots
- `p.copy()` – Create a copy of `p`

Conversion

Methods for converting a polynomial instance of one kind to another.

- `p.cast(Poly)` – Convert `p` to instance of kind `Poly`
- `p.convert(Poly)` – Convert `p` to instance of kind `Poly` or map between `domain` and `window`

Calculus

- `p.deriv()` – Take the derivative of `p`
- `p.integ()` – Integrate `p`

Validation

- `Poly.has_samecoef(p1, p2)` – Check if coefficients match
- `Poly.has_samedomain(p1, p2)` – Check if domains match
- `Poly.has_sametype(p1, p2)` – Check if types match
- `Poly.has_samewindow(p1, p2)` – Check if windows match

Misc

- `p.linspace()` – Return `x, p(x)` at equally-spaced points in `domain`
- `p.mapparms()` – Return the parameters for the linear mapping between `domain` and `window`.
- `p.roots()` – Return the roots of `p`.
- `p.trim()` – Remove trailing coefficients.
- `p.cutdeg(degree)` – Truncate `p` to given degree
- `p.truncate(size)` – Truncate `p` to given size

Configuration

numpy.polynomial.set_default_printstyle(style)	Set the default format for the string representation of polynomials.

polynomial.**set_default_printstyle**(*style*)

Set the default format for the string representation of polynomials.

Values for `style` must be valid inputs to `__format__`, i.e. 'ascii' or 'unicode'.

Parameters

style
[str] Format string for default printing style. Must be either 'ascii' or 'unicode'.

Notes

The default format depends on the platform: 'unicode' is used on Unix-based systems and 'ascii' on Windows. This determination is based on default font support for the unicode superscript and subscript ranges.

Examples

```
>>> p = np.polynomial.Polynomial([1, 2, 3])
>>> c = np.polynomial.Chebyshev([1, 2, 3])
>>> np.polynomial.set_default_printstyle('unicode')
>>> print(p)
1.0 + 2.0·x + 3.0·x²
>>> print(c)
1.0 + 2.0·T₁(x) + 3.0·T₂(x)
>>> np.polynomial.set_default_printstyle('ascii')
>>> print(p)
1.0 + 2.0 x + 3.0 x**2
>>> print(c)
1.0 + 2.0 T_1(x) + 3.0 T_2(x)
>>> # Formatting supersedes all class/package-level defaults
>>> print(f"{p:unicode}")
1.0 + 2.0·x + 3.0·x²
```

Random sampling (`numpy.random`)

Quick start

The *numpy.random* module implements pseudo-random number generators (PRNGs or RNGs, for short) with the ability to draw samples from a variety of probability distributions. In general, users will create a *Generator* instance with *default_rng* and call the various methods on it to obtain samples from different distributions.

```
>>> import numpy as np
>>> rng = np.random.default_rng()
# Generate one random float uniformly distributed over the range [0, 1)
>>> rng.random()
0.06369197489564249  # may vary
# Generate an array of 10 numbers according to a unit Gaussian distribution
>>> rng.standard_normal(10)
```

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```
array([-0.31018314, -1.8922078 , -0.3628523 , -0.63526532,  0.43181166,  # may vary
        0.51640373,  1.25693945,  0.07779185,  0.84090247, -2.13406828])
# Generate an array of 5 integers uniformly over the range [0, 10)
>>> rng.integers(low=0, high=10, size=5)
array([8, 7, 6, 2, 0])  # may vary
```

Our RNGs are deterministic sequences and can be reproduced by specifying a seed integer to derive its initial state. By default, with no seed provided, *default_rng* will seed the RNG from nondeterministic data from the operating system and therefore generate different numbers each time. The pseudo-random sequences will be independent for all practical purposes, at least those purposes for which our pseudo-randomness was good for in the first place.

```
>>> import numpy as np
>>> rng1 = np.random.default_rng()
>>> rng1.random()
0.6596288841243357  # may vary
>>> rng2 = np.random.default_rng()
>>> rng2.random()
0.11885628817151628  # may vary
```

Warning: The pseudo-random number generators implemented in this module are designed for statistical modeling and simulation. They are not suitable for security or cryptographic purposes. See the `secrets` module from the standard library for such use cases.

Seeds should be large positive integers. *default_rng* can take positive integers of any size. We recommend using very large, unique numbers to ensure that your seed is different from anyone else's. This is good practice to ensure that your results are statistically independent from theirs unless you are intentionally *trying* to reproduce their result. A convenient way to get such a seed number is to use `secrets.randbits` to get an arbitrary 128-bit integer.

```
>>> import numpy as np
>>> import secrets
>>> secrets.randbits(128)
122807528840384100672342137672332424406  # may vary
>>> rng1 = np.random.default_rng(122807528840384100672342137672332424406)
>>> rng1.random()
0.5363922081269535
>>> rng2 = np.random.default_rng(122807528840384100672342137672332424406)
>>> rng2.random()
0.5363922081269535
```

See the documentation on *default_rng* and *SeedSequence* for more advanced options for controlling the seed in specialized scenarios.

Generator and its associated infrastructure was introduced in NumPy version 1.17.0. There is still a lot of code that uses the older *RandomState* and the functions in *numpy.random*. While there are no plans to remove them at this time, we do recommend transitioning to *Generator* as you can. The algorithms are faster, more flexible, and will receive more improvements in the future. For the most part, *Generator* can be used as a replacement for *RandomState*. See *Legacy random generation* for information on the legacy infrastructure, *What's new or different* for information on transitioning, and NEP 19 for some of the reasoning for the transition.

Design

Users primarily interact with `Generator` instances. Each `Generator` instance owns a `BitGenerator` instance that implements the core RNG algorithm. The `BitGenerator` has a limited set of responsibilities. It manages state and provides functions to produce random doubles and random unsigned 32- and 64-bit values.

The `Generator` takes the bit generator-provided stream and transforms them into more useful distributions, e.g., simulated normal random values. This structure allows alternative bit generators to be used with little code duplication.

NumPy implements several different `BitGenerator` classes implementing different RNG algorithms. `default_rng` currently uses `PCG64` as the default `BitGenerator`. It has better statistical properties and performance than the `MT19937` algorithm used in the legacy `RandomState`. See *Bit generators* for more details on the supported BitGenerators.

`default_rng` and BitGenerators delegate the conversion of seeds into RNG states to `SeedSequence` internally. `SeedSequence` implements a sophisticated algorithm that intermediates between the user's input and the internal implementation details of each `BitGenerator` algorithm, each of which can require different amounts of bits for its state. Importantly, it lets you use arbitrary-sized integers and arbitrary sequences of such integers to mix together into the RNG state. This is a useful primitive for constructing a *flexible pattern for parallel RNG streams*.

For backward compatibility, we still maintain the legacy `RandomState` class. It continues to use the `MT19937` algorithm by default, and old seeds continue to reproduce the same results. The convenience *Functions in numpy.random* are still aliases to the methods on a single global `RandomState` instance. See *Legacy random generation* for the complete details. See *What's new or different* for a detailed comparison between `Generator` and `RandomState`.

Parallel Generation

The included generators can be used in parallel, distributed applications in a number of ways:

- *SeedSequence spawning*
- *Sequence of integer seeds*
- *Independent streams*
- *Jumping the BitGenerator state*

Users with a very large amount of parallelism will want to consult *Upgrading PCG64 with PCG64DXSM*.

Concepts

Random `Generator`

The `Generator` provides access to a wide range of distributions, and served as a replacement for `RandomState`. The main difference between the two is that `Generator` relies on an additional BitGenerator to manage state and generate the random bits, which are then transformed into random values from useful distributions. The default BitGenerator used by `Generator` is `PCG64`. The BitGenerator can be changed by passing an instantized BitGenerator to `Generator`.

`numpy.random.`**`default_rng`**(*seed=None*)

Construct a new Generator with the default BitGenerator (PCG64).

Parameters

seed

[{None, int, array_like[ints], SeedSequence, BitGenerator, Generator, RandomState}, optional] A seed to initialize the `BitGenerator`. If None, then fresh, unpredictable entropy will be pulled from the OS. If an `int` or `array_like[ints]` is passed, then all values must be non-negative and will be passed to `SeedSequence` to derive the initial `BitGenerator` state. One may also pass in a `SeedSequence` instance. Additionally, when passed

a *BitGenerator*, it will be wrapped by *Generator*. If passed a *Generator*, it will be returned unaltered. When passed a legacy *RandomState* instance it will be coerced to a *Generator*.

Returns

Generator
The initialized generator object.

Notes

If `seed` is not a *BitGenerator* or a *Generator*, a new *BitGenerator* is instantiated. This function does not manage a default global instance.

See *Seeding and entropy* for more information about seeding.

Examples

default_rng is the recommended constructor for the random number class *Generator*. Here are several ways we can construct a random number generator using *default_rng* and the *Generator* class.

Here we use *default_rng* to generate a random float:

```
>>> import numpy as np
>>> rng = np.random.default_rng(12345)
>>> print(rng)
Generator(PCG64)
>>> rfloat = rng.random()
>>> rfloat
0.22733602246716966
>>> type(rfloat)
<class 'float'>
```

Here we use *default_rng* to generate 3 random integers between 0 (inclusive) and 10 (exclusive):

```
>>> import numpy as np
>>> rng = np.random.default_rng(12345)
>>> rints = rng.integers(low=0, high=10, size=3)
>>> rints
array([6, 2, 7])
>>> type(rints[0])
<class 'numpy.int64'>
```

Here we specify a seed so that we have reproducible results:

```
>>> import numpy as np
>>> rng = np.random.default_rng(seed=42)
>>> print(rng)
Generator(PCG64)
>>> arr1 = rng.random((3, 3))
>>> arr1
array([[0.77395605, 0.43887844, 0.85859792],
       [0.69736803, 0.09417735, 0.97562235],
       [0.7611397 , 0.78606431, 0.12811363]])
```

If we exit and restart our Python interpreter, we'll see that we generate the same random numbers again:

```
>>> import numpy as np
>>> rng = np.random.default_rng(seed=42)
>>> arr2 = rng.random((3, 3))
>>> arr2
array([[0.77395605, 0.43887844, 0.85859792],
       [0.69736803, 0.09417735, 0.97562235],
       [0.7611397 , 0.78606431, 0.12811363]])
```

class numpy.random.**Generator**(*bit_generator*)

Container for the BitGenerators.

Generator exposes a number of methods for generating random numbers drawn from a variety of probability distributions. In addition to the distribution-specific arguments, each method takes a keyword argument *size* that defaults to None. If *size* is None, then a single value is generated and returned. If *size* is an integer, then a 1-D array filled with generated values is returned. If *size* is a tuple, then an array with that shape is filled and returned.

The function *numpy.random.default_rng* will instantiate a *Generator* with numpy's default *BitGenerator*.

No Compatibility Guarantee

Generator does not provide a version compatibility guarantee. In particular, as better algorithms evolve the bit stream may change.

Parameters

bit_generator
[BitGenerator] BitGenerator to use as the core generator.

See also:

default_rng
Recommended constructor for *Generator*.

Notes

The Python stdlib module random contains pseudo-random number generator with a number of methods that are similar to the ones available in *Generator*. It uses Mersenne Twister, and this bit generator can be accessed using *MT19937*. *Generator*, besides being NumPy-aware, has the advantage that it provides a much larger number of probability distributions to choose from.

Examples

```
>>> from numpy.random import Generator, PCG64
>>> rng = Generator(PCG64())
>>> rng.standard_normal()
-0.203  # random
```

Accessing the BitGenerator and spawning

bit_generator	Gets the bit generator instance used by the generator
spawn(n_children)	Create new independent child generators.

attribute

random.Generator.**bit_generator**

Gets the bit generator instance used by the generator

Returns

bit_generator
[BitGenerator] The bit generator instance used by the generator

method

random.Generator.**spawn**(*n_children*)

Create new independent child generators.

See *SeedSequence spawning* for additional notes on spawning children.

New in version 1.25.0.

Parameters

n_children
[int]

Returns

child_generators
[list of Generators]

Raises

TypeError
When the underlying SeedSequence does not implement spawning.

See also:

random.BitGenerator.spawn*, *random.SeedSequence.spawn
Equivalent method on the bit generator and seed sequence.

bit_generator
The bit generator instance used by the generator.

Examples

Starting from a seeded default generator:

```
>>> # High quality entropy created with: f"0x{secrets.randbits(128):x}"
>>> entropy = 0x3034c61a9ae04ff8cb62ab8ec2c4b501
>>> rng = np.random.default_rng(entropy)
```

Create two new generators for example for parallel execution:

```
>>> child_rng1, child_rng2 = rng.spawn(2)
```

Drawn numbers from each are independent but derived from the initial seeding entropy:

```
>>> rng.uniform(), child_rng1.uniform(), child_rng2.uniform()
(0.19029263503854454, 0.9475673279178444, 0.4702687338396767)
```

It is safe to spawn additional children from the original `rng` or the children:

```
>>> more_child_rngs = rng.spawn(20)
>>> nested_spawn = child_rng1.spawn(20)
```

Simple random data

integers(low[, high, size, dtype, endpoint])	Return random integers from *low* (inclusive) to *high* (exclusive), or if endpoint=True, *low* (inclusive) to *high* (inclusive).
random([size, dtype, out])	Return random floats in the half-open interval [0.0, 1.0).
choice(a[, size, replace, p, axis, shuffle])	Generates a random sample from a given array
bytes(length)	Return random bytes.

method

`random.Generator.`**`integers`**(*low*, *high=None*, *size=None*, *dtype=np.int64*, *endpoint=False*)

Return random integers from *low* (inclusive) to *high* (exclusive), or if endpoint=True, *low* (inclusive) to *high* (inclusive). Replaces *RandomState.randint* (with endpoint=False) and *RandomState.random_integers* (with endpoint=True)

Return random integers from the "discrete uniform" distribution of the specified dtype. If *high* is None (the default), then results are from 0 to *low*.

Parameters

low
: [int or array-like of ints] Lowest (signed) integers to be drawn from the distribution (unless `high=None`, in which case this parameter is 0 and this value is used for *high*).

high
: [int or array-like of ints, optional] If provided, one above the largest (signed) integer to be drawn from the distribution (see above for behavior if `high=None`). If array-like, must contain integer values

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

dtype
: [dtype, optional] Desired dtype of the result. Byteorder must be native. The default value is np.int64.

endpoint
: [bool, optional] If true, sample from the interval [low, high] instead of the default [low, high) Defaults to False

Returns

out
: [int or ndarray of ints] *size*-shaped array of random integers from the appropriate distribution, or a single such random int if *size* not provided.

Notes

When using broadcasting with uint64 dtypes, the maximum value (2**64) cannot be represented as a standard integer type. The high array (or low if high is None) must have object dtype, e.g., array([2**64]).

References

[1]

Examples

```
>>> rng = np.random.default_rng()
>>> rng.integers(2, size=10)
array([1, 0, 0, 0, 1, 1, 0, 0, 1, 0])  # random
>>> rng.integers(1, size=10)
array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0])
```

Generate a 2 x 4 array of ints between 0 and 4, inclusive:

```
>>> rng.integers(5, size=(2, 4))
array([[4, 0, 2, 1],
       [3, 2, 2, 0]])  # random
```

Generate a 1 x 3 array with 3 different upper bounds

```
>>> rng.integers(1, [3, 5, 10])
array([2, 2, 9])  # random
```

Generate a 1 by 3 array with 3 different lower bounds

```
>>> rng.integers([1, 5, 7], 10)
array([9, 8, 7])  # random
```

Generate a 2 by 4 array using broadcasting with dtype of uint8

```
>>> rng.integers([1, 3, 5, 7], [[10], [20]], dtype=np.uint8)
array([[ 8,  6,  9,  7],
       [ 1, 16,  9, 12]], dtype=uint8)  # random
```

method

`random.Generator.`**`random`**(*size=None*, *dtype=np.float64*, *out=None*)

Return random floats in the half-open interval [0.0, 1.0).

Results are from the "continuous uniform" distribution over the stated interval. To sample $Unif[a, b), b > a$ use *`uniform`* or multiply the output of *`random`* by `(b - a)` and add `a`:

```
(b - a) * random() + a
```

Parameters

size

[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

dtype
: [dtype, optional] Desired dtype of the result, only *float64* and *float32* are supported. Byteorder must be native. The default value is np.float64.

out
: [ndarray, optional] Alternative output array in which to place the result. If size is not None, it must have the same shape as the provided size and must match the type of the output values.

Returns

out
: [float or ndarray of floats] Array of random floats of shape *size* (unless `size=None`, in which case a single float is returned).

See also:

uniform
: Draw samples from the parameterized uniform distribution.

Examples

```
>>> rng = np.random.default_rng()
>>> rng.random()
0.47108547995356098 # random
>>> type(rng.random())
<class 'float'>
>>> rng.random((5,))
array([ 0.30220482,  0.86820401,  0.1654503 ,  0.11659149,  0.54323428]) # random
```

Three-by-two array of random numbers from [-5, 0):

```
>>> 5 * rng.random((3, 2)) - 5
array([[-3.99149989, -0.52338984], # random
       [-2.99091858, -0.79479508],
       [-1.23204345, -1.75224494]])
```

method

`random.Generator.`**`choice`**(*a*, *size=None*, *replace=True*, *p=None*, *axis=0*, *shuffle=True*)

Generates a random sample from a given array

Parameters

a
: [{array_like, int}] If an ndarray, a random sample is generated from its elements. If an int, the random sample is generated from np.arange(a).

size
: [{int, tuple[int]}, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn from the 1-d *a*. If *a* has more than one dimension, the *size* shape will be inserted into the *axis* dimension, so the output `ndim` will be `a.ndim - 1 + len(size)`. Default is None, in which case a single value is returned.

replace
: [bool, optional] Whether the sample is with or without replacement. Default is True, meaning that a value of `a` can be selected multiple times.

p
: [1-D array_like, optional] The probabilities associated with each entry in a. If not given, the sample assumes a uniform distribution over all entries in `a`.

axis
: [int, optional] The axis along which the selection is performed. The default, 0, selects by row.

shuffle
: [bool, optional] Whether the sample is shuffled when sampling without replacement. Default is True, False provides a speedup.

Returns

samples
: [single item or ndarray] The generated random samples

Raises

ValueError
: If a is an int and less than zero, if p is not 1-dimensional, if a is array-like with a size 0, if p is not a vector of probabilities, if a and p have different lengths, or if replace=False and the sample size is greater than the population size.

See also:

integers, ***shuffle***, ***permutation***

Notes

Setting user-specified probabilities through `p` uses a more general but less efficient sampler than the default. The general sampler produces a different sample than the optimized sampler even if each element of `p` is 1 / len(a).

`p` must sum to 1 when cast to `float64`. To ensure this, you may wish to normalize using `p = p / np.sum(p, dtype=float)`.

When passing `a` as an integer type and `size` is not specified, the return type is a native Python `int`.

Examples

Generate a uniform random sample from np.arange(5) of size 3:

```
>>> rng = np.random.default_rng()
>>> rng.choice(5, 3)
array([0, 3, 4]) # random
>>> #This is equivalent to rng.integers(0,5,3)
```

Generate a non-uniform random sample from np.arange(5) of size 3:

```
>>> rng.choice(5, 3, p=[0.1, 0, 0.3, 0.6, 0])
array([3, 3, 0]) # random
```

Generate a uniform random sample from np.arange(5) of size 3 without replacement:

```
>>> rng.choice(5, 3, replace=False)
array([3,1,0]) # random
>>> #This is equivalent to rng.permutation(np.arange(5))[:3]
```

Generate a uniform random sample from a 2-D array along the first axis (the default), without replacement:

```
>>> rng.choice([[0, 1, 2], [3, 4, 5], [6, 7, 8]], 2, replace=False)
array([[3, 4, 5], # random
       [0, 1, 2]])
```

Generate a non-uniform random sample from np.arange(5) of size 3 without replacement:

```
>>> rng.choice(5, 3, replace=False, p=[0.1, 0, 0.3, 0.6, 0])
array([2, 3, 0]) # random
```

Any of the above can be repeated with an arbitrary array-like instead of just integers. For instance:

```
>>> aa_milne_arr = ['pooh', 'rabbit', 'piglet', 'Christopher']
>>> rng.choice(aa_milne_arr, 5, p=[0.5, 0.1, 0.1, 0.3])
array(['pooh', 'pooh', 'pooh', 'Christopher', 'piglet'], # random
      dtype='<U11')
```

method

random.Generator.**bytes**(*length*)

Return random bytes.

Parameters

length
[int] Number of random bytes.

Returns

out
[bytes] String of length *length*.

Notes

This function generates random bytes from a discrete uniform distribution. The generated bytes are independent from the CPU's native endianness.

Examples

```
>>> rng = np.random.default_rng()
>>> rng.bytes(10)
b'\xfeC\x9b\x86\x17\xf2\xa1\xafcp'  # random
```

Permutations

The methods for randomly permuting a sequence are

shuffle(x[, axis])	Modify an array or sequence in-place by shuffling its contents.
permutation(x[, axis])	Randomly permute a sequence, or return a permuted range.
permuted(x[, axis, out])	Randomly permute *x* along axis *axis*.

method

random.Generator.**shuffle**(*x*, *axis=0*)

Modify an array or sequence in-place by shuffling its contents.

The order of sub-arrays is changed but their contents remains the same.

Parameters

x
[ndarray or MutableSequence] The array, list or mutable sequence to be shuffled.

axis
[int, optional] The axis which *x* is shuffled along. Default is 0. It is only supported on *ndarray* objects.

Returns

None

See also:

permuted
permutation

Notes

An important distinction between methods `shuffle` and `permuted` is how they both treat the `axis` parameter which can be found at *Handling the axis parameter*.

Examples

```
>>> rng = np.random.default_rng()
>>> arr = np.arange(10)
>>> arr
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> rng.shuffle(arr)
>>> arr
array([2, 0, 7, 5, 1, 4, 8, 9, 3, 6]) # random
```

```
>>> arr = np.arange(9).reshape((3, 3))
>>> arr
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
>>> rng.shuffle(arr)
>>> arr
array([[3, 4, 5], # random
       [6, 7, 8],
       [0, 1, 2]])
```

```
>>> arr = np.arange(9).reshape((3, 3))
>>> arr
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
>>> rng.shuffle(arr, axis=1)
>>> arr
```

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```
array([[2, 0, 1], # random
       [5, 3, 4],
       [8, 6, 7]])
```

method

`random.Generator.`**`permutation`**(*x*, *axis=0*)

Randomly permute a sequence, or return a permuted range.

Parameters

x
[int or array_like] If *x* is an integer, randomly permute `np.arange(x)`. If *x* is an array, make a copy and shuffle the elements randomly.

axis
[int, optional] The axis which *x* is shuffled along. Default is 0.

Returns

out
[ndarray] Permuted sequence or array range.

Examples

```
>>> rng = np.random.default_rng()
>>> rng.permutation(10)
array([1, 7, 4, 3, 0, 9, 2, 5, 8, 6]) # random
```

```
>>> rng.permutation([1, 4, 9, 12, 15])
array([15,  1,  9,  4, 12]) # random
```

```
>>> arr = np.arange(9).reshape((3, 3))
>>> rng.permutation(arr)
array([[6, 7, 8], # random
       [0, 1, 2],
       [3, 4, 5]])
```

```
>>> rng.permutation("abc")
Traceback (most recent call last):
    ...
numpy.exceptions.AxisError: axis 0 is out of bounds for array of dimension 0
```

```
>>> arr = np.arange(9).reshape((3, 3))
>>> rng.permutation(arr, axis=1)
array([[0, 2, 1], # random
       [3, 5, 4],
       [6, 8, 7]])
```

method

`random.Generator.`**`permuted`**(*x*, *axis=None*, *out=None*)

Randomly permute *x* along axis *axis*.

Unlike *`shuffle`*, each slice along the given axis is shuffled independently of the others.

Parameters

x
[array_like, at least one-dimensional] Array to be shuffled.

axis
[int, optional] Slices of *x* in this axis are shuffled. Each slice is shuffled independently of the others. If *axis* is None, the flattened array is shuffled.

out
[ndarray, optional] If given, this is the destination of the shuffled array. If *out* is None, a shuffled copy of the array is returned.

Returns

ndarray
If *out* is None, a shuffled copy of *x* is returned. Otherwise, the shuffled array is stored in *out*, and *out* is returned

See also:

shuffle
permutation

Notes

An important distinction between methods `shuffle` and `permuted` is how they both treat the `axis` parameter which can be found at *Handling the axis parameter*.

Examples

Create a *numpy.random.Generator* instance:

```
>>> rng = np.random.default_rng()
```

Create a test array:

```
>>> x = np.arange(24).reshape(3, 8)
>>> x
array([[ 0,  1,  2,  3,  4,  5,  6,  7],
       [ 8,  9, 10, 11, 12, 13, 14, 15],
       [16, 17, 18, 19, 20, 21, 22, 23]])
```

Shuffle the rows of *x*:

```
>>> y = rng.permuted(x, axis=1)
>>> y
array([[ 4,  3,  6,  7,  1,  2,  5,  0],  # random
       [15, 10, 14,  9, 12, 11,  8, 13],
       [17, 16, 20, 21, 18, 22, 23, 19]])
```

x has not been modified:

```
>>> x
array([[ 0,  1,  2,  3,  4,  5,  6,  7],
       [ 8,  9, 10, 11, 12, 13, 14, 15],
       [16, 17, 18, 19, 20, 21, 22, 23]])
```

To shuffle the rows of *x* in-place, pass *x* as the *out* parameter:

```
>>> y = rng.permuted(x, axis=1, out=x)
>>> x
array([[ 3,  0,  4,  7,  1,  6,  2,  5],  # random
       [ 8, 14, 13,  9, 12, 11, 15, 10],
       [17, 18, 16, 22, 19, 23, 20, 21]])
```

Note that when the `out` parameter is given, the return value is `out`:

```
>>> y is x
True
```

The following table summarizes the behaviors of the methods.

method	copy/in-place	axis handling
shuffle	in-place	as if 1d
permutation	copy	as if 1d
permuted	either (use 'out' for in-place)	axis independent

The following subsections provide more details about the differences.

In-place vs. copy

The main difference between *Generator.shuffle* and *Generator.permutation* is that *Generator.shuffle* operates in-place, while *Generator.permutation* returns a copy.

By default, *Generator.permuted* returns a copy. To operate in-place with *Generator.permuted*, pass the same array as the first argument *and* as the value of the `out` parameter. For example,

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> x = np.arange(0, 15).reshape(3, 5)
>>> x
array([[ 0,  1,  2,  3,  4],
       [ 5,  6,  7,  8,  9],
       [10, 11, 12, 13, 14]])
>>> y = rng.permuted(x, axis=1, out=x)
>>> x
array([[ 1,  0,  2,  4,  3],  # random
       [ 6,  7,  8,  9,  5],
       [10, 14, 11, 13, 12]])
```

Note that when `out` is given, the return value is `out`:

```
>>> y is x
True
```

Handling the `axis` parameter

An important distinction for these methods is how they handle the `axis` parameter. Both *`Generator.shuffle`* and *`Generator.permutation`* treat the input as a one-dimensional sequence, and the `axis` parameter determines which dimension of the input array to use as the sequence. In the case of a two-dimensional array, `axis=0` will, in effect, rearrange the rows of the array, and `axis=1` will rearrange the columns. For example

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> x = np.arange(0, 15).reshape(3, 5)
>>> x
array([[ 0,  1,  2,  3,  4],
       [ 5,  6,  7,  8,  9],
       [10, 11, 12, 13, 14]])
>>> rng.permutation(x, axis=1)
array([[ 1,  3,  2,  0,  4],  # random
       [ 6,  8,  7,  5,  9],
       [11, 13, 12, 10, 14]])
```

Note that the columns have been rearranged "in bulk": the values within each column have not changed.

The method *`Generator.permuted`* treats the `axis` parameter similar to how *`numpy.sort`* treats it. Each slice along the given axis is shuffled independently of the others. Compare the following example of the use of *`Generator.permuted`* to the above example of *`Generator.permutation`*:

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> rng.permuted(x, axis=1)
array([[ 1,  0,  2,  4,  3],  # random
       [ 5,  7,  6,  9,  8],
       [10, 14, 12, 13, 11]])
```

In this example, the values within each row (i.e. the values along `axis=1`) have been shuffled independently. This is not a "bulk" shuffle of the columns.

Shuffling non-NumPy sequences

`Generator.shuffle` works on non-NumPy sequences. That is, if it is given a sequence that is not a NumPy array, it shuffles that sequence in-place.

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> a = ['A', 'B', 'C', 'D', 'E']
>>> rng.shuffle(a)  # shuffle the list in-place
>>> a
['B', 'D', 'A', 'E', 'C']  # random
```

Distributions

beta(a, b[, size])	Draw samples from a Beta distribution.
binomial(n, p[, size])	Draw samples from a binomial distribution.
chisquare(df[, size])	Draw samples from a chi-square distribution.
dirichlet(alpha[, size])	Draw samples from the Dirichlet distribution.
exponential([scale, size])	Draw samples from an exponential distribution.
f(dfnum, dfden[, size])	Draw samples from an F distribution.
gamma(shape[, scale, size])	Draw samples from a Gamma distribution.
geometric(p[, size])	Draw samples from the geometric distribution.
gumbel([loc, scale, size])	Draw samples from a Gumbel distribution.
hypergeometric(ngood, nbad, nsample[, size])	Draw samples from a Hypergeometric distribution.
laplace([loc, scale, size])	Draw samples from the Laplace or double exponential distribution with specified location (or mean) and scale (decay).
logistic([loc, scale, size])	Draw samples from a logistic distribution.
lognormal([mean, sigma, size])	Draw samples from a log-normal distribution.
logseries(p[, size])	Draw samples from a logarithmic series distribution.
multinomial(n, pvals[, size])	Draw samples from a multinomial distribution.
multivariate_hypergeometric(colors, nsample)	Generate variates from a multivariate hypergeometric distribution.
multivariate_normal(mean, cov[, size, ...])	Draw random samples from a multivariate normal distribution.
negative_binomial(n, p[, size])	Draw samples from a negative binomial distribution.
noncentral_chisquare(df, nonc[, size])	Draw samples from a noncentral chi-square distribution.
noncentral_f(dfnum, dfden, nonc[, size])	Draw samples from the noncentral F distribution.
normal([loc, scale, size])	Draw random samples from a normal (Gaussian) distribution.
pareto(a[, size])	Draw samples from a Pareto II (AKA Lomax) distribution with specified shape.
poisson([lam, size])	Draw samples from a Poisson distribution.
power(a[, size])	Draws samples in [0, 1] from a power distribution with positive exponent a - 1.
rayleigh([scale, size])	Draw samples from a Rayleigh distribution.
standard_cauchy([size])	Draw samples from a standard Cauchy distribution with mode = 0.
standard_exponential([size, dtype, method, out])	Draw samples from the standard exponential distribution.
standard_gamma(shape[, size, dtype, out])	Draw samples from a standard Gamma distribution.
standard_normal([size, dtype, out])	Draw samples from a standard Normal distribution (mean=0, stdev=1).
standard_t(df[, size])	Draw samples from a standard Student's t distribution with *df* degrees of freedom.
triangular(left, mode, right[, size])	Draw samples from the triangular distribution over the interval `[left, right]`.
uniform([low, high, size])	Draw samples from a uniform distribution.
vonmises(mu, kappa[, size])	Draw samples from a von Mises distribution.
wald(mean, scale[, size])	Draw samples from a Wald, or inverse Gaussian, distribution.
weibull(a[, size])	Draw samples from a Weibull distribution.
zipf(a[, size])	Draw samples from a Zipf distribution.

method

random.Generator.**beta**(*a*, *b*, *size=None*)

Draw samples from a Beta distribution.

The Beta distribution is a special case of the Dirichlet distribution, and is related to the Gamma distribution. It has the probability distribution function

$$f(x; a, b) = \frac{1}{B(\alpha, \beta)} x^{\alpha-1}(1-x)^{\beta-1},$$

where the normalization, B, is the beta function,

$$B(\alpha, \beta) = \int_0^1 t^{\alpha-1}(1-t)^{\beta-1} dt.$$

It is often seen in Bayesian inference and order statistics.

Parameters

a
[float or array_like of floats] Alpha, positive (>0).

b
[float or array_like of floats] Beta, positive (>0).

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` and `b` are both scalars. Otherwise, `np.broadcast(a, b).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized beta distribution.

References

[1]

Examples

The beta distribution has mean a/(a+b). If `a == b` and both are > 1, the distribution is symmetric with mean 0.5.

```
>>> rng = np.random.default_rng()
>>> a, b, size = 2.0, 2.0, 10000
>>> sample = rng.beta(a=a, b=b, size=size)
>>> np.mean(sample)
0.5047328775385895  # may vary
```

Otherwise the distribution is skewed left or right according to whether `a` or `b` is greater. The distribution is mirror symmetric. See for example:

```
>>> a, b, size = 2, 7, 10000
>>> sample_left = rng.beta(a=a, b=b, size=size)
>>> sample_right = rng.beta(a=b, b=a, size=size)
>>> m_left, m_right = np.mean(sample_left), np.mean(sample_right)
>>> print(m_left, m_right)
```

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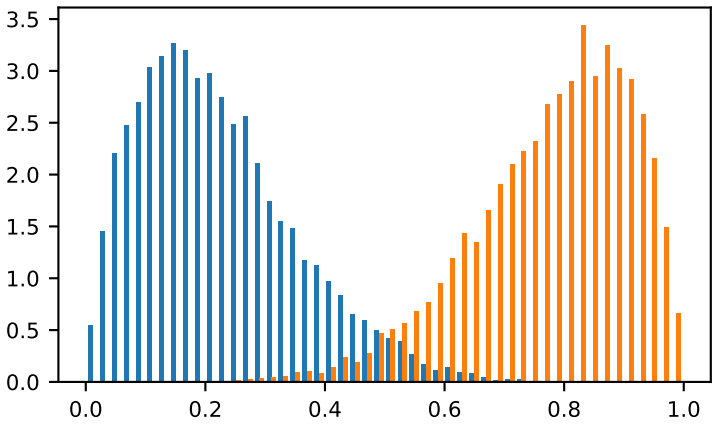
```
0.2238596793678923 0.7774613834041182  # may vary
>>> print(m_left - a/(a+b))
0.001637457145670096  # may vary
>>> print(m_right - b/(a+b))
-0.0003163943736596009  # may vary
```

Display the histogram of the two samples:

```
>>> import matplotlib.pyplot as plt
>>> plt.hist([sample_left, sample_right],
...          50, density=True, histtype='bar')
>>> plt.show()
```



method

`random.Generator.`**`binomial`**(*n*, *p*, *size=None*)

Draw samples from a binomial distribution.

Samples are drawn from a binomial distribution with specified parameters, n trials and p probability of success where n an integer >= 0 and p is in the interval [0,1]. (n may be input as a float, but it is truncated to an integer in use)

Parameters

n
: [int or array_like of ints] Parameter of the distribution, >= 0. Floats are also accepted, but they will be truncated to integers.

p
: [float or array_like of floats] Parameter of the distribution, >= 0 and <=1.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `n` and `p` are both scalars. Otherwise, `np.broadcast(n, p).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized binomial distribution, where each sample is equal to the number of successes over the n trials.

See also:

`scipy.stats.binom`
: probability density function, distribution or cumulative density function, etc.

Notes

The probability mass function (PMF) for the binomial distribution is

$$P(N) = \binom{n}{N} p^N (1-p)^{n-N},$$

where n is the number of trials, p is the probability of success, and N is the number of successes.

When estimating the standard error of a proportion in a population by using a random sample, the normal distribution works well unless the product p*n <=5, where p = population proportion estimate, and n = number of samples, in which case the binomial distribution is used instead. For example, a sample of 15 people shows 4 who are left handed, and 11 who are right handed. Then p = 4/15 = 27%. 0.27*15 = 4, so the binomial distribution should be used in this case.

References

[1], [2], [3], [4], [5]

Examples

Draw samples from the distribution:

```
>>> rng = np.random.default_rng()
>>> n, p, size = 10, .5, 10000
>>> s = rng.binomial(n, p, 10000)
```

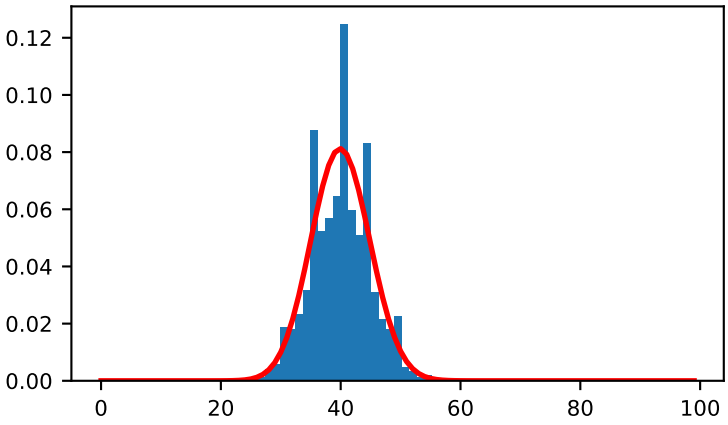
Assume a company drills 9 wild-cat oil exploration wells, each with an estimated probability of success of `p=0.1`. All nine wells fail. What is the probability of that happening?

Over `size = 20,000` trials the probability of this happening is on average:

```
>>> n, p, size = 9, 0.1, 20000
>>> np.sum(rng.binomial(n=n, p=p, size=size) == 0)/size
0.39015  # may vary
```

The following can be used to visualize a sample with `n=100`, `p=0.4` and the corresponding probability density function:

```
>>> import matplotlib.pyplot as plt
>>> from scipy.stats import binom
>>> n, p, size = 100, 0.4, 10000
>>> sample = rng.binomial(n, p, size=size)
>>> count, bins, _ = plt.hist(sample, 30, density=True)
>>> x = np.arange(n)
>>> y = binom.pmf(x, n, p)
>>> plt.plot(x, y, linewidth=2, color='r')
```



method

`random.Generator.`**`chisquare`**(*df*, *size=None*)

Draw samples from a chi-square distribution.

When *df* independent random variables, each with standard normal distributions (mean 0, variance 1), are squared and summed, the resulting distribution is chi-square (see Notes). This distribution is often used in hypothesis testing.

Parameters

df
[float or array_like of floats] Number of degrees of freedom, must be > 0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `df` is a scalar. Otherwise, `np.array(df).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized chi-square distribution.

Raises

ValueError
When *df* <= 0 or when an inappropriate *size* (e.g. `size=-1`) is given.

Notes

The variable obtained by summing the squares of *df* independent, standard normally distributed random variables:

$$Q = \sum_{i=1}^{\texttt{df}} X_i^2$$

is chi-square distributed, denoted

$$Q \sim \chi_k^2.$$

The probability density function of the chi-squared distribution is

$$p(x) = \frac{(1/2)^{k/2}}{\Gamma(k/2)} x^{k/2-1} e^{-x/2},$$

where Γ is the gamma function,

$$\Gamma(x) = \int_0^{-\infty} t^{x-1} e^{-t} dt.$$

References

[1]

Examples

```
>>> rng = np.random.default_rng()
>>> rng.chisquare(2,4)
array([ 1.89920014,  9.00867716,  3.13710533,  5.62318272]) # random
```

The distribution of a chi-square random variable with 20 degrees of freedom looks as follows:

```
>>> import matplotlib.pyplot as plt
>>> import scipy.stats as stats
>>> s = rng.chisquare(20, 10000)
>>> count, bins, _ = plt.hist(s, 30, density=True)
>>> x = np.linspace(0, 60, 1000)
>>> plt.plot(x, stats.chi2.pdf(x, df=20))
>>> plt.xlim([0, 60])
>>> plt.show()
```

method

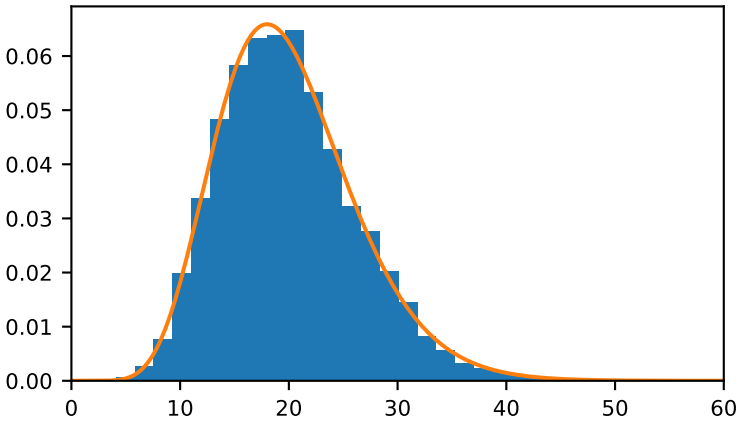
`random.Generator.`**`dirichlet`**(*alpha*, *size=None*)

Draw samples from the Dirichlet distribution.

Draw *size* samples of dimension k from a Dirichlet distribution. A Dirichlet-distributed random variable can be seen as a multivariate generalization of a Beta distribution. The Dirichlet distribution is a conjugate prior of a multinomial distribution in Bayesian inference.

Parameters

alpha
[sequence of floats, length k] Parameter of the distribution (length `k` for sample of length `k`).



size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n)`, then `m * n * k` samples are drawn. Default is None, in which case a vector of length `k` is returned.

Returns

samples
: [ndarray,] The drawn samples, of shape `(size, k)`.

Raises

ValueError
: If any value in `alpha` is less than zero

Notes

The Dirichlet distribution is a distribution over vectors x that fulfil the conditions $x_i > 0$ and $\sum_{i=1}^{k} x_i = 1$.

The probability density function p of a Dirichlet-distributed random vector X is proportional to

$$p(x) \propto \prod_{i=1}^{k} x_i^{\alpha_i - 1},$$

where α is a vector containing the positive concentration parameters.

The method uses the following property for computation: let Y be a random vector which has components that follow a standard gamma distribution, then $X = \frac{1}{\sum_{i=1}^{k} Y_i} Y$ is Dirichlet-distributed

References

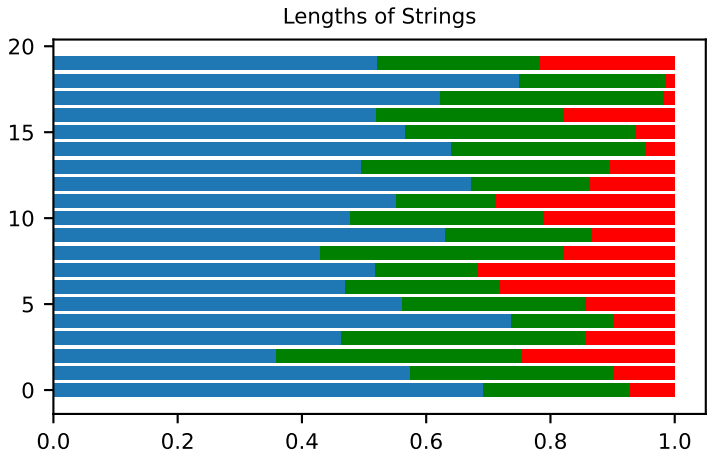
[1], [2]

Examples

Taking an example cited in Wikipedia, this distribution can be used if one wanted to cut strings (each of initial length 1.0) into K pieces with different lengths, where each piece had, on average, a designated average length, but allowing some variation in the relative sizes of the pieces.

```
>>> rng = np.random.default_rng()
>>> s = rng.dirichlet((10, 5, 3), 20).transpose()
```

```
>>> import matplotlib.pyplot as plt
>>> plt.barh(range(20), s[0])
>>> plt.barh(range(20), s[1], left=s[0], color='g')
>>> plt.barh(range(20), s[2], left=s[0]+s[1], color='r')
>>> plt.title("Lengths of Strings")
```



method

`random.Generator.`**`exponential`**(*scale=1.0*, *size=None*)

Draw samples from an exponential distribution.

Its probability density function is

$$f(x; \frac{1}{\beta}) = \frac{1}{\beta} \exp(-\frac{x}{\beta}),$$

for `x > 0` and 0 elsewhere. β is the scale parameter, which is the inverse of the rate parameter $\lambda = 1/\beta$. The rate parameter is an alternative, widely used parameterization of the exponential distribution [3].

The exponential distribution is a continuous analogue of the geometric distribution. It describes many common situations, such as the size of raindrops measured over many rainstorms [1], or the time between page requests to Wikipedia [2].

Parameters

scale
[float or array_like of floats] The scale parameter, $\beta = 1/\lambda$. Must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `scale` is a scalar. Otherwise, `np.array(scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized exponential distribution.

References

[1], [2], [3]

Examples

Assume a company has 10000 customer support agents and the time between customer calls is exponentially distributed and that the average time between customer calls is 4 minutes.

```
>>> scale, size = 4, 10000
>>> rng = np.random.default_rng()
>>> time_between_calls = rng.exponential(scale=scale, size=size)
```

What is the probability that a customer will call in the next 4 to 5 minutes?

```
>>> x = ((time_between_calls < 5).sum())/size
>>> y = ((time_between_calls < 4).sum())/size
>>> x - y
0.08  # may vary
```

The corresponding distribution can be visualized as follows:

```
>>> import matplotlib.pyplot as plt
>>> scale, size = 4, 10000
>>> rng = np.random.default_rng()
>>> sample = rng.exponential(scale=scale, size=size)
>>> count, bins, _ = plt.hist(sample, 30, density=True)
>>> plt.plot(bins, scale**(-1)*np.exp(-scale**-1*bins), linewidth=2, color='r')
>>> plt.show()
```

method

`random.Generator.`**`f`**(*dfnum*, *dfden*, *size=None*)

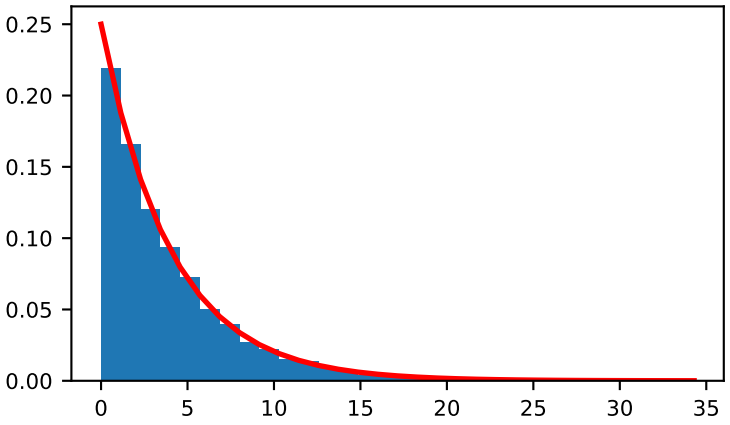
Draw samples from an F distribution.

Samples are drawn from an F distribution with specified parameters, *dfnum* (degrees of freedom in numerator) and *dfden* (degrees of freedom in denominator), where both parameters must be greater than zero.

The random variate of the F distribution (also known as the Fisher distribution) is a continuous probability distribution that arises in ANOVA tests, and is the ratio of two chi-square variates.

Parameters

dfnum
[float or array_like of floats] Degrees of freedom in numerator, must be > 0.



dfden
: [float or array_like of float] Degrees of freedom in denominator, must be > 0.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `dfnum` and `dfden` are both scalars. Otherwise, `np.broadcast(dfnum, dfden).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Fisher distribution.

See also:

`scipy.stats.f`
: probability density function, distribution or cumulative density function, etc.

Notes

The F statistic is used to compare in-group variances to between-group variances. Calculating the distribution depends on the sampling, and so it is a function of the respective degrees of freedom in the problem. The variable *dfnum* is the number of samples minus one, the between-groups degrees of freedom, while *dfden* is the within-groups degrees of freedom, the sum of the number of samples in each group minus the number of groups.

References

[1], [2]

Examples

An example from Glantz[1], pp 47-40:

Two groups, children of diabetics (25 people) and children from people without diabetes (25 controls). Fasting blood glucose was measured, case group had a mean value of 86.1, controls had a mean value of 82.2. Standard deviations were 2.09 and 2.49 respectively. Are these data consistent with the null hypothesis that the parents diabetic status does not affect their children's blood glucose levels? Calculating the F statistic from the data gives a value of 36.01.

Draw samples from the distribution:

```
>>> dfnum = 1. # between group degrees of freedom
>>> dfden = 48. # within groups degrees of freedom
>>> rng = np.random.default_rng()
>>> s = rng.f(dfnum, dfden, 1000)
```

The lower bound for the top 1% of the samples is :

```
>>> np.sort(s)[-10]
7.61988120985 # random
```

So there is about a 1% chance that the F statistic will exceed 7.62, the measured value is 36, so the null hypothesis is rejected at the 1% level.

The corresponding probability density function for `n = 20` and `m = 20` is:

```
>>> import matplotlib.pyplot as plt
>>> from scipy import stats
>>> dfnum, dfden, size = 20, 20, 10000
>>> s = rng.f(dfnum=dfnum, dfden=dfden, size=size)
>>> bins, density, _ = plt.hist(s, 30, density=True)
>>> x = np.linspace(0, 5, 1000)
>>> plt.plot(x, stats.f.pdf(x, dfnum, dfden))
>>> plt.xlim([0, 5])
>>> plt.show()
```

method

`random.Generator.`**`gamma`**(*shape*, *scale=1.0*, *size=None*)

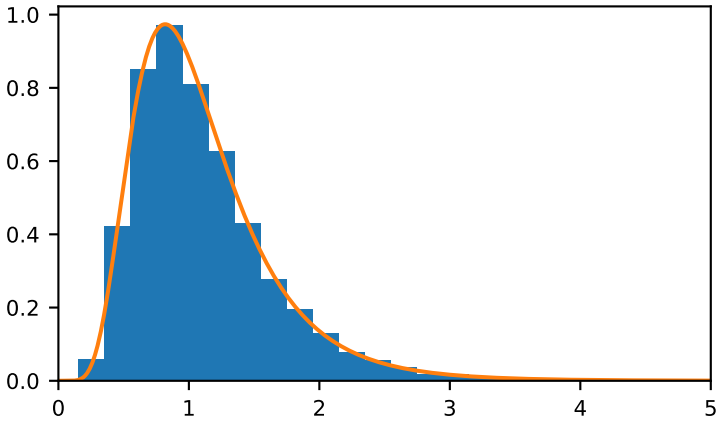
Draw samples from a Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, *shape* (sometimes designated "k") and *scale* (sometimes designated "theta"), where both parameters are > 0.

Parameters

shape
[float or array_like of floats] The shape of the gamma distribution. Must be non-negative.

scale
[float or array_like of floats, optional] The scale of the gamma distribution. Must be non-negative. Default is equal to 1.



size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `shape` and `scale` are both scalars. Otherwise, `np.broadcast(shape, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized gamma distribution.

See also:

`scipy.stats.gamma`
: probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Gamma distribution is

$$p(x) = x^{k-1}\frac{e^{-x/\theta}}{\theta^k \Gamma(k)},$$

where k is the shape and θ the scale, and Γ is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.

References

[1], [2]

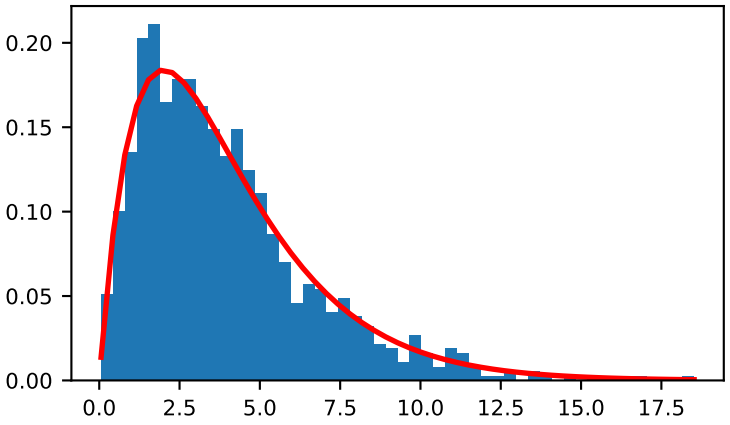
Examples

Draw samples from the distribution:

```
>>> shape, scale = 2., 2.  # mean=4, std=2*sqrt(2)
>>> rng = np.random.default_rng()
>>> s = rng.gamma(shape, scale, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, _ = plt.hist(s, 50, density=True)
>>> y = bins**(shape-1)*(np.exp(-bins/scale) /
...                      (sps.gamma(shape)*scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```



method

`random.Generator.`**`geometric`**(*p*, *size=None*)

Draw samples from the geometric distribution.

Bernoulli trials are experiments with one of two outcomes: success or failure (an example of such an experiment is flipping a coin). The geometric distribution models the number of trials that must be run in order to achieve success. It is therefore supported on the positive integers, `k = 1, 2, ...`.

The probability mass function of the geometric distribution is

$$f(k) = (1-p)^{k-1}p$$

where p is the probability of success of an individual trial.

Parameters

p
[float or array_like of floats] The probability of success of an individual trial.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `p` is a scalar. Otherwise, `np.array(p).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized geometric distribution.

References

[1]

Examples

Draw 10,000 values from the geometric distribution, with the probability of an individual success equal to `p = 0.35`:

```
>>> p, size = 0.35, 10000
>>> rng = np.random.default_rng()
>>> sample = rng.geometric(p=p, size=size)
```

What proportion of trials succeeded after a single run?

```
>>> (sample == 1).sum()/size
0.34889999999999999  # may vary
```

The geometric distribution with `p=0.35` looks as follows:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(sample, bins=30, density=True)
>>> plt.plot(bins, (1-p)**(bins-1)*p)
>>> plt.xlim([0, 25])
>>> plt.show()
```

method

`random.Generator.`**`gumbel`**(*loc=0.0*, *scale=1.0*, *size=None*)

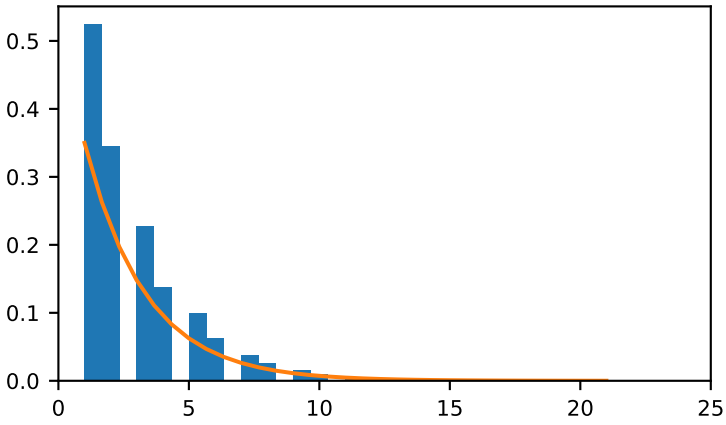
Draw samples from a Gumbel distribution.

Draw samples from a Gumbel distribution with specified location and scale. For more information on the Gumbel distribution, see Notes and References below.

Parameters

loc
[float or array_like of floats, optional] The location of the mode of the distribution. Default is 0.

scale
[float or array_like of floats, optional] The scale parameter of the distribution. Default is 1. Must be non- negative.



size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Gumbel distribution.

See also:

scipy.stats.gumbel_l
scipy.stats.gumbel_r
scipy.stats.genextreme
weibull

Notes

The Gumbel (or Smallest Extreme Value (SEV) or the Smallest Extreme Value Type I) distribution is one of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems. The Gumbel is a special case of the Extreme Value Type I distribution for maximums from distributions with "exponential-like" tails.

The probability density for the Gumbel distribution is

$$p(x) = \frac{e^{-(x-\mu)/\beta}}{\beta} e^{-e^{-(x-\mu)/\beta}},$$

where μ is the mode, a location parameter, and β is the scale parameter.

The Gumbel (named for German mathematician Emil Julius Gumbel) was used very early in the hydrology literature, for modeling the occurrence of flood events. It is also used for modeling maximum wind speed and rainfall rates. It is a "fat-tailed" distribution - the probability of an event in the tail of the distribution is larger than if one used a Gaussian, hence the surprisingly frequent occurrence of 100-year floods. Floods were initially modeled as a Gaussian process, which underestimated the frequency of extreme events.

It is one of a class of extreme value distributions, the Generalized Extreme Value (GEV) distributions, which also includes the Weibull and Frechet.

The function has a mean of $\mu + 0.57721\beta$ and a variance of $\frac{\pi^2}{6}\beta^2$.

References

[1], [2]

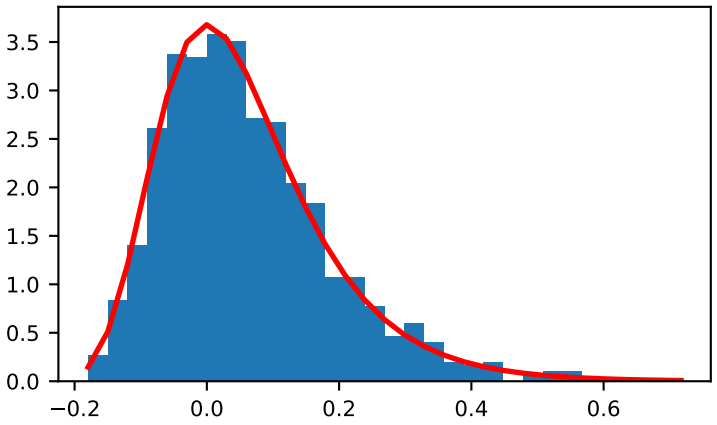
Examples

Draw samples from the distribution:

```
>>> rng = np.random.default_rng()
>>> mu, beta = 0, 0.1 # location and scale
>>> s = rng.gumbel(mu, beta, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, 30, density=True)
>>> plt.plot(bins, (1/beta)*np.exp(-(bins - mu)/beta)
...          * np.exp( -np.exp( -(bins - mu) /beta) ),
...          linewidth=2, color='r')
>>> plt.show()
```



Show how an extreme value distribution can arise from a Gaussian process and compare to a Gaussian:

```
>>> means = []
>>> maxima = []
>>> for i in range(0,1000) :
...    a = rng.normal(mu, beta, 1000)
...    means.append(a.mean())
...    maxima.append(a.max())
>>> count, bins, _ = plt.hist(maxima, 30, density=True)
```

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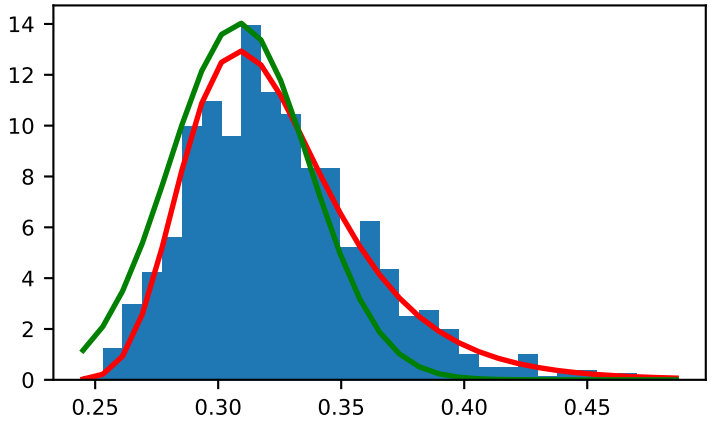
```
>>> beta = np.std(maxima) * np.sqrt(6) / np.pi
>>> mu = np.mean(maxima) - 0.57721*beta
>>> plt.plot(bins, (1/beta)*np.exp(-(bins - mu)/beta)
...           * np.exp(-np.exp(-(bins - mu)/beta)),
...           linewidth=2, color='r')
>>> plt.plot(bins, 1/(beta * np.sqrt(2 * np.pi))
...           * np.exp(-(bins - mu)**2 / (2 * beta**2)),
...           linewidth=2, color='g')
>>> plt.show()
```



method

`random.Generator.`**`hypergeometric`**(*ngood*, *nbad*, *nsample*, *size=None*)

Draw samples from a Hypergeometric distribution.

Samples are drawn from a hypergeometric distribution with specified parameters, *ngood* (ways to make a good selection), *nbad* (ways to make a bad selection), and *nsample* (number of items sampled, which is less than or equal to the sum `ngood + nbad`).

Parameters

ngood

[int or array_like of ints] Number of ways to make a good selection. Must be nonnegative and less than 10**9.

nbad

[int or array_like of ints] Number of ways to make a bad selection. Must be nonnegative and less than 10**9.

nsample

[int or array_like of ints] Number of items sampled. Must be nonnegative and less than `ngood + nbad`.

size

[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if *ngood*, *nbad*, and *nsample* are all scalars. Otherwise, `np.broadcast(ngood, nbad, nsample).size` samples are drawn.

Returns

out

[ndarray or scalar] Drawn samples from the parameterized hypergeometric distribution. Each sample is the number of good items within a randomly selected subset of size *nsample* taken from a set of *ngood* good items and *nbad* bad items.

See also:

multivariate_hypergeometric
Draw samples from the multivariate hypergeometric distribution.

scipy.stats.hypergeom
probability density function, distribution or cumulative density function, etc.

Notes

The probability mass function (PMF) for the Hypergeometric distribution is

$$P(x) = \frac{\binom{g}{x}\binom{b}{n-x}}{\binom{g+b}{n}},$$

where $0 \leq x \leq n$ and $n - b \leq x \leq g$

for P(x) the probability of `x` good results in the drawn sample, g = *ngood*, b = *nbad*, and n = *nsample*.

Consider an urn with black and white marbles in it, *ngood* of them are black and *nbad* are white. If you draw *nsample* balls without replacement, then the hypergeometric distribution describes the distribution of black balls in the drawn sample.

Note that this distribution is very similar to the binomial distribution, except that in this case, samples are drawn without replacement, whereas in the Binomial case samples are drawn with replacement (or the sample space is infinite). As the sample space becomes large, this distribution approaches the binomial.

The arguments *ngood* and *nbad* each must be less than *10**9*. For extremely large arguments, the algorithm that is used to compute the samples [4] breaks down because of loss of precision in floating point calculations. For such large values, if *nsample* is not also large, the distribution can be approximated with the binomial distribution, *binomial(n=nsample, p=ngood/(ngood + nbad))*.

References

[1], [2], [3], [4]

Examples

Draw samples from the distribution:

```
>>> rng = np.random.default_rng()
>>> ngood, nbad, nsamp = 100, 2, 10
# number of good, number of bad, and number of samples
>>> s = rng.hypergeometric(ngood, nbad, nsamp, 1000)
>>> from matplotlib.pyplot import hist
>>> hist(s)
#   note that it is very unlikely to grab both bad items
```

Suppose you have an urn with 15 white and 15 black marbles. If you pull 15 marbles at random, how likely is it that 12 or more of them are one color?

```
>>> s = rng.hypergeometric(15, 15, 15, 100000)
>>> sum(s>=12)/100000. + sum(s<=3)/100000.
#   answer = 0.003 ... pretty unlikely!
```

method

random.Generator.**laplace**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw samples from the Laplace or double exponential distribution with specified location (or mean) and scale (decay).

The Laplace distribution is similar to the Gaussian/normal distribution, but is sharper at the peak and has fatter tails. It represents the difference between two independent, identically distributed exponential random variables.

Parameters

loc
[float or array_like of floats, optional] The position, μ, of the distribution peak. Default is 0.

scale
[float or array_like of floats, optional] λ, the exponential decay. Default is 1. Must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Laplace distribution.

Notes

It has the probability density function

$$f(x; \mu, \lambda) = \frac{1}{2\lambda} \exp\left(-\frac{|x - \mu|}{\lambda}\right).$$

The first law of Laplace, from 1774, states that the frequency of an error can be expressed as an exponential function of the absolute magnitude of the error, which leads to the Laplace distribution. For many problems in economics and health sciences, this distribution seems to model the data better than the standard Gaussian distribution.

References

[1], [2], [3], [4]

Examples

Draw samples from the distribution

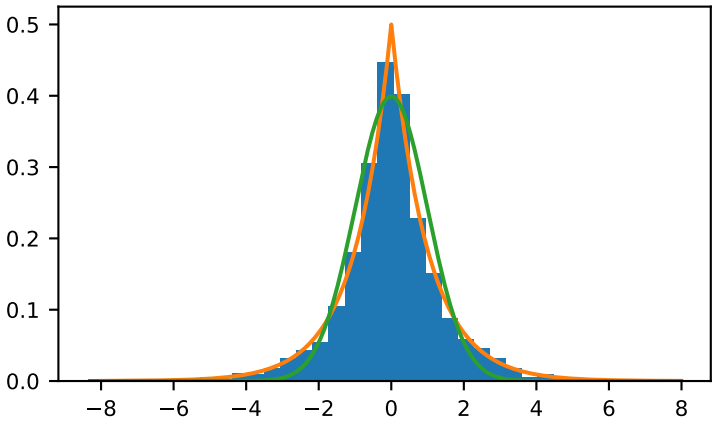
```
>>> loc, scale = 0., 1.
>>> rng = np.random.default_rng()
>>> s = rng.laplace(loc, scale, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, 30, density=True)
>>> x = np.arange(-8., 8., .01)
>>> pdf = np.exp(-abs(x-loc)/scale)/(2.*scale)
>>> plt.plot(x, pdf)
```

Plot Gaussian for comparison:

```
>>> g = (1/(scale * np.sqrt(2 * np.pi)) *
...      np.exp(-(x - loc)**2 / (2 * scale**2)))
>>> plt.plot(x,g)
```



method

`random.Generator.`**`logistic`**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw samples from a logistic distribution.

Samples are drawn from a logistic distribution with specified parameters, loc (location or mean, also median), and scale (>0).

Parameters

loc
[float or array_like of floats, optional] Parameter of the distribution. Default is 0.

scale
[float or array_like of floats, optional] Parameter of the distribution. Must be non-negative. Default is 1.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized logistic distribution.

See also:

`scipy.stats.logistic`
: probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Logistic distribution is

$$P(x) = \frac{e^{-(x-\mu)/s}}{s(1+e^{-(x-\mu)/s})^2},$$

where μ = location and s = scale.

The Logistic distribution is used in Extreme Value problems where it can act as a mixture of Gumbel distributions, in Epidemiology, and by the World Chess Federation (FIDE) where it is used in the Elo ranking system, assuming the performance of each player is a logistically distributed random variable.

References

[1], [2], [3]

Examples

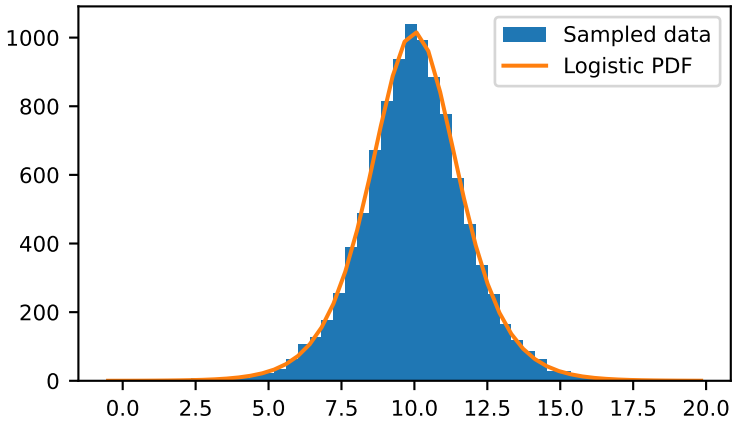
Draw samples from the distribution:

```
>>> loc, scale = 10, 1
>>> rng = np.random.default_rng()
>>> s = rng.logistic(loc, scale, 10000)
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, bins=50, label='Sampled data')
```

plot sampled data against the exact distribution

```
>>> def logistic(x, loc, scale):
...     return np.exp((loc-x)/scale)/(scale*(1+np.exp((loc-x)/scale))**2)
>>> logistic_values  = logistic(bins, loc, scale)
>>> bin_spacing = np.mean(np.diff(bins))
>>> plt.plot(bins, logistic_values  * bin_spacing * s.size, label='Logistic PDF')
>>> plt.legend()
>>> plt.show()
```

method



`random.Generator.`**`lognormal`**(*mean=0.0*, *sigma=1.0*, *size=None*)

Draw samples from a log-normal distribution.

Draw samples from a log-normal distribution with specified mean, standard deviation, and array shape. Note that the mean and standard deviation are not the values for the distribution itself, but of the underlying normal distribution it is derived from.

Parameters

mean
[float or array_like of floats, optional] Mean value of the underlying normal distribution. Default is 0.

sigma
[float or array_like of floats, optional] Standard deviation of the underlying normal distribution. Must be non-negative. Default is 1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `mean` and `sigma` are both scalars. Otherwise, `np.broadcast(mean, sigma).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized log-normal distribution.

See also:

`scipy.stats.lognorm`
probability density function, distribution, cumulative density function, etc.

Notes

A variable *x* has a log-normal distribution if *log(x)* is normally distributed. The probability density function for the log-normal distribution is:

$$p(x) = \frac{1}{\sigma x\sqrt{2\pi}} e^{(-\frac{(ln(x)-\mu)^2}{2\sigma^2})}$$

where μ is the mean and σ is the standard deviation of the normally distributed logarithm of the variable. A log-normal distribution results if a random variable is the *product* of a large number of independent, identically-distributed variables in the same way that a normal distribution results if the variable is the *sum* of a large number of independent, identically-distributed variables.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> rng = np.random.default_rng()
>>> mu, sigma = 3., 1. # mean and standard deviation
>>> s = rng.lognormal(mu, sigma, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, 100, density=True, align='mid')
```

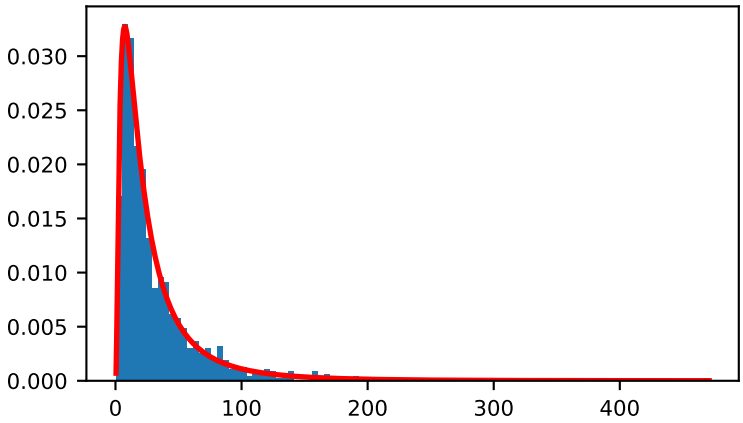
```
>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
...        / (x * sigma * np.sqrt(2 * np.pi)))
```

```
>>> plt.plot(x, pdf, linewidth=2, color='r')
>>> plt.axis('tight')
>>> plt.show()
```

Demonstrate that taking the products of random samples from a uniform distribution can be fit well by a log-normal probability density function.

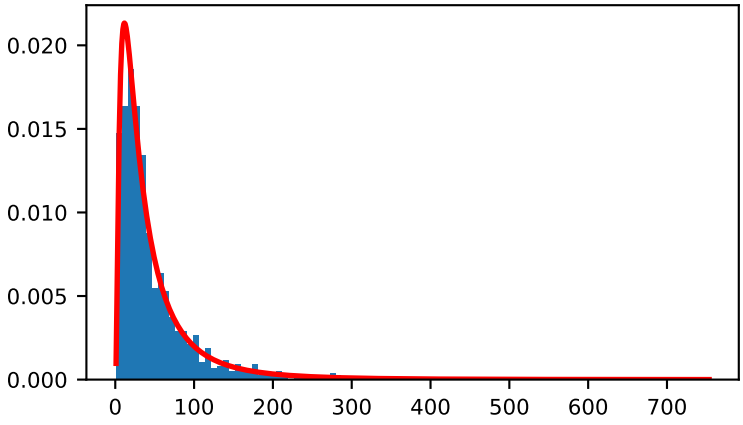
```
>>> # Generate a thousand samples: each is the product of 100 random
>>> # values, drawn from a normal distribution.
>>> rng = rng
>>> b = []
>>> for i in range(1000):
...     a = 10. + rng.standard_normal(100)
...     b.append(np.prod(a))
```

```
>>> b = np.array(b) / np.min(b) # scale values to be positive
>>> count, bins, _ = plt.hist(b, 100, density=True, align='mid')
>>> sigma = np.std(np.log(b))
>>> mu = np.mean(np.log(b))
```




```
>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
...         / (x * sigma * np.sqrt(2 * np.pi)))
```

```
>>> plt.plot(x, pdf, color='r', linewidth=2)
>>> plt.show()
```



method

`random.Generator.`**`logseries`**(*p*, *size=None*)

Draw samples from a logarithmic series distribution.

Samples are drawn from a log series distribution with specified shape parameter, 0 <= p < 1.

Parameters

p
: [float or array_like of floats] Shape parameter for the distribution. Must be in the range [0, 1).

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `p` is a scalar. Otherwise, `np.array(p).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized logarithmic series distribution.

See also:

`scipy.stats.logser`
: probability density function, distribution or cumulative density function, etc.

Notes

The probability mass function for the Log Series distribution is

$$P(k) = \frac{-p^k}{k \ln(1-p)},$$

where p = probability.

The log series distribution is frequently used to represent species richness and occurrence, first proposed by Fisher, Corbet, and Williams in 1943 [2]. It may also be used to model the numbers of occupants seen in cars [3].

References

[1], [2], [3], [4]

Examples

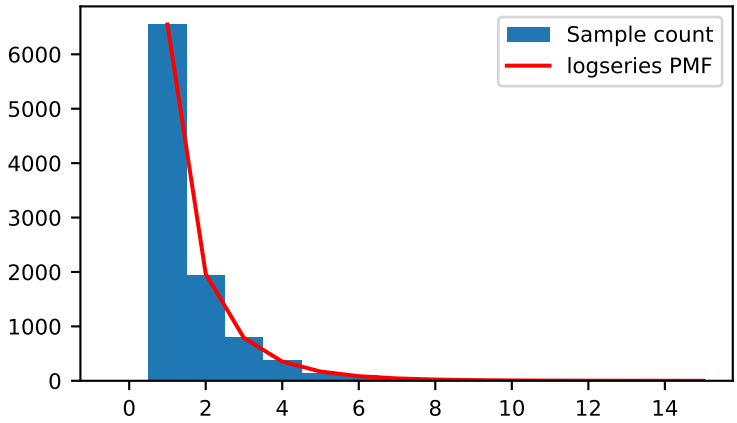
Draw samples from the distribution:

```
>>> a = .6
>>> rng = np.random.default_rng()
>>> s = rng.logseries(a, 10000)
>>> import matplotlib.pyplot as plt
>>> bins = np.arange(-.5, max(s) + .5 )
>>> count, bins, _ = plt.hist(s, bins=bins, label='Sample count')
```

plot against distribution

```
>>> def logseries(k, p):
...     return -p**k/(k*np.log(1-p))
>>> centres = np.arange(1, max(s) + 1)
>>> plt.plot(centres, logseries(centres, a) * s.size, 'r', label='logseries PMF')
>>> plt.legend()
>>> plt.show()
```

method



`random.Generator.`**`multinomial`**(*n*, *pvals*, *size=None*)

Draw samples from a multinomial distribution.

The multinomial distribution is a multivariate generalization of the binomial distribution. Take an experiment with one of `p` possible outcomes. An example of such an experiment is throwing a dice, where the outcome can be 1 through 6. Each sample drawn from the distribution represents *n* such experiments. Its values, `X_i = [X_0, X_1, ..., X_p]`, represent the number of times the outcome was `i`.

Parameters

n

[int or array-like of ints] Number of experiments.

pvals

[array-like of floats] Probabilities of each of the `p` different outcomes with shape `(k0, k1, ..., kn, p)`. Each element `pvals[i,j,...,:]` must sum to 1 (however, the last element is always assumed to account for the remaining probability, as long as `sum(pvals[..., :-1], axis=-1) <= 1.0`. Must have at least 1 dimension where pvals.shape[-1] > 0.

size

[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn each with `p` elements. Default is None where the output size is determined by the broadcast shape of `n` and all by the final dimension of `pvals`, which is denoted as `b=(b0, b1, ..., bq)`. If size is not None, then it must be compatible with the broadcast shape `b`. Specifically, size must have `q` or more elements and size[-(q-j):] must equal `bj`.

Returns

out

[ndarray] The drawn samples, of shape size, if provided. When size is provided, the output shape is size + (p,) If not specified, the shape is determined by the broadcast shape of `n` and `pvals`, `(b0, b1, ..., bq)` augmented with the dimension of the multinomial, `p`, so that that output shape is `(b0, b1, ..., bq, p)`.

Each entry `out[i,j,...,:]` is a `p`-dimensional value drawn from the distribution.

Examples

Throw a dice 20 times:

```
>>> rng = np.random.default_rng()
>>> rng.multinomial(20, [1/6.]*6, size=1)
array([[4, 1, 7, 5, 2, 1]])  # random
```

It landed 4 times on 1, once on 2, etc.

Now, throw the dice 20 times, and 20 times again:

```
>>> rng.multinomial(20, [1/6.]*6, size=2)
array([[3, 4, 3, 3, 4, 3],
       [2, 4, 3, 4, 0, 7]])  # random
```

For the first run, we threw 3 times 1, 4 times 2, etc. For the second, we threw 2 times 1, 4 times 2, etc.

Now, do one experiment throwing the dice 10 time, and 10 times again, and another throwing the dice 20 times, and 20 times again:

```
>>> rng.multinomial([[10], [20]], [1/6.]*6, size=(2, 2))
array([[[2, 4, 0, 1, 2, 1],
        [1, 3, 0, 3, 1, 2]],
       [[1, 4, 4, 4, 4, 3],
        [3, 3, 2, 5, 5, 2]]])  # random
```

The first array shows the outcomes of throwing the dice 10 times, and the second shows the outcomes from throwing the dice 20 times.

A loaded die is more likely to land on number 6:

```
>>> rng.multinomial(100, [1/7.]*5 + [2/7.])
array([11, 16, 14, 17, 16, 26])  # random
```

Simulate 10 throws of a 4-sided die and 20 throws of a 6-sided die

```
>>> rng.multinomial([10, 20],[[1/4]*4 + [0]*2, [1/6]*6])
array([[2, 1, 4, 3, 0, 0],
       [3, 3, 3, 6, 1, 4]], dtype=int64)  # random
```

Generate categorical random variates from two categories where the first has 3 outcomes and the second has 2.

```
>>> rng.multinomial(1, [[.1, .5, .4 ], [.3, .7, .0]])
array([[0, 0, 1],
       [0, 1, 0]], dtype=int64)  # random
```

`argmax(axis=-1)` is then used to return the categories.

```
>>> pvals = [[.1, .5, .4 ], [.3, .7, .0]]
>>> rvs = rng.multinomial(1, pvals, size=(4,2))
>>> rvs.argmax(axis=-1)
array([[0, 1],
       [2, 0],
       [2, 1],
       [2, 0]], dtype=int64)  # random
```

The same output dimension can be produced using broadcasting.

```
>>> rvs = rng.multinomial([[1]] * 4, pvals)
>>> rvs.argmax(axis=-1)
array([[0, 1],
       [2, 0],
       [2, 1],
       [2, 0]], dtype=int64)  # random
```

The probability inputs should be normalized. As an implementation detail, the value of the last entry is ignored and assumed to take up any leftover probability mass, but this should not be relied on. A biased coin which has twice as much weight on one side as on the other should be sampled like so:

```
>>> rng.multinomial(100, [1.0 / 3, 2.0 / 3])  # RIGHT
array([38, 62])  # random
```

not like:

```
>>> rng.multinomial(100, [1.0, 2.0])  # WRONG
Traceback (most recent call last):
ValueError: pvals < 0, pvals > 1 or pvals contains NaNs
```

method

`random.Generator.`**`multivariate_hypergeometric`**(*colors*, *nsample*, *size=None*, *method='marginals'*)

Generate variates from a multivariate hypergeometric distribution.

The multivariate hypergeometric distribution is a generalization of the hypergeometric distribution.

Choose `nsample` items at random without replacement from a collection with `N` distinct types. `N` is the length of `colors`, and the values in `colors` are the number of occurrences of that type in the collection. The total number of items in the collection is `sum(colors)`. Each random variate generated by this function is a vector of length `N` holding the counts of the different types that occurred in the `nsample` items.

The name `colors` comes from a common description of the distribution: it is the probability distribution of the number of marbles of each color selected without replacement from an urn containing marbles of different colors; `colors[i]` is the number of marbles in the urn with color `i`.

Parameters

colors
[sequence of integers] The number of each type of item in the collection from which a sample is drawn. The values in `colors` must be nonnegative. To avoid loss of precision in the algorithm, `sum(colors)` must be less than `10**9` when *method* is “marginals”.

nsample
[int] The number of items selected. `nsample` must not be greater than `sum(colors)`.

size
[int or tuple of ints, optional] The number of variates to generate, either an integer or a tuple holding the shape of the array of variates. If the given size is, e.g., `(k, m)`, then `k * m` variates are drawn, where one variate is a vector of length `len(colors)`, and the return value has shape `(k, m, len(colors))`. If *`size`* is an integer, the output has shape `(size, len(colors))`. Default is None, in which case a single variate is returned as an array with shape `(len(colors),)`.

method
[string, optional] Specify the algorithm that is used to generate the variates. Must be ‘count’ or ‘marginals’ (the default). See the Notes for a description of the methods.

Returns

variates
[ndarray] Array of variates drawn from the multivariate hypergeometric distribution.

See also:

hypergeometric
Draw samples from the (univariate) hypergeometric distribution.

Notes

The two methods do not return the same sequence of variates.

The "count" algorithm is roughly equivalent to the following numpy code:

```
choices = np.repeat(np.arange(len(colors)), colors)
selection = np.random.choice(choices, nsample, replace=False)
variate = np.bincount(selection, minlength=len(colors))
```

The "count" algorithm uses a temporary array of integers with length `sum(colors)`.

The "marginals" algorithm generates a variate by using repeated calls to the univariate hypergeometric sampler. It is roughly equivalent to:

```
variate = np.zeros(len(colors), dtype=np.int64)
# `remaining` is the cumulative sum of `colors` from the last
# element to the first; e.g. if `colors` is [3, 1, 5], then
# `remaining` is [9, 6, 5].
remaining = np.cumsum(colors[::-1])[::-1]
for i in range(len(colors)-1):
    if nsample < 1:
        break
    variate[i] = hypergeometric(colors[i], remaining[i+1],
                                nsample)
    nsample -= variate[i]
variate[-1] = nsample
```

The default method is "marginals". For some cases (e.g. when *colors* contains relatively small integers), the "count" method can be significantly faster than the "marginals" method. If performance of the algorithm is important, test the two methods with typical inputs to decide which works best.

Examples

```
>>> colors = [16, 8, 4]
>>> seed = 4861946401452
>>> gen = np.random.Generator(np.random.PCG64(seed))
>>> gen.multivariate_hypergeometric(colors, 6)
array([5, 0, 1])
>>> gen.multivariate_hypergeometric(colors, 6, size=3)
array([[5, 0, 1],
       [2, 2, 2],
       [3, 3, 0]])
>>> gen.multivariate_hypergeometric(colors, 6, size=(2, 2))
array([[[3, 2, 1],
        [3, 2, 1]],
       [[4, 1, 1],
        [3, 2, 1]]])
```

method

random.Generator.**multivariate_normal**(*mean*, *cov*, *size=None*, *check_valid='warn'*, *tol=1e-8*, ***, *method='svd'*)

Draw random samples from a multivariate normal distribution.

The multivariate normal, multinormal or Gaussian distribution is a generalization of the one-dimensional normal distribution to higher dimensions. Such a distribution is specified by its mean and covariance matrix. These parameters are analogous to the mean (average or "center") and variance (the squared standard deviation, or "width") of the one-dimensional normal distribution.

Parameters

mean
[1-D array_like, of length N] Mean of the N-dimensional distribution.

cov
[2-D array_like, of shape (N, N)] Covariance matrix of the distribution. It must be symmetric and positive-semidefinite for proper sampling.

size
[int or tuple of ints, optional] Given a shape of, for example, `(m,n,k)`, `m*n*k` samples are generated, and packed in an *m*-by-*n*-by-*k* arrangement. Because each sample is *N*-dimensional, the output shape is `(m,n,k,N)`. If no shape is specified, a single (*N*-D) sample is returned.

check_valid
[{ 'warn', 'raise', 'ignore' }, optional] Behavior when the covariance matrix is not positive semidefinite.

tol
[float, optional] Tolerance when checking the singular values in covariance matrix. cov is cast to double before the check.

method
[{ 'svd', 'eigh', 'cholesky'}, optional] The cov input is used to compute a factor matrix A such that `A @ A.T = cov`. This argument is used to select the method used to compute the factor matrix A. The default method 'svd' is the slowest, while 'cholesky' is the fastest but less robust than the slowest method. The method *eigh* uses eigen decomposition to compute A and is faster than svd but slower than cholesky.

Returns

out
[ndarray] The drawn samples, of shape *size*, if that was provided. If not, the shape is `(N,)`.

In other words, each entry `out[i,j,...,:]` is an N-dimensional value drawn from the distribution.

Notes

The mean is a coordinate in N-dimensional space, which represents the location where samples are most likely to be generated. This is analogous to the peak of the bell curve for the one-dimensional or univariate normal distribution.

Covariance indicates the level to which two variables vary together. From the multivariate normal distribution, we draw N-dimensional samples, $X = [x_1, x_2, ...x_N]$. The covariance matrix element C_{ij} is the covariance of x_i and x_j. The element C_{ii} is the variance of x_i (i.e. its "spread").

Instead of specifying the full covariance matrix, popular approximations include:

- Spherical covariance (*cov* is a multiple of the identity matrix)

- Diagonal covariance (*cov* has non-negative elements, and only on the diagonal)

This geometrical property can be seen in two dimensions by plotting generated data-points:

```
>>> mean = [0, 0]
>>> cov = [[1, 0], [0, 100]]  # diagonal covariance
```

Diagonal covariance means that points are oriented along x or y-axis:

```
>>> import matplotlib.pyplot as plt
>>> rng = np.random.default_rng()
>>> x, y = rng.multivariate_normal(mean, cov, 5000).T
>>> plt.plot(x, y, 'x')
>>> plt.axis('equal')
>>> plt.show()
```

Note that the covariance matrix must be positive semidefinite (a.k.a. nonnegative-definite). Otherwise, the behavior of this method is undefined and backwards compatibility is not guaranteed.

This function internally uses linear algebra routines, and thus results may not be identical (even up to precision) across architectures, OSes, or even builds. For example, this is likely if `cov` has multiple equal singular values and `method` is `'svd'` (default). In this case, `method='cholesky'` may be more robust.

References

[1], [2]

Examples

```
>>> mean = (1, 2)
>>> cov = [[1, 0], [0, 1]]
>>> rng = np.random.default_rng()
>>> x = rng.multivariate_normal(mean, cov, (3, 3))
>>> x.shape
(3, 3, 2)
```

We can use a different method other than the default to factorize cov:

```
>>> y = rng.multivariate_normal(mean, cov, (3, 3), method='cholesky')
>>> y.shape
(3, 3, 2)
```

Here we generate 800 samples from the bivariate normal distribution with mean [0, 0] and covariance matrix [[6, -3], [-3, 3.5]]. The expected variances of the first and second components of the sample are 6 and 3.5, respectively, and the expected correlation coefficient is -3/sqrt(6*3.5) ≈ -0.65465.

```
>>> cov = np.array([[6, -3], [-3, 3.5]])
>>> pts = rng.multivariate_normal([0, 0], cov, size=800)
```

Check that the mean, covariance, and correlation coefficient of the sample are close to the expected values:

```
>>> pts.mean(axis=0)
array([ 0.0326911 , -0.01280782])  # may vary
>>> np.cov(pts.T)
array([[ 5.96202397, -2.85602287],
```

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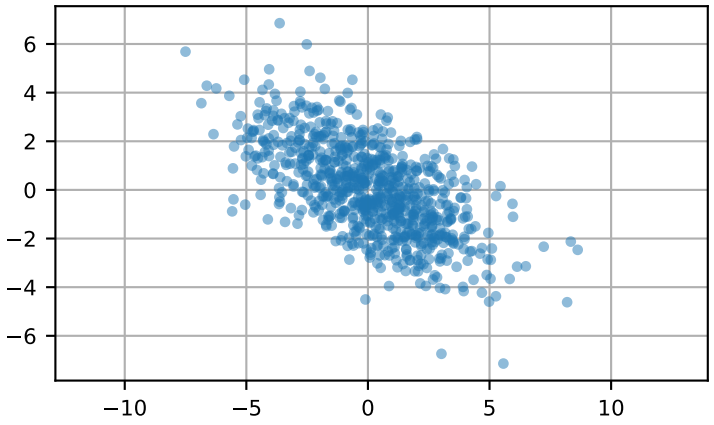
```
       [-2.85602287,  3.47613949]])  # may vary
>>> np.corrcoef(pts.T)[0, 1]
-0.6273591314603949  # may vary
```

We can visualize this data with a scatter plot. The orientation of the point cloud illustrates the negative correlation of the components of this sample.

```
>>> import matplotlib.pyplot as plt
>>> plt.plot(pts[:, 0], pts[:, 1], '.', alpha=0.5)
>>> plt.axis('equal')
>>> plt.grid()
>>> plt.show()
```



method

`random.Generator.`**`negative_binomial`**(*n*, *p*, *size=None*)

Draw samples from a negative binomial distribution.

Samples are drawn from a negative binomial distribution with specified parameters, *n* successes and *p* probability of success where *n* is > 0 and *p* is in the interval (0, 1].

Parameters

n
[float or array_like of floats] Parameter of the distribution, > 0.

p
[float or array_like of floats] Parameter of the distribution. Must satisfy 0 < p <= 1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `n` and `p` are both scalars. Otherwise, `np.broadcast(n, p).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized negative binomial distribution,

where each sample is equal to N, the number of failures that occurred before a total of n successes was reached.

Notes

The probability mass function of the negative binomial distribution is

$$P(N;n,p) = \frac{\Gamma(N+n)}{N!\Gamma(n)}p^n(1-p)^N,$$

where n is the number of successes, p is the probability of success, $N+n$ is the number of trials, and Γ is the gamma function. When n is an integer, $\frac{\Gamma(N+n)}{N!\Gamma(n)} = \binom{N+n-1}{N}$, which is the more common form of this term in the pmf. The negative binomial distribution gives the probability of N failures given n successes, with a success on the last trial.

If one throws a die repeatedly until the third time a "1" appears, then the probability distribution of the number of non-"1"s that appear before the third "1" is a negative binomial distribution.

Because this method internally calls `Generator.poisson` with an intermediate random value, a ValueError is raised when the choice of n and p would result in the mean + 10 sigma of the sampled intermediate distribution exceeding the max acceptable value of the `Generator.poisson` method. This happens when p is too low (a lot of failures happen for every success) and n is too big (a lot of successes are allowed). Therefore, the n and p values must satisfy the constraint:

$$n\frac{1-p}{p} + 10n\sqrt{n}\frac{1-p}{p} < 2^{63} - 1 - 10\sqrt{2^{63}-1},$$

Where the left side of the equation is the derived mean + 10 sigma of a sample from the gamma distribution internally used as the lam parameter of a poisson sample, and the right side of the equation is the constraint for maximum value of lam in `Generator.poisson`.

References

[1], [2]

Examples

Draw samples from the distribution:

A real world example. A company drills wild-cat oil exploration wells, each with an estimated probability of success of 0.1. What is the probability of having one success for each successive well, that is what is the probability of a single success after drilling 5 wells, after 6 wells, etc.?

```
>>> rng = np.random.default_rng()
>>> s = rng.negative_binomial(1, 0.1, 100000)
>>> for i in range(1, 11):
...    probability = sum(s<i) / 100000.
...    print(i, "wells drilled, probability of one success =", probability)
```

method

`random.Generator.`**`noncentral_chisquare`**(*df*, *nonc*, *size=None*)

Draw samples from a noncentral chi-square distribution.

The noncentral χ^2 distribution is a generalization of the χ^2 distribution.

Parameters

df
[float or array_like of floats] Degrees of freedom, must be > 0.

nonc
[float or array_like of floats] Non-centrality, must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `df` and `nonc` are both scalars. Otherwise, `np.broadcast(df, nonc).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized noncentral chi-square distribution.

Notes

The probability density function for the noncentral Chi-square distribution is

$$P(x;df,nonc) = \sum_{i=0}^{\infty} \frac{e^{-nonc/2}(nonc/2)^i}{i!} P_{Y_{df+2i}}(x),$$

where Y_q is the Chi-square with q degrees of freedom.

References

[1]

Examples

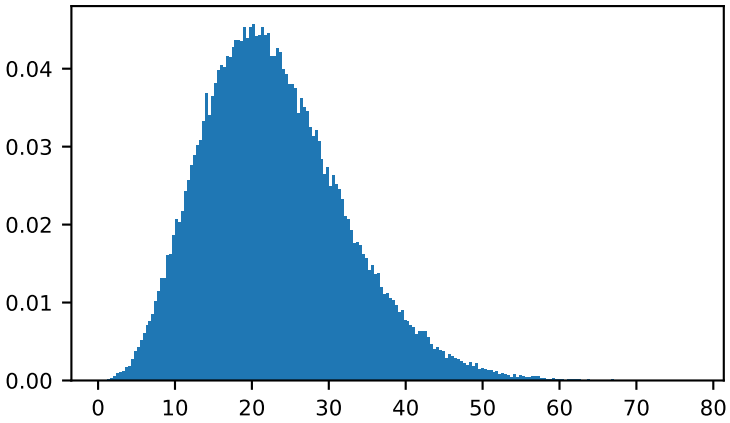
Draw values from the distribution and plot the histogram

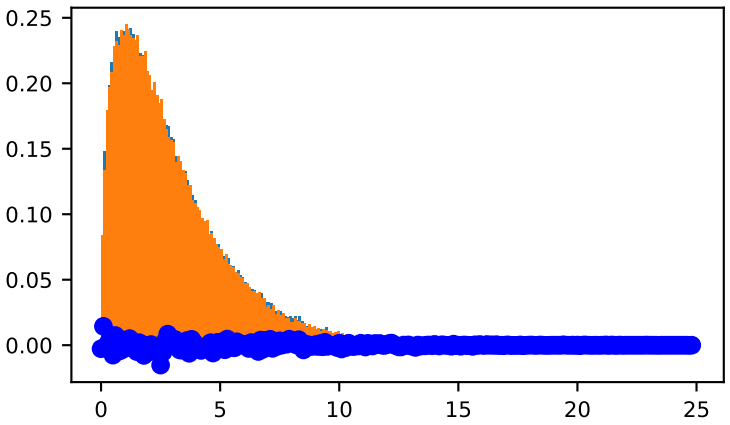
```
>>> rng = np.random.default_rng()
>>> import matplotlib.pyplot as plt
>>> values = plt.hist(rng.noncentral_chisquare(3, 20, 100000),
...                   bins=200, density=True)
>>> plt.show()
```

Draw values from a noncentral chisquare with very small noncentrality, and compare to a chisquare.

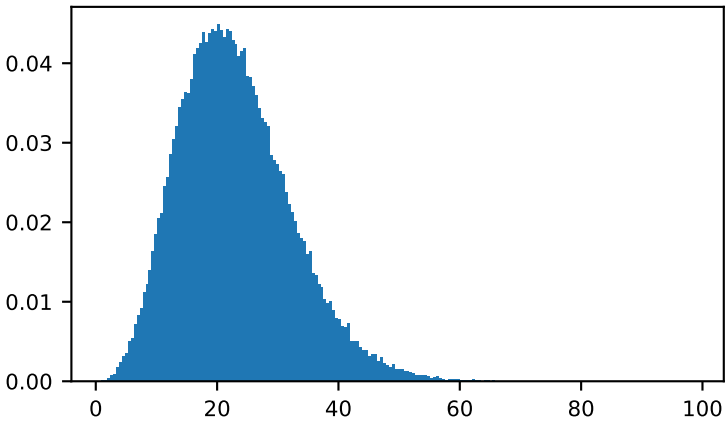
```
>>> plt.figure()
>>> values = plt.hist(rng.noncentral_chisquare(3, .0000001, 100000),
...                   bins=np.arange(0., 25, .1), density=True)
>>> values2 = plt.hist(rng.chisquare(3, 100000),
...                    bins=np.arange(0., 25, .1), density=True)
>>> plt.plot(values[1][0:-1], values[0]-values2[0], 'ob')
>>> plt.show()
```

Demonstrate how large values of non-centrality lead to a more symmetric distribution.


0.04
0.03
0.02
0.01
0.00
0
10
20
30
40
50
60
70
80


0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25

```
>>> plt.figure()
>>> values = plt.hist(rng.noncentral_chisquare(3, 20, 100000),
...                   bins=200, density=True)
>>> plt.show()
```



method

`random.Generator.`**`noncentral_f`**(*dfnum*, *dfden*, *nonc*, *size=None*)

Draw samples from the noncentral F distribution.

Samples are drawn from an F distribution with specified parameters, *dfnum* (degrees of freedom in numerator) and *dfden* (degrees of freedom in denominator), where both parameters > 1. *nonc* is the non-centrality parameter.

Parameters

dfnum
[float or array_like of floats] Numerator degrees of freedom, must be > 0.

dfden
[float or array_like of floats] Denominator degrees of freedom, must be > 0.

nonc
[float or array_like of floats] Non-centrality parameter, the sum of the squares of the numerator means, must be >= 0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `dfnum`, `dfden`, and `nonc` are all scalars. Otherwise, `np.broadcast(dfnum, dfden, nonc).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized noncentral Fisher distribution.

Notes

When calculating the power of an experiment (power = probability of rejecting the null hypothesis when a specific alternative is true) the non-central F statistic becomes important. When the null hypothesis is true, the F statistic follows a central F distribution. When the null hypothesis is not true, then it follows a non-central F statistic.

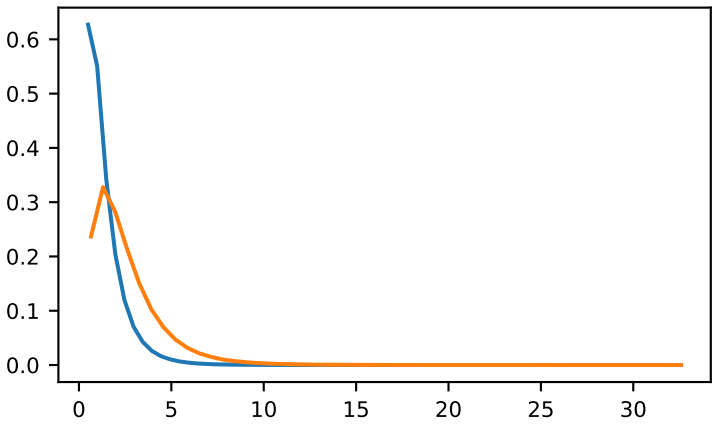
References

[1], [2]

Examples

In a study, testing for a specific alternative to the null hypothesis requires use of the Noncentral F distribution. We need to calculate the area in the tail of the distribution that exceeds the value of the F distribution for the null hypothesis. We'll plot the two probability distributions for comparison.

```
>>> rng = np.random.default_rng()
>>> dfnum = 3 # between group deg of freedom
>>> dfden = 20 # within groups degrees of freedom
>>> nonc = 3.0
>>> nc_vals = rng.noncentral_f(dfnum, dfden, nonc, 1000000)
>>> NF = np.histogram(nc_vals, bins=50, density=True)
>>> c_vals = rng.f(dfnum, dfden, 1000000)
>>> F = np.histogram(c_vals, bins=50, density=True)
>>> import matplotlib.pyplot as plt
>>> plt.plot(F[1][1:], F[0])
>>> plt.plot(NF[1][1:], NF[0])
>>> plt.show()
```



method

`random.Generator.`**`normal`**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw random samples from a normal (Gaussian) distribution.

The probability density function of the normal distribution, first derived by De Moivre and 200 years later by both Gauss and Laplace independently [2], is often called the bell curve because of its characteristic shape (see the example below).

The normal distributions occurs often in nature. For example, it describes the commonly occurring distribution of samples influenced by a large number of tiny, random disturbances, each with its own unique distribution [2].

Parameters

loc
[float or array_like of floats] Mean ("centre") of the distribution.

scale
[float or array_like of floats] Standard deviation (spread or "width") of the distribution. Must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized normal distribution.

See also:

`scipy.stats.norm`
probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Gaussian distribution is

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}},$$

where μ is the mean and σ the standard deviation. The square of the standard deviation, σ^2, is called the variance.

The function has its peak at the mean, and its "spread" increases with the standard deviation (the function reaches 0.607 times its maximum at $x + \sigma$ and $x - \sigma$ [2]). This implies that *normal* is more likely to return samples lying close to the mean, rather than those far away.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> mu, sigma = 0, 0.1 # mean and standard deviation
>>> rng = np.random.default_rng()
>>> s = rng.normal(mu, sigma, 1000)
```

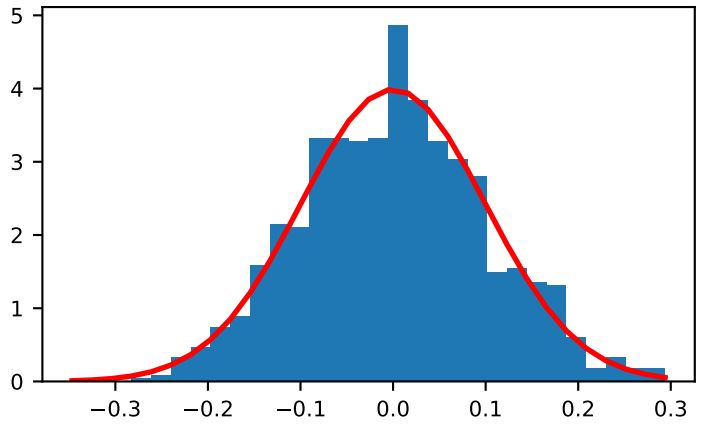
Verify the mean and the standard deviation:

```
>>> abs(mu - np.mean(s))
0.0  # may vary
```

```
>>> abs(sigma - np.std(s, ddof=1))
0.0  # may vary
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, 30, density=True)
>>> plt.plot(bins, 1/(sigma * np.sqrt(2 * np.pi)) *
...                np.exp( - (bins - mu)**2 / (2 * sigma**2) ),
...          linewidth=2, color='r')
>>> plt.show()
```



Two-by-four array of samples from the normal distribution with mean 3 and standard deviation 2.5:

```
>>> rng = np.random.default_rng()
>>> rng.normal(3, 2.5, size=(2, 4))
array([[-4.49401501,  4.00950034, -1.81814867,  7.29718677],   # random
       [ 0.39924804,  4.68456316,  4.99394529,  4.84057254]])  # random
```

method

`random.Generator.`**`pareto`**(*a*, *size=None*)

Draw samples from a Pareto II (AKA Lomax) distribution with specified shape.

Parameters

a
[float or array_like of floats] Shape of the distribution. Must be positive.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the Pareto II distribution.

See also:

scipy.stats.pareto
Pareto I distribution

scipy.stats.lomax
Lomax (Pareto II) distribution

scipy.stats.genpareto
Generalized Pareto distribution

Notes

The probability density for the Pareto II distribution is

$$p(x) = \frac{a}{x + 1^{a+1}}, x \geq 0$$

where $a > 0$ is the shape.

The Pareto II distribution is a shifted and scaled version of the Pareto I distribution, which can be found in `scipy.stats.pareto`.

References

[1], [2], [3], [4]

Examples

Draw samples from the distribution:

```
>>> a = 3.
>>> rng = np.random.default_rng()
>>> s = rng.pareto(a, 10000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(0, 3, 50)
>>> pdf = a / (x+1)**(a+1)
>>> plt.hist(s, bins=x, density=True, label='histogram')
>>> plt.plot(x, pdf, linewidth=2, color='r', label='pdf')
```

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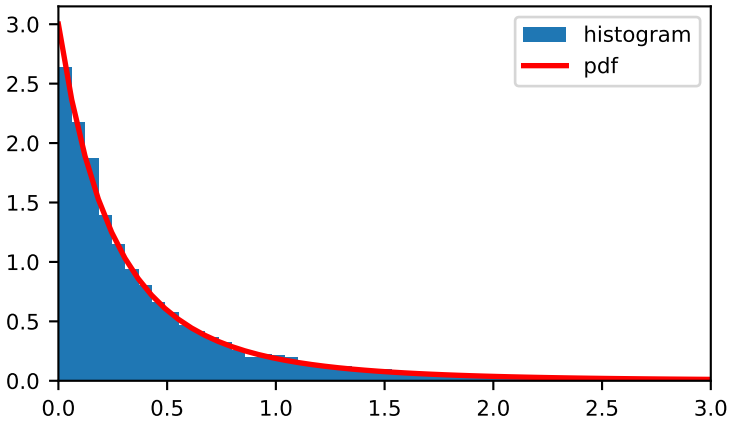
```
>>> plt.xlim(x.min(), x.max())
>>> plt.legend()
>>> plt.show()
```



method

`random.Generator.`**`poisson`**(*lam=1.0*, *size=None*)

Draw samples from a Poisson distribution.

The Poisson distribution is the limit of the binomial distribution for large N.

Parameters

lam

[float or array_like of floats] Expected number of events occurring in a fixed-time interval, must be >= 0. A sequence must be broadcastable over the requested size.

size

[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `lam` is a scalar. Otherwise, `np.array(lam).size` samples are drawn.

Returns

out

[ndarray or scalar] Drawn samples from the parameterized Poisson distribution.

Notes

The probability mass function (PMF) of Poisson distribution is

$$f(k;\lambda) = \frac{\lambda^k e^{-\lambda}}{k!}$$

For events with an expected separation λ the Poisson distribution $f(k;\lambda)$ describes the probability of k events occurring within the observed interval λ.

Because the output is limited to the range of the C int64 type, a ValueError is raised when *lam* is within 10 sigma of the maximum representable value.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> rng = np.random.default_rng()
>>> lam, size = 5, 10000
>>> s = rng.poisson(lam=lam, size=size)
```

Verify the mean and variance, which should be approximately `lam`:

```
>>> s.mean(), s.var()
(4.9917 5.1088311)  # may vary
```

Display the histogram and probability mass function:

```
>>> import matplotlib.pyplot as plt
>>> from scipy import stats
>>> x = np.arange(0, 21)
>>> pmf = stats.poisson.pmf(x, mu=lam)
>>> plt.hist(s, bins=x, density=True, width=0.5)
>>> plt.stem(x, pmf, 'C1-')
>>> plt.show()
```

Draw each 100 values for lambda 100 and 500:

```
>>> s = rng.poisson(lam=(100., 500.), size=(100, 2))
```

method

`random.Generator.`**`power`**(*a*, *size=None*)

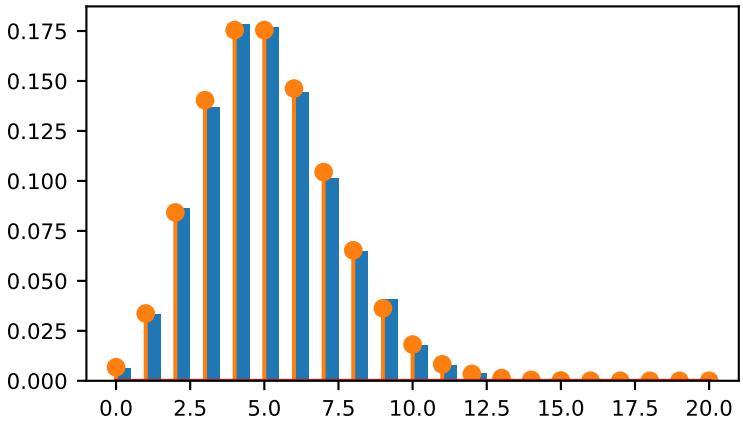
Draws samples in [0, 1] from a power distribution with positive exponent a - 1.

Also known as the power function distribution.

Parameters

a

[float or array_like of floats] Parameter of the distribution. Must be non-negative.



size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized power distribution.

Raises

ValueError
: If a <= 0.

Notes

The probability density function is

$$P(x; a) = ax^{a-1}, 0 \leq x \leq 1, a > 0.$$

The power function distribution is just the inverse of the Pareto distribution. It may also be seen as a special case of the Beta distribution.

It is used, for example, in modeling the over-reporting of insurance claims.

References

[1], [2]

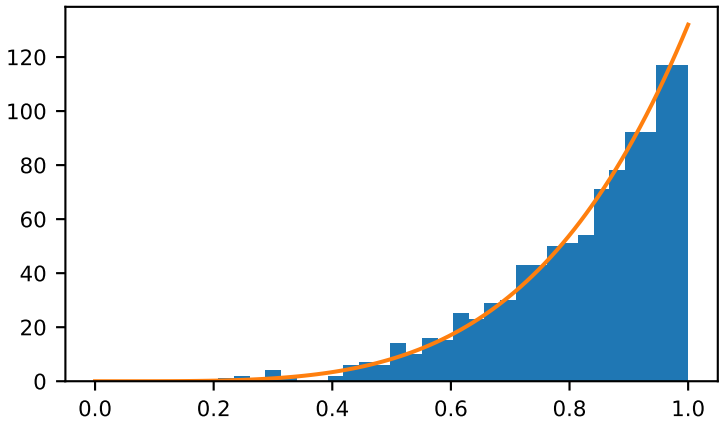
Examples

Draw samples from the distribution:

```
>>> rng = np.random.default_rng()
>>> a = 5. # shape
>>> samples = 1000
>>> s = rng.power(a, samples)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, bins=30)
>>> x = np.linspace(0, 1, 100)
>>> y = a*x**(a-1.)
>>> normed_y = samples*np.diff(bins)[0]*y
>>> plt.plot(x, normed_y)
>>> plt.show()
```



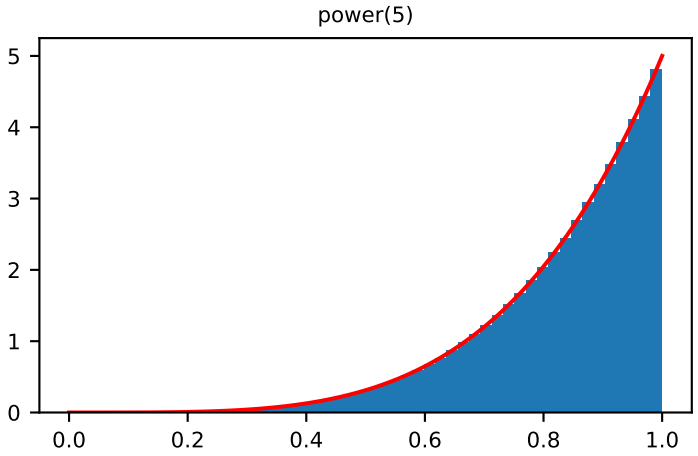
Compare the power function distribution to the inverse of the Pareto.

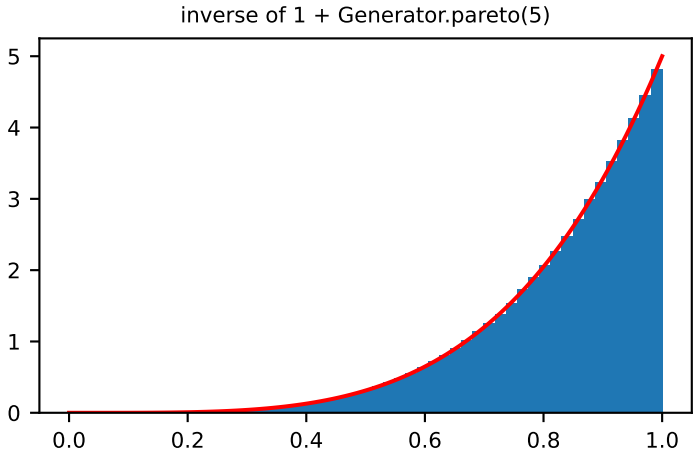
```
>>> from scipy import stats
>>> rvs = rng.power(5, 1000000)
>>> rvsp = rng.pareto(5, 1000000)
>>> xx = np.linspace(0,1,100)
>>> powpdf = stats.powerlaw.pdf(xx,5)
```

```
>>> plt.figure()
>>> plt.hist(rvs, bins=50, density=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('power(5)')
```

```
>>> plt.figure()
>>> plt.hist(1./(1.+rvsp), bins=50, density=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('inverse of 1 + Generator.pareto(5)')
```

```
>>> plt.figure()
>>> plt.hist(1./(1.+rvsp), bins=50, density=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('inverse of stats.pareto(5)')
```





method

`random.Generator.`**`rayleigh`**(*scale=1.0*, *size=None*)

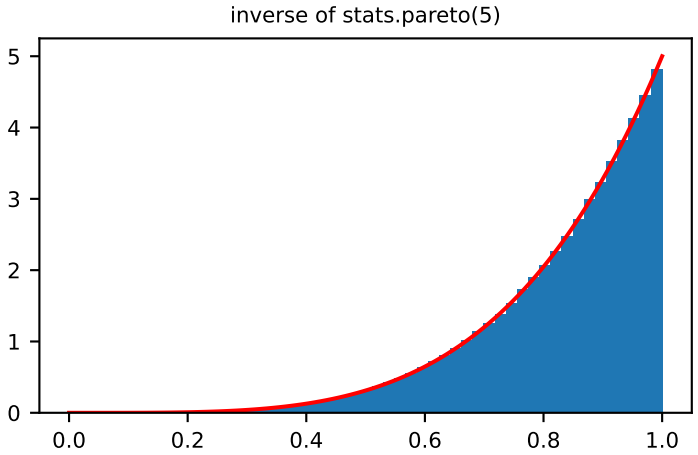
Draw samples from a Rayleigh distribution.

The χ and Weibull distributions are generalizations of the Rayleigh.

Parameters

scale

[float or array_like of floats, optional] Scale, also equals the mode. Must be non-negative. Default is 1.



size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `scale` is a scalar. Otherwise, `np.array(scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Rayleigh distribution.

Notes

The probability density function for the Rayleigh distribution is

$$P(x;scale) = \frac{x}{scale^2}e^{\frac{-x^2}{2\cdot scale^2}}$$

The Rayleigh distribution would arise, for example, if the East and North components of the wind velocity had identical zero-mean Gaussian distributions. Then the wind speed would have a Rayleigh distribution.

References

[1], [2]

Examples

Draw values from the distribution and plot the histogram

```
>>> from matplotlib.pyplot import hist
>>> rng = np.random.default_rng()
>>> values = hist(rng.rayleigh(3, 100000), bins=200, density=True)
```

Wave heights tend to follow a Rayleigh distribution. If the mean wave height is 1 meter, what fraction of waves are likely to be larger than 3 meters?

```
>>> meanvalue = 1
>>> modevalue = np.sqrt(2 / np.pi) * meanvalue
>>> s = rng.rayleigh(modevalue, 1000000)
```

The percentage of waves larger than 3 meters is:

```
>>> 100.*sum(s>3)/1000000.
0.087300000000000003 # random
```

method

random.Generator.**standard_cauchy**(*size=None*)

Draw samples from a standard Cauchy distribution with mode = 0.

Also known as the Lorentz distribution.

Parameters

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

samples
[ndarray or scalar] The drawn samples.

Notes

The probability density function for the full Cauchy distribution is

$$P(x; x_0, \gamma) = \frac{1}{\pi\gamma\left[1 + (\frac{x-x_0}{\gamma})^2\right]}$$

and the Standard Cauchy distribution just sets $x_0 = 0$ and $\gamma = 1$

The Cauchy distribution arises in the solution to the driven harmonic oscillator problem, and also describes spectral line broadening. It also describes the distribution of values at which a line tilted at a random angle will cut the x axis.

When studying hypothesis tests that assume normality, seeing how the tests perform on data from a Cauchy distribution is a good indicator of their sensitivity to a heavy-tailed distribution, since the Cauchy looks very much like a Gaussian distribution, but with heavier tails.

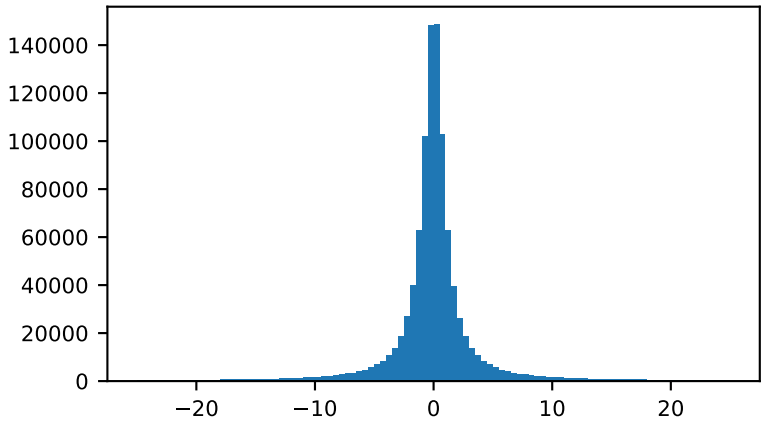
References

[1], [2], [3]

Examples

Draw samples and plot the distribution:

```
>>> import matplotlib.pyplot as plt
>>> rng = np.random.default_rng()
>>> s = rng.standard_cauchy(1000000)
>>> s = s[(s>-25) & (s<25)]  # truncate distribution so it plots well
>>> plt.hist(s, bins=100)
>>> plt.show()
```



method

`random.Generator.`**`standard_exponential`**(*size=None*, *dtype=np.float64*, *method='zig'*, *out=None*)

Draw samples from the standard exponential distribution.

`standard_exponential` is identical to the exponential distribution with a scale parameter of 1.

Parameters

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

dtype
: [dtype, optional] Desired dtype of the result, only *`float64`* and *`float32`* are supported. Byteorder must be native. The default value is np.float64.

method
: [str, optional] Either 'inv' or 'zig'. 'inv' uses the default inverse CDF method. 'zig' uses the much faster Ziggurat method of Marsaglia and Tsang.

out
: [ndarray, optional] Alternative output array in which to place the result. If size is not None, it must have the same shape as the provided size and must match the type of the output values.

Returns

out
: [float or ndarray] Drawn samples.

Examples

Output a 3x8000 array:

```
>>> rng = np.random.default_rng()
>>> n = rng.standard_exponential((3, 8000))
```

method

random.Generator.**standard_gamma**(*shape*, *size=None*, *dtype=np.float64*, *out=None*)

Draw samples from a standard Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, shape (sometimes designated "k") and scale=1.

Parameters

shape
[float or array_like of floats] Parameter, must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `shape` is a scalar. Otherwise, `np.array(shape).size` samples are drawn.

dtype
[dtype, optional] Desired dtype of the result, only *`float64`* and *`float32`* are supported. Byteorder must be native. The default value is np.float64.

out
[ndarray, optional] Alternative output array in which to place the result. If size is not None, it must have the same shape as the provided size and must match the type of the output values.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized standard gamma distribution.

See also:

`scipy.stats.gamma`
probability density function, distribution or cumulative density function, etc.

Notes

The probability density for the Gamma distribution is

$$p(x) = x^{k-1}\frac{e^{-x/\theta}}{\theta^k\Gamma(k)},$$

where k is the shape and θ the scale, and Γ is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.

References

[1], [2]

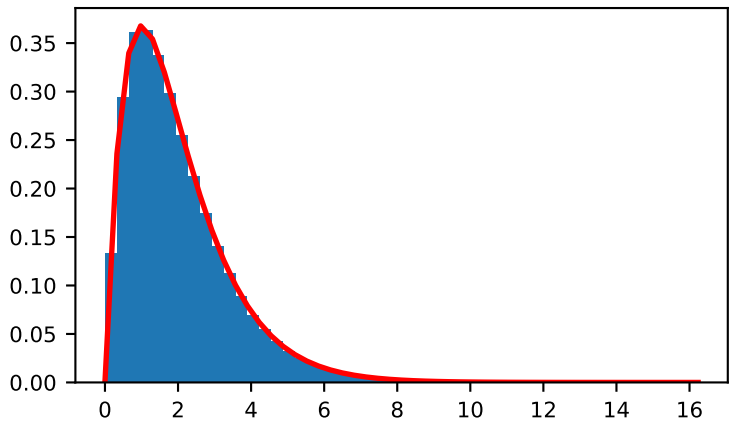
Examples

Draw samples from the distribution:

```
>>> shape, scale = 2., 1. # mean and width
>>> rng = np.random.default_rng()
>>> s = rng.standard_gamma(shape, 1000000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, _ = plt.hist(s, 50, density=True)
>>> y = bins**(shape-1) * ((np.exp(-bins/scale))/
...                        (sps.gamma(shape) * scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```



method

`random.Generator.`**`standard_normal`**(*size=None*, *dtype=np.float64*, *out=None*)

Draw samples from a standard Normal distribution (mean=0, stdev=1).

Parameters

size

[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

dtype

[dtype, optional] Desired dtype of the result, only *`float64`* and *`float32`* are supported. Byteorder must be native. The default value is np.float64.

out
: [ndarray, optional] Alternative output array in which to place the result. If size is not None, it must have the same shape as the provided size and must match the type of the output values.

Returns

out
: [float or ndarray] A floating-point array of shape `size` of drawn samples, or a single sample if `size` was not specified.

See also:

normal
: Equivalent function with additional `loc` and `scale` arguments for setting the mean and standard deviation.

Notes

For random samples from the normal distribution with mean `mu` and standard deviation `sigma`, use one of:

```
mu + sigma * rng.standard_normal(size=...)
rng.normal(mu, sigma, size=...)
```

Examples

```
>>> rng = np.random.default_rng()
>>> rng.standard_normal()
2.1923875335537315 # random
```

```
>>> s = rng.standard_normal(8000)
>>> s
array([ 0.6888893 ,  0.78096262, -0.89086505, ...,  0.49876311,  # random
       -0.38672696, -0.4685006 ])                                # random
>>> s.shape
(8000,)
>>> s = rng.standard_normal(size=(3, 4, 2))
>>> s.shape
(3, 4, 2)
```

Two-by-four array of samples from the normal distribution with mean 3 and standard deviation 2.5:

```
>>> 3 + 2.5 * rng.standard_normal(size=(2, 4))
array([[-4.49401501,  4.00950034, -1.81814867,  7.29718677],   # random
       [ 0.39924804,  4.68456316,  4.99394529,  4.84057254]])  # random
```

method

`random.Generator.`**`standard_t`**(*df*, *size=None*)

Draw samples from a standard Student's t distribution with *df* degrees of freedom.

A special case of the hyperbolic distribution. As *df* gets large, the result resembles that of the standard normal distribution (*standard_normal*).

Parameters

df
: [float or array_like of floats] Degrees of freedom, must be > 0.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `df` is a scalar. Otherwise, `np.array(df).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized standard Student's t distribution.

Notes

The probability density function for the t distribution is

$$P(x, df) = \frac{\Gamma(\frac{df+1}{2})}{\sqrt{\pi df}\,\Gamma(\frac{df}{2})}\left(1 + \frac{x^2}{df}\right)^{-(df+1)/2}$$

The t test is based on an assumption that the data come from a Normal distribution. The t test provides a way to test whether the sample mean (that is the mean calculated from the data) is a good estimate of the true mean.

The derivation of the t-distribution was first published in 1908 by William Gosset while working for the Guinness Brewery in Dublin. Due to proprietary issues, he had to publish under a pseudonym, and so he used the name Student.

References

[1], [2]

Examples

From Dalgaard page 83 [1], suppose the daily energy intake for 11 women in kilojoules (kJ) is:

```
>>> intake = np.array([5260., 5470, 5640, 6180, 6390, 6515, 6805, 7515, \
...                    7515, 8230, 8770])
```

Does their energy intake deviate systematically from the recommended value of 7725 kJ? Our null hypothesis will be the absence of deviation, and the alternate hypothesis will be the presence of an effect that could be either positive or negative, hence making our test 2-tailed.

Because we are estimating the mean and we have N=11 values in our sample, we have N-1=10 degrees of freedom. We set our significance level to 95% and compute the t statistic using the empirical mean and empirical standard deviation of our intake. We use a ddof of 1 to base the computation of our empirical standard deviation on an unbiased estimate of the variance (note: the final estimate is not unbiased due to the concave nature of the square root).

```
>>> np.mean(intake)
6753.636363636364
>>> intake.std(ddof=1)
1142.1232221373727
>>> t = (np.mean(intake)-7725)/(intake.std(ddof=1)/np.sqrt(len(intake)))
>>> t
-2.8207540608310198
```

We draw 1000000 samples from Student's t distribution with the adequate degrees of freedom.

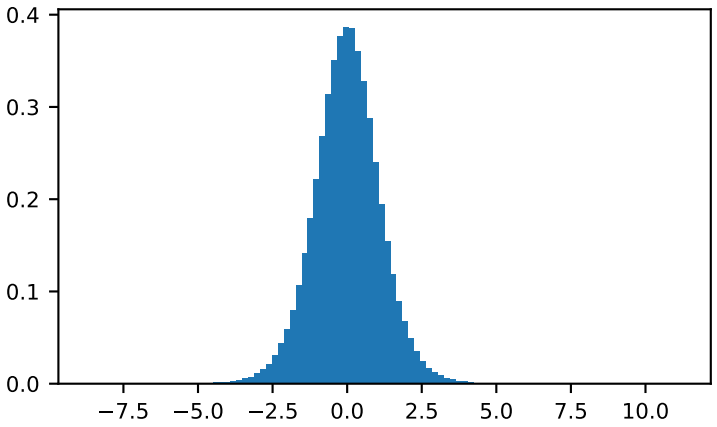
```
>>> import matplotlib.pyplot as plt
>>> rng = np.random.default_rng()
>>> s = rng.standard_t(10, size=1000000)
>>> h = plt.hist(s, bins=100, density=True)
```

Does our t statistic land in one of the two critical regions found at both tails of the distribution?

```
>>> np.sum(np.abs(t) < np.abs(s)) / float(len(s))
0.018318  #random < 0.05, statistic is in critical region
```

The probability value for this 2-tailed test is about 1.83%, which is lower than the 5% pre-determined significance threshold.

Therefore, the probability of observing values as extreme as our intake conditionally on the null hypothesis being true is too low, and we reject the null hypothesis of no deviation.



method

`random.Generator.`**`triangular`**(*left*, *mode*, *right*, *size=None*)

Draw samples from the triangular distribution over the interval `[left, right]`.

The triangular distribution is a continuous probability distribution with lower limit left, peak at mode, and upper limit right. Unlike the other distributions, these parameters directly define the shape of the pdf.

Parameters

left
[float or array_like of floats] Lower limit.

mode
[float or array_like of floats] The value where the peak of the distribution occurs. The value must fulfill the condition `left <= mode <= right`.

right
[float or array_like of floats] Upper limit, must be larger than *left*.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `left`, `mode`,

and `right` are all scalars. Otherwise, `np.broadcast(left, mode, right).size` samples are drawn.

Returns

out

[ndarray or scalar] Drawn samples from the parameterized triangular distribution.

Notes

The probability density function for the triangular distribution is

$$P(x;l,m,r) = \begin{cases} \frac{2(x-l)}{(r-l)(m-l)} & \text{for } l \leq x \leq m, \\ \frac{2(r-x)}{(r-l)(r-m)} & \text{for } m \leq x \leq r, \\ 0 & \text{otherwise.} \end{cases}$$

The triangular distribution is often used in ill-defined problems where the underlying distribution is not known, but some knowledge of the limits and mode exists. Often it is used in simulations.

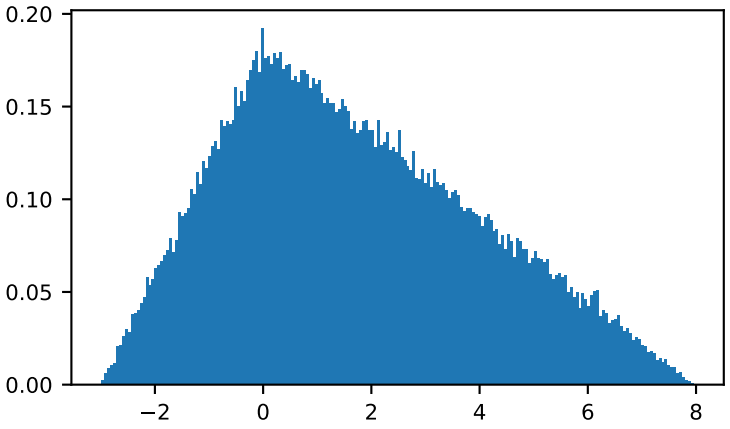
References

[1]

Examples

Draw values from the distribution and plot the histogram:

```
>>> import matplotlib.pyplot as plt
>>> rng = np.random.default_rng()
>>> h = plt.hist(rng.triangular(-3, 0, 8, 100000), bins=200,
...              density=True)
>>> plt.show()
```



method

random.Generator.**uniform**(*low=0.0*, *high=1.0*, *size=None*)

Draw samples from a uniform distribution.

Samples are uniformly distributed over the half-open interval `[low, high)` (includes low, but excludes high). In other words, any value within the given interval is equally likely to be drawn by *uniform*.

Parameters

low
[float or array_like of floats, optional] Lower boundary of the output interval. All values generated will be greater than or equal to low. The default value is 0.

high
[float or array_like of floats] Upper boundary of the output interval. All values generated will be less than high. The high limit may be included in the returned array of floats due to floating-point rounding in the equation `low + (high-low) * random_sample()`. high - low must be non-negative. The default value is 1.0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `low` and `high` are both scalars. Otherwise, `np.broadcast(low, high).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized uniform distribution.

See also:

integers
Discrete uniform distribution, yielding integers.

random
Floats uniformly distributed over `[0, 1)`.

Notes

The probability density function of the uniform distribution is

$$p(x) = \frac{1}{b - a}$$

anywhere within the interval `[a, b)`, and zero elsewhere.

When `high` == `low`, values of `low` will be returned.

Examples

Draw samples from the distribution:

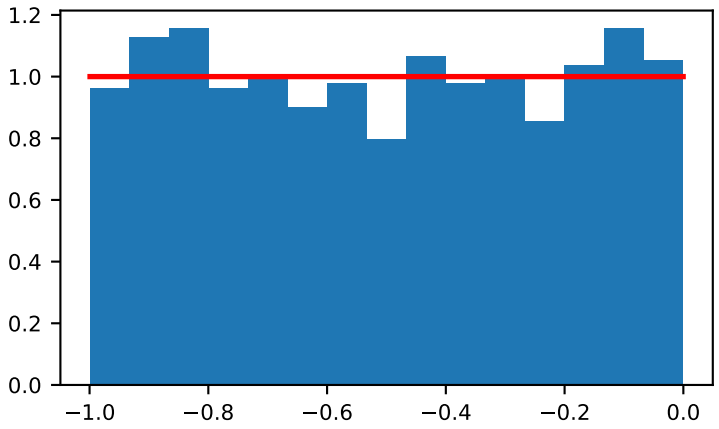
```
>>> rng = np.random.default_rng()
>>> s = rng.uniform(-1,0,1000)
```

All values are within the given interval:

```
>>> np.all(s >= -1)
True
>>> np.all(s < 0)
True
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, 15, density=True)
>>> plt.plot(bins, np.ones_like(bins), linewidth=2, color='r')
>>> plt.show()
```



method

`random.Generator.`**`vonmises`**(*mu*, *kappa*, *size=None*)

Draw samples from a von Mises distribution.

Samples are drawn from a von Mises distribution with specified mode (mu) and concentration (kappa), on the interval [-pi, pi].

The von Mises distribution (also known as the circular normal distribution) is a continuous probability distribution on the unit circle. It may be thought of as the circular analogue of the normal distribution.

Parameters

mu
[float or array_like of floats] Mode (“center”) of the distribution.

kappa
[float or array_like of floats] Concentration of the distribution, has to be >=0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `mu` and `kappa` are both scalars. Otherwise, `np.broadcast(mu, kappa).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized von Mises distribution.

See also:

`scipy.stats.vonmises`
probability density function, distribution, or cumulative density function, etc.

Notes

The probability density for the von Mises distribution is

$$p(x) = \frac{e^{\kappa cos(x-\mu)}}{2\pi I_0(\kappa)},$$

where μ is the mode and κ the concentration, and $I_0(\kappa)$ is the modified Bessel function of order 0.

The von Mises is named for Richard Edler von Mises, who was born in Austria-Hungary, in what is now the Ukraine. He fled to the United States in 1939 and became a professor at Harvard. He worked in probability theory, aerodynamics, fluid mechanics, and philosophy of science.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> mu, kappa = 0.0, 4.0 # mean and concentration
>>> rng = np.random.default_rng()
>>> s = rng.vonmises(mu, kappa, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> from scipy.special import i0
>>> plt.hist(s, 50, density=True)
>>> x = np.linspace(-np.pi, np.pi, num=51)
>>> y = np.exp(kappa*np.cos(x-mu))/(2*np.pi*i0(kappa))
>>> plt.plot(x, y, linewidth=2, color='r')
>>> plt.show()
```

method

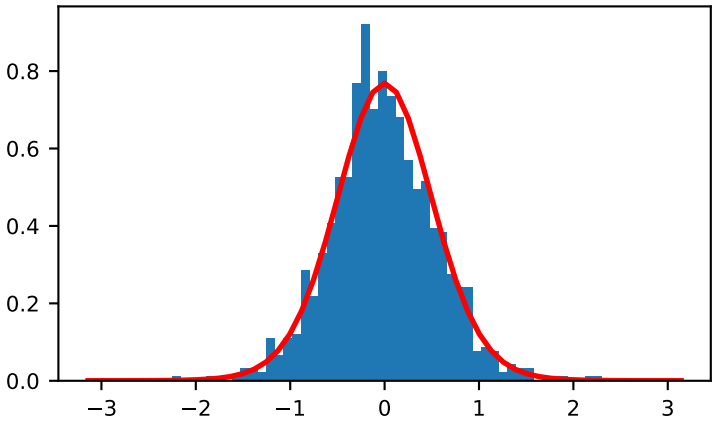
`random.Generator.`**`wald`**(*mean*, *scale*, *size=None*)

Draw samples from a Wald, or inverse Gaussian, distribution.

As the scale approaches infinity, the distribution becomes more like a Gaussian. Some references claim that the Wald is an inverse Gaussian with mean equal to 1, but this is by no means universal.

The inverse Gaussian distribution was first studied in relationship to Brownian motion. In 1956 M.C.K. Tweedie used the name inverse Gaussian because there is an inverse relationship between the time to cover a unit distance and distance covered in unit time.

Parameters



mean
: [float or array_like of floats] Distribution mean, must be > 0.

scale
: [float or array_like of floats] Scale parameter, must be > 0.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `mean` and `scale` are both scalars. Otherwise, `np.broadcast(mean, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Wald distribution.

Notes

The probability density function for the Wald distribution is

$$P(x; mean, scale) = \sqrt{\frac{scale}{2\pi x^3}} e^{\frac{-scale(x-mean)^2}{2 \cdot mean^2 x}}$$

As noted above the inverse Gaussian distribution first arise from attempts to model Brownian motion. It is also a competitor to the Weibull for use in reliability modeling and modeling stock returns and interest rate processes.

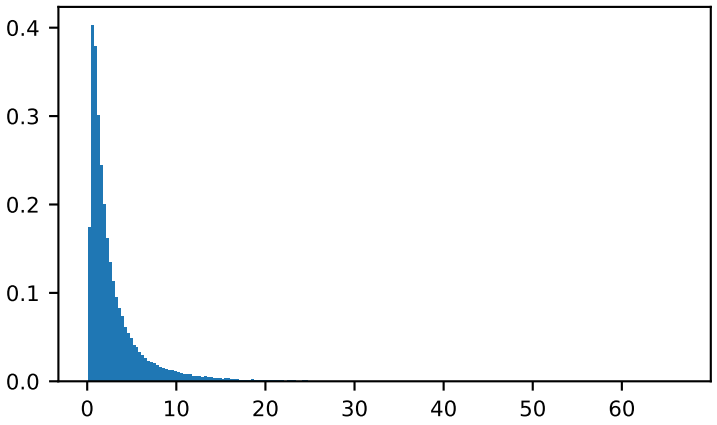
References

[1], [2], [3]

Examples

Draw values from the distribution and plot the histogram:

```
>>> import matplotlib.pyplot as plt
>>> rng = np.random.default_rng()
>>> h = plt.hist(rng.wald(3, 2, 100000), bins=200, density=True)
>>> plt.show()
```



method

`random.Generator.`**`weibull`**(*a*, *size=None*)

Draw samples from a Weibull distribution.

Draw samples from a 1-parameter Weibull distribution with the given shape parameter a.

$$X = (-ln(U))^{1/a}$$

Here, U is drawn from the uniform distribution over (0,1].

The more common 2-parameter Weibull, including a scale parameter λ is just $X = \lambda(-ln(U))^{1/a}$.

Parameters

a
: [float or array_like of floats] Shape parameter of the distribution. Must be nonnegative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Weibull distribution.

See also:

scipy.stats.weibull_max
scipy.stats.weibull_min
scipy.stats.genextreme
gumbel

Notes

The Weibull (or Type III asymptotic extreme value distribution for smallest values, SEV Type III, or Rosin-Rammler distribution) is one of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems. This class includes the Gumbel and Frechet distributions.

The probability density for the Weibull distribution is

$$p(x) = \frac{a}{\lambda}(\frac{x}{\lambda})^{a-1}e^{-(x/\lambda)^a},$$

where a is the shape and λ the scale.

The function has its peak (the mode) at $\lambda(\frac{a-1}{a})^{1/a}$.

When `a = 1`, the Weibull distribution reduces to the exponential distribution.

References

[1], [2], [3]

Examples

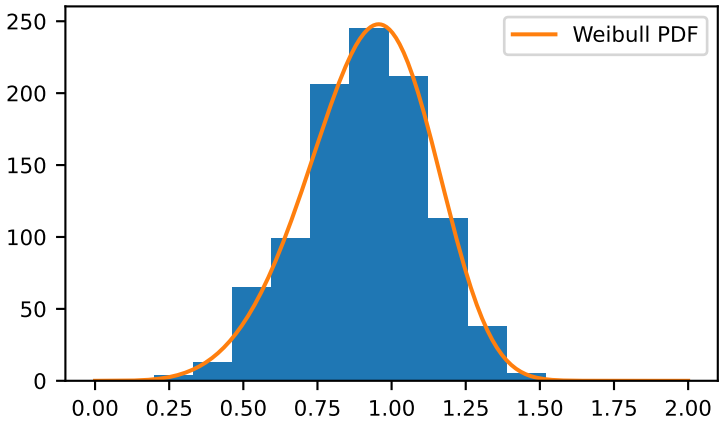
Draw samples from the distribution:

```
>>> rng = np.random.default_rng()
>>> a = 5. # shape
>>> s = rng.weibull(a, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> def weibull(x, n, a):
...     return (a / n) * (x / n)**(a - 1) * np.exp(-(x / n)**a)
>>> count, bins, _ = plt.hist(rng.weibull(5., 1000))
>>> x = np.linspace(0, 2, 1000)
>>> bin_spacing = np.mean(np.diff(bins))
>>> plt.plot(x, weibull(x, 1., 5.) * bin_spacing * s.size, label='Weibull PDF')
>>> plt.legend()
>>> plt.show()
```

method



random.Generator.**zipf**(*a*, *size=None*)

Draw samples from a Zipf distribution.

Samples are drawn from a Zipf distribution with specified parameter $a > 1$.

The Zipf distribution (also known as the zeta distribution) is a discrete probability distribution that satisfies Zipf's law: the frequency of an item is inversely proportional to its rank in a frequency table.

Parameters

a
[float or array_like of floats] Distribution parameter. Must be greater than 1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Zipf distribution.

See also:

`scipy.stats.zipf`
probability density function, distribution, or cumulative density function, etc.

Notes

The probability mass function (PMF) for the Zipf distribution is

$$p(k) = \frac{k^{-a}}{\zeta(a)},$$

for integers $k \geq 1$, where ζ is the Riemann Zeta function.

It is named for the American linguist George Kingsley Zipf, who noted that the frequency of any word in a sample of a language is inversely proportional to its rank in the frequency table.

References

[1]

Examples

Draw samples from the distribution:

```
>>> a = 4.0
>>> n = 20000
>>> rng = np.random.default_rng()
>>> s = rng.zipf(a, size=n)
```

Display the histogram of the samples, along with the expected histogram based on the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> from scipy.special import zeta
```

bincount provides a fast histogram for small integers.

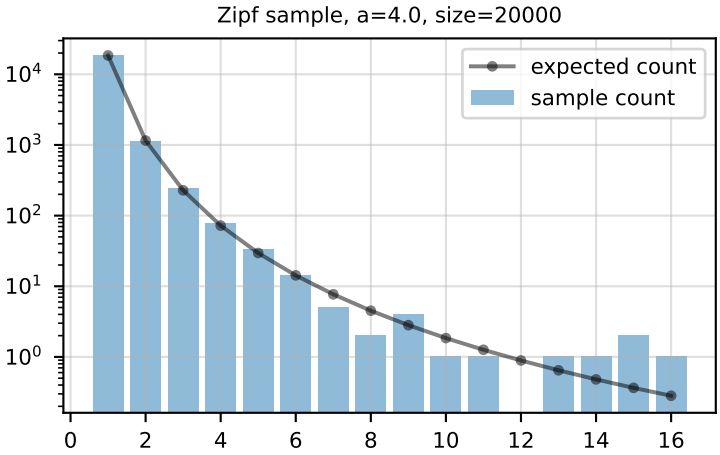
```
>>> count = np.bincount(s)
>>> k = np.arange(1, s.max() + 1)
```

```
>>> plt.bar(k, count[1:], alpha=0.5, label='sample count')
>>> plt.plot(k, n*(k**-a)/zeta(a), 'k.-', alpha=0.5,
...          label='expected count')
>>> plt.semilogy()
>>> plt.grid(alpha=0.4)
>>> plt.legend()
>>> plt.title(f'Zipf sample, a={a}, size={n}')
>>> plt.show()
```

Legacy random generation

The *RandomState* provides access to legacy generators. This generator is considered frozen and will have no further improvements. It is guaranteed to produce the same values as the final point release of NumPy v1.16. These all depend on Box-Muller normals or inverse CDF exponentials or gammas. This class should only be used if it is essential to have randoms that are identical to what would have been produced by previous versions of NumPy.

RandomState adds additional information to the state which is required when using Box-Muller normals since these are produced in pairs. It is important to use *RandomState.get_state*, and not the underlying bit generators *state*, when accessing the state so that these extra values are saved.



Although we provide the *MT19937* BitGenerator for use independent of *RandomState*, note that its default seeding uses *SeedSequence* rather than the legacy seeding algorithm. *RandomState* will use the legacy seeding algorithm. The methods to use the legacy seeding algorithm are currently private as the main reason to use them is just to implement *RandomState*. However, one can reset the state of *MT19937* using the state of the *RandomState*:

```
from numpy.random import MT19937
from numpy.random import RandomState

rs = RandomState(12345)
mt19937 = MT19937()
mt19937.state = rs.get_state()
rs2 = RandomState(mt19937)

# Same output
rs.standard_normal()
rs2.standard_normal()

rs.random()
rs2.random()

rs.standard_exponential()
rs2.standard_exponential()
```

class numpy.random.**RandomState**(*seed=None*)

Container for the slow Mersenne Twister pseudo-random number generator. Consider using a different BitGenerator with the Generator container instead.

RandomState and *Generator* expose a number of methods for generating random numbers drawn from a variety of probability distributions. In addition to the distribution-specific arguments, each method takes a keyword argument *size* that defaults to `None`. If *size* is `None`, then a single value is generated and returned. If *size* is an integer, then a 1-D array filled with generated values is returned. If *size* is a tuple, then an array with that shape is filled and returned.

Compatibility Guarantee

A fixed bit generator using a fixed seed and a fixed series of calls to 'RandomState' methods using the same parameters will always produce the same results up to roundoff error except when the values were incorrect. *Random-*

State is effectively frozen and will only receive updates that are required by changes in the internals of Numpy. More substantial changes, including algorithmic improvements, are reserved for *Generator*.

Parameters

seed
[{None, int, array_like, BitGenerator}, optional] Random seed used to initialize the pseudo-random number generator or an instantized BitGenerator. If an integer or array, used as a seed for the MT19937 BitGenerator. Values can be any integer between 0 and 2**32 - 1 inclusive, an array (or other sequence) of such integers, or `None` (the default). If *seed* is `None`, then the *MT19937* BitGenerator is initialized by reading data from `/dev/urandom` (or the Windows analogue) if available or seed from the clock otherwise.

See also:

Generator
MT19937
numpy.random.BitGenerator

Notes

The Python stdlib module "random" also contains a Mersenne Twister pseudo-random number generator with a number of methods that are similar to the ones available in *RandomState*. *RandomState*, besides being NumPy-aware, has the advantage that it provides a much larger number of probability distributions to choose from.

Seeding and state

get_state([legacy])	Return a tuple representing the internal state of the generator.
set_state(state)	Set the internal state of the generator from a tuple.
seed([seed])	Reseed a legacy MT19937 BitGenerator

method

`random.RandomState.`**`get_state`**`(`*legacy=True*`)`

Return a tuple representing the internal state of the generator.

For more details, see *set_state*.

Parameters

legacy
[bool, optional] Flag indicating to return a legacy tuple state when the BitGenerator is MT19937, instead of a dict. Raises ValueError if the underlying bit generator is not an instance of MT19937.

Returns

out
[{tuple(str, ndarray of 624 uints, int, int, float), dict}] If legacy is True, the returned tuple has the following items:

1. the string 'MT19937'.
2. a 1-D array of 624 unsigned integer keys.

3. an integer `pos`.
4. an integer `has_gauss`.
5. a float `cached_gaussian`.

If *legacy* is False, or the BitGenerator is not MT19937, then state is returned as a dictionary.

See also:

set_state

Notes

set_state and *get_state* are not needed to work with any of the random distributions in NumPy. If the internal state is manually altered, the user should know exactly what he/she is doing.

method

`random.RandomState.`**`set_state`**`(`*state*`)`

Set the internal state of the generator from a tuple.

For use if one has reason to manually (re-)set the internal state of the bit generator used by the RandomState instance. By default, RandomState uses the "Mersenne Twister"[1] pseudo-random number generating algorithm.

Parameters

state
[{tuple(str, ndarray of 624 uints, int, int, float), dict}] The *state* tuple has the following items:

1. the string 'MT19937', specifying the Mersenne Twister algorithm.
2. a 1-D array of 624 unsigned integers `keys`.
3. an integer `pos`.
4. an integer `has_gauss`.
5. a float `cached_gaussian`.

If state is a dictionary, it is directly set using the BitGenerators *state* property.

Returns

out
[None] Returns 'None' on success.

See also:

get_state

Notes

set_state and *get_state* are not needed to work with any of the random distributions in NumPy. If the internal state is manually altered, the user should know exactly what he/she is doing.

For backwards compatibility, the form (str, array of 624 uints, int) is also accepted although it is missing some information about the cached Gaussian value: `state = ('MT19937', keys, pos)`.

References

[1]

method

`random.RandomState.`**`seed`**(*seed=None*)

Reseed a legacy MT19937 BitGenerator

Notes

This is a convenience, legacy function.

The best practice is to **not** reseed a BitGenerator, rather to recreate a new one. This method is here for legacy reasons. This example demonstrates best practice.

```
>>> from numpy.random import MT19937
>>> from numpy.random import RandomState, SeedSequence
>>> rs = RandomState(MT19937(SeedSequence(123456789)))
# Later, you want to restart the stream
>>> rs = RandomState(MT19937(SeedSequence(987654321)))
```

Simple random data

rand(d0, d1, ..., dn)	Random values in a given shape.
randn(d0, d1, ..., dn)	Return a sample (or samples) from the "standard normal" distribution.
randint(low[, high, size, dtype])	Return random integers from *low* (inclusive) to *high* (exclusive).
random_integers(low[, high, size])	Random integers of type *numpy.int_* between *low* and *high*, inclusive.
random_sample([size])	Return random floats in the half-open interval [0.0, 1.0).
choice(a[, size, replace, p])	Generates a random sample from a given 1-D array
bytes(length)	Return random bytes.

method

`random.RandomState.`**`rand`**(*d0*, *d1*, ..., *dn*)

Random values in a given shape.

Note: This is a convenience function for users porting code from Matlab, and wraps *random_sample*. That function takes a tuple to specify the size of the output, which is consistent with other NumPy functions like *numpy.zeros* and *numpy.ones*.

Create an array of the given shape and populate it with random samples from a uniform distribution over `[0, 1)`.

Parameters

d0, d1, …, dn
[int, optional] The dimensions of the returned array, must be non-negative. If no argument is given a single Python float is returned.

Returns

out
[ndarray, shape `(d0, d1, ..., dn)`] Random values.

See also:

random

Examples

```
>>> np.random.rand(3,2)
array([[ 0.14022471,  0.96360618],  #random
       [ 0.37601032,  0.25528411],  #random
       [ 0.49313049,  0.94909878]]) #random
```

method

`random.RandomState.`**randn**(*d0*, *d1*, ..., *dn*)

Return a sample (or samples) from the "standard normal" distribution.

Note: This is a convenience function for users porting code from Matlab, and wraps *`standard_normal`*. That function takes a tuple to specify the size of the output, which is consistent with other NumPy functions like *`numpy.zeros`* and *`numpy.ones`*.

Note: New code should use the *`standard_normal`* method of a *`Generator`* instance instead; please see the *Quick start*.

If positive int_like arguments are provided, *`randn`* generates an array of shape `(d0, d1, ..., dn)`, filled with random floats sampled from a univariate "normal" (Gaussian) distribution of mean 0 and variance 1. A single float randomly sampled from the distribution is returned if no argument is provided.

Parameters

d0, d1, …, dn
[int, optional] The dimensions of the returned array, must be non-negative. If no argument is given a single Python float is returned.

Returns

Z
[ndarray or float] A `(d0, d1, ..., dn)`-shaped array of floating-point samples from the standard normal distribution, or a single such float if no parameters were supplied.

See also:

standard_normal
Similar, but takes a tuple as its argument.

normal
Also accepts mu and sigma arguments.

random.Generator.standard_normal
which should be used for new code.

Notes

For random samples from the normal distribution with mean `mu` and standard deviation `sigma`, use:

```
sigma * np.random.randn(...) + mu
```

Examples

```
>>> np.random.randn()
2.1923875335537315  # random
```

Two-by-four array of samples from the normal distribution with mean 3 and standard deviation 2.5:

```
>>> 3 + 2.5 * np.random.randn(2, 4)
array([[-4.49401501,  4.00950034, -1.81814867,  7.29718677],   # random
       [ 0.39924804,  4.68456316,  4.99394529,  4.84057254]])  # random
```

method

`random.RandomState.`**`randint`**(*low*, *high=None*, *size=None*, *dtype=int*)

Return random integers from *low* (inclusive) to *high* (exclusive).

Return random integers from the "discrete uniform" distribution of the specified dtype in the "half-open" interval [*low*, *high*). If *high* is None (the default), then results are from [0, *low*).

Note: New code should use the *`integers`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

low
: [int or array-like of ints] Lowest (signed) integers to be drawn from the distribution (unless `high=None`, in which case this parameter is one above the *highest* such integer).

high
: [int or array-like of ints, optional] If provided, one above the largest (signed) integer to be drawn from the distribution (see above for behavior if `high=None`). If array-like, must contain integer values

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

dtype
: [dtype, optional] Desired dtype of the result. Byteorder must be native. The default value is long.

> **Warning:** This function defaults to the C-long dtype, which is 32bit on windows and otherwise 64bit on 64bit platforms (and 32bit on 32bit ones). Since NumPy 2.0, NumPy's default integer is 32bit on 32bit platforms and 64bit on 64bit platforms. Which corresponds to *np.intp*. (*dtype=int* is not the same as in most NumPy functions.)

Returns

out
[int or ndarray of ints] *size*-shaped array of random integers from the appropriate distribution, or a single such random int if *size* not provided.

See also:

random_integers
similar to *randint*, only for the closed interval [*low*, *high*], and 1 is the lowest value if *high* is omitted.

random.Generator.integers
which should be used for new code.

Examples

```
>>> np.random.randint(2, size=10)
array([1, 0, 0, 0, 1, 1, 0, 0, 1, 0]) # random
>>> np.random.randint(1, size=10)
array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0])
```

Generate a 2 x 4 array of ints between 0 and 4, inclusive:

```
>>> np.random.randint(5, size=(2, 4))
array([[4, 0, 2, 1], # random
       [3, 2, 2, 0]])
```

Generate a 1 x 3 array with 3 different upper bounds

```
>>> np.random.randint(1, [3, 5, 10])
array([2, 2, 9]) # random
```

Generate a 1 by 3 array with 3 different lower bounds

```
>>> np.random.randint([1, 5, 7], 10)
array([9, 8, 7]) # random
```

Generate a 2 by 4 array using broadcasting with dtype of uint8

```
>>> np.random.randint([1, 3, 5, 7], [[10], [20]], dtype=np.uint8)
array([[ 8,  6,  9,  7], # random
       [ 1, 16,  9, 12]], dtype=uint8)
```

method

`random.RandomState.`**`random_integers`**(*low*, *high=None*, *size=None*)

Random integers of type *numpy.int_* between *low* and *high*, inclusive.

Return random integers of type *numpy.int_* from the "discrete uniform" distribution in the closed interval [*low*, *high*]. If *high* is None (the default), then results are from [1, *low*]. The *numpy.int_* type translates to the C long integer type and its precision is platform dependent.

This function has been deprecated. Use randint instead.

Deprecated since version 1.11.0.

Parameters

low
: [int] Lowest (signed) integer to be drawn from the distribution (unless `high=None`, in which case this parameter is the *highest* such integer).

high
: [int, optional] If provided, the largest (signed) integer to be drawn from the distribution (see above for behavior if `high=None`).

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

out
: [int or ndarray of ints] *size*-shaped array of random integers from the appropriate distribution, or a single such random int if *size* not provided.

See also:

randint
: Similar to *random_integers*, only for the half-open interval [*low*, *high*), and 0 is the lowest value if *high* is omitted.

Notes

To sample from N evenly spaced floating-point numbers between a and b, use:

```
a + (b - a) * (np.random.random_integers(N) - 1) / (N - 1.)
```

Examples

```
>>> np.random.random_integers(5)
4 # random
>>> type(np.random.random_integers(5))
<class 'numpy.int64'>
>>> np.random.random_integers(5, size=(3,2))
array([[5, 4], # random
       [3, 3],
       [4, 5]])
```

Choose five random numbers from the set of five evenly-spaced numbers between 0 and 2.5, inclusive (*i.e.*, from the set $0, 5/8, 10/8, 15/8, 20/8$):

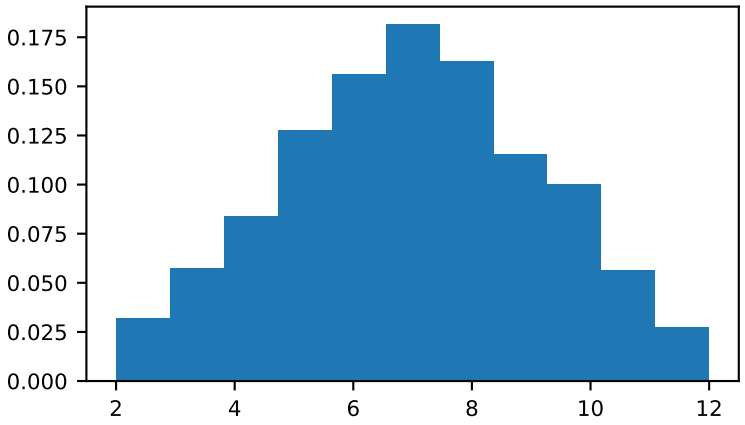
```
>>> 2.5 * (np.random.random_integers(5, size=(5,)) - 1) / 4.
array([ 0.625,  1.25 ,  0.625,  0.625,  2.5  ]) # random
```

Roll two six sided dice 1000 times and sum the results:

```
>>> d1 = np.random.random_integers(1, 6, 1000)
>>> d2 = np.random.random_integers(1, 6, 1000)
>>> dsums = d1 + d2
```

Display results as a histogram:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(dsums, 11, density=True)
>>> plt.show()
```



method

`random.RandomState.`**`random_sample`**(*size=None*)

Return random floats in the half-open interval [0.0, 1.0).

Results are from the "continuous uniform" distribution over the stated interval. To sample $Unif[a, b), b > a$ multiply the output of *random_sample* by *(b-a)* and add a:

```
(b - a) * random_sample() + a
```

Note: New code should use the *random* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

size

[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

out

[float or ndarray of floats] Array of random floats of shape *size* (unless `size=None`, in which case a single float is returned).

See also:

random.Generator.random

which should be used for new code.

Examples

```
>>> np.random.random_sample()
0.47108547995356098 # random
>>> type(np.random.random_sample())
<class 'float'>
>>> np.random.random_sample((5,))
array([ 0.30220482,  0.86820401,  0.1654503 ,  0.11659149,  0.54323428]) # random
```

Three-by-two array of random numbers from [-5, 0):

```
>>> 5 * np.random.random_sample((3, 2)) - 5
array([[-3.99149989, -0.52338984], # random
       [-2.99091858, -0.79479508],
       [-1.23204345, -1.75224494]])
```

method

`random.RandomState.`**`choice`**(*a*, *size=None*, *replace=True*, *p=None*)

Generates a random sample from a given 1-D array

Note: New code should use the `choice` method of a `Generator` instance instead; please see the *Quick start*.

Warning: This function uses the C-long dtype, which is 32bit on windows and otherwise 64bit on 64bit platforms (and 32bit on 32bit ones). Since NumPy 2.0, NumPy's default integer is 32bit on 32bit platforms and 64bit on 64bit platforms.

Parameters

a
: [1-D array-like or int] If an ndarray, a random sample is generated from its elements. If an int, the random sample is generated as if it were `np.arange(a)`

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

replace
: [boolean, optional] Whether the sample is with or without replacement. Default is True, meaning that a value of `a` can be selected multiple times.

p
: [1-D array-like, optional] The probabilities associated with each entry in a. If not given, the sample assumes a uniform distribution over all entries in `a`.

Returns

samples
: [single item or ndarray] The generated random samples

Raises

ValueError
: If a is an int and less than zero, if a or p are not 1-dimensional, if a is an array-like of size 0, if p is not a vector of probabilities, if a and p have different lengths, or if replace=False and the sample size is greater than the population size

See also:

randint, *shuffle*, *permutation*
random.Generator.choice
which should be used in new code

Notes

Setting user-specified probabilities through `p` uses a more general but less efficient sampler than the default. The general sampler produces a different sample than the optimized sampler even if each element of `p` is 1 / len(a).

Sampling random rows from a 2-D array is not possible with this function, but is possible with *Generator.choice* through its `axis` keyword.

Examples

Generate a uniform random sample from np.arange(5) of size 3:

```
>>> np.random.choice(5, 3)
array([0, 3, 4]) # random
>>> #This is equivalent to np.random.randint(0,5,3)
```

Generate a non-uniform random sample from np.arange(5) of size 3:

```
>>> np.random.choice(5, 3, p=[0.1, 0, 0.3, 0.6, 0])
array([3, 3, 0]) # random
```

Generate a uniform random sample from np.arange(5) of size 3 without replacement:

```
>>> np.random.choice(5, 3, replace=False)
array([3,1,0]) # random
>>> #This is equivalent to np.random.permutation(np.arange(5))[:3]
```

Generate a non-uniform random sample from np.arange(5) of size 3 without replacement:

```
>>> np.random.choice(5, 3, replace=False, p=[0.1, 0, 0.3, 0.6, 0])
array([2, 3, 0]) # random
```

Any of the above can be repeated with an arbitrary array-like instead of just integers. For instance:

```
>>> aa_milne_arr = ['pooh', 'rabbit', 'piglet', 'Christopher']
>>> np.random.choice(aa_milne_arr, 5, p=[0.5, 0.1, 0.1, 0.3])
array(['pooh', 'pooh', 'pooh', 'Christopher', 'piglet'], # random
      dtype='<U11')
```

method

`random.RandomState.bytes`(*length*)

Return random bytes.

Note: New code should use the *bytes* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

length
[int] Number of random bytes.

Returns

out
[bytes] String of length *length*.

See also:

random.Generator.bytes
which should be used for new code.

Examples

```
>>> np.random.bytes(10)
b' eh\x85\x022SZ\xbf\xa4' #random
```

Permutations

shuffle(x)	Modify a sequence in-place by shuffling its contents.
permutation(x)	Randomly permute a sequence, or return a permuted range.

method

random.RandomState.**shuffle**(*x*)

Modify a sequence in-place by shuffling its contents.

This function only shuffles the array along the first axis of a multi-dimensional array. The order of sub-arrays is changed but their contents remains the same.

Note: New code should use the *shuffle* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

x
[ndarray or MutableSequence] The array, list or mutable sequence to be shuffled.

Returns

None

See also:

random.Generator.shuffle
which should be used for new code.

Examples

```
>>> arr = np.arange(10)
>>> np.random.shuffle(arr)
>>> arr
[1 7 5 2 9 4 3 6 0 8] # random
```

Multi-dimensional arrays are only shuffled along the first axis:

```
>>> arr = np.arange(9).reshape((3, 3))
>>> np.random.shuffle(arr)
>>> arr
array([[3, 4, 5], # random
       [6, 7, 8],
       [0, 1, 2]])
```

method

`random.RandomState.`**`permutation`**`(x)`

Randomly permute a sequence, or return a permuted range.

If *x* is a multi-dimensional array, it is only shuffled along its first index.

Note: New code should use the *`permutation`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

x
: [int or array_like] If *x* is an integer, randomly permute `np.arange(x)`. If *x* is an array, make a copy and shuffle the elements randomly.

Returns

out
: [ndarray] Permuted sequence or array range.

See also:

`random.Generator.permutation`
: which should be used for new code.

Examples

```
>>> np.random.permutation(10)
array([1, 7, 4, 3, 0, 9, 2, 5, 8, 6]) # random
```

```
>>> np.random.permutation([1, 4, 9, 12, 15])
array([15,  1,  9,  4, 12]) # random
```

```
>>> arr = np.arange(9).reshape((3, 3))
>>> np.random.permutation(arr)
array([[6, 7, 8], # random
```

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```
       [0, 1, 2],
       [3, 4, 5]])
```

Distributions

beta(a, b[, size])	Draw samples from a Beta distribution.
binomial(n, p[, size])	Draw samples from a binomial distribution.
chisquare(df[, size])	Draw samples from a chi-square distribution.
dirichlet(alpha[, size])	Draw samples from the Dirichlet distribution.
exponential([scale, size])	Draw samples from an exponential distribution.
f(dfnum, dfden[, size])	Draw samples from an F distribution.
gamma(shape[, scale, size])	Draw samples from a Gamma distribution.
geometric(p[, size])	Draw samples from the geometric distribution.
gumbel([loc, scale, size])	Draw samples from a Gumbel distribution.
hypergeometric(ngood, nbad, nsample[, size])	Draw samples from a Hypergeometric distribution.
laplace([loc, scale, size])	Draw samples from the Laplace or double exponential distribution with specified location (or mean) and scale (decay).
logistic([loc, scale, size])	Draw samples from a logistic distribution.
lognormal([mean, sigma, size])	Draw samples from a log-normal distribution.
logseries(p[, size])	Draw samples from a logarithmic series distribution.
multinomial(n, pvals[, size])	Draw samples from a multinomial distribution.
multivariate_normal(mean, cov[, size, ...])	Draw random samples from a multivariate normal distribution.
negative_binomial(n, p[, size])	Draw samples from a negative binomial distribution.
noncentral_chisquare(df, nonc[, size])	Draw samples from a noncentral chi-square distribution.
noncentral_f(dfnum, dfden, nonc[, size])	Draw samples from the noncentral F distribution.
normal([loc, scale, size])	Draw random samples from a normal (Gaussian) distribution.
pareto(a[, size])	Draw samples from a Pareto II or Lomax distribution with specified shape.
poisson([lam, size])	Draw samples from a Poisson distribution.
power(a[, size])	Draws samples in [0, 1] from a power distribution with positive exponent a - 1.
rayleigh([scale, size])	Draw samples from a Rayleigh distribution.
standard_cauchy([size])	Draw samples from a standard Cauchy distribution with mode = 0.
standard_exponential([size])	Draw samples from the standard exponential distribution.
standard_gamma(shape[, size])	Draw samples from a standard Gamma distribution.
standard_normal([size])	Draw samples from a standard Normal distribution (mean=0, stdev=1).
standard_t(df[, size])	Draw samples from a standard Student's t distribution with *df* degrees of freedom.
triangular(left, mode, right[, size])	Draw samples from the triangular distribution over the interval `[left, right]`.
uniform([low, high, size])	Draw samples from a uniform distribution.
vonmises(mu, kappa[, size])	Draw samples from a von Mises distribution.
wald(mean, scale[, size])	Draw samples from a Wald, or inverse Gaussian, distribution.

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Table 2 – continued from previous page

weibull(a[, size])	Draw samples from a Weibull distribution.
zipf(a[, size])	Draw samples from a Zipf distribution.

method

random.RandomState.**beta**(*a*, *b*, *size=None*)

Draw samples from a Beta distribution.

The Beta distribution is a special case of the Dirichlet distribution, and is related to the Gamma distribution. It has the probability distribution function

$$f(x; a, b) = \frac{1}{B(\alpha, \beta)} x^{\alpha-1}(1-x)^{\beta-1},$$

where the normalization, B, is the beta function,

$$B(\alpha, \beta) = \int_0^1 t^{\alpha-1}(1-t)^{\beta-1} dt.$$

It is often seen in Bayesian inference and order statistics.

Note: New code should use the *beta* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

a
[float or array_like of floats] Alpha, positive (>0).

b
[float or array_like of floats] Beta, positive (>0).

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` and `b` are both scalars. Otherwise, `np.broadcast(a, b).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized beta distribution.

See also:

random.Generator.beta
which should be used for new code.

method

random.RandomState.**binomial**(*n*, *p*, *size=None*)

Draw samples from a binomial distribution.

Samples are drawn from a binomial distribution with specified parameters, n trials and p probability of success where n an integer >= 0 and p is in the interval [0,1]. (n may be input as a float, but it is truncated to an integer in use)

Note: New code should use the *binomial* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

n
[int or array_like of ints] Parameter of the distribution, >= 0. Floats are also accepted, but they will be truncated to integers.

p
[float or array_like of floats] Parameter of the distribution, >= 0 and <=1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `n` and `p` are both scalars. Otherwise, `np.broadcast(n, p).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized binomial distribution, where each sample is equal to the number of successes over the n trials.

See also:

scipy.stats.binom
probability density function, distribution or cumulative density function, etc.

random.Generator.binomial
which should be used for new code.

Notes

The probability mass function (PMF) for the binomial distribution is

$$P(N) = \binom{n}{N} p^N (1-p)^{n-N},$$

where n is the number of trials, p is the probability of success, and N is the number of successes.

When estimating the standard error of a proportion in a population by using a random sample, the normal distribution works well unless the product p*n <=5, where p = population proportion estimate, and n = number of samples, in which case the binomial distribution is used instead. For example, a sample of 15 people shows 4 who are left handed, and 11 who are right handed. Then p = 4/15 = 27%. 0.27*15 = 4, so the binomial distribution should be used in this case.

References

[1], [2], [3], [4], [5]

Examples

Draw samples from the distribution:

```
>>> n, p = 10, .5  # number of trials, probability of each trial
>>> s = np.random.binomial(n, p, 1000)
# result of flipping a coin 10 times, tested 1000 times.
```

A real world example. A company drills 9 wild-cat oil exploration wells, each with an estimated probability of success of 0.1. All nine wells fail. What is the probability of that happening?

Let's do 20,000 trials of the model, and count the number that generate zero positive results.

```
>>> sum(np.random.binomial(9, 0.1, 20000) == 0)/20000.
# answer = 0.38885, or 38%.
```

method

`random.RandomState.`**`chisquare`**(*df*, *size=None*)

Draw samples from a chi-square distribution.

When *df* independent random variables, each with standard normal distributions (mean 0, variance 1), are squared and summed, the resulting distribution is chi-square (see Notes). This distribution is often used in hypothesis testing.

Note: New code should use the *`chisquare`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

df
: [float or array_like of floats] Number of degrees of freedom, must be > 0.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `df` is a scalar. Otherwise, `np.array(df).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized chi-square distribution.

Raises

ValueError
: When *df* <= 0 or when an inappropriate *`size`* (e.g. `size=-1`) is given.

See also:

`random.Generator.chisquare`
: which should be used for new code.

Notes

The variable obtained by summing the squares of *df* independent, standard normally distributed random variables:

$$Q = \sum_{i=1}^{\mathtt{df}} X_i^2$$

is chi-square distributed, denoted

$$Q \sim \chi_k^2.$$

The probability density function of the chi-squared distribution is

$$p(x) = \frac{(1/2)^{k/2}}{\Gamma(k/2)} x^{k/2-1} e^{-x/2},$$

where Γ is the gamma function,

$$\Gamma(x) = \int_0^{-\infty} t^{x-1} e^{-t} dt.$$

References

[1]

Examples

```
>>> np.random.chisquare(2,4)
array([ 1.89920014,  9.00867716,  3.13710533,  5.62318272]) # random
```

method

`random.RandomState.`**`dirichlet`**(*alpha*, *size=None*)

Draw samples from the Dirichlet distribution.

Draw *size* samples of dimension k from a Dirichlet distribution. A Dirichlet-distributed random variable can be seen as a multivariate generalization of a Beta distribution. The Dirichlet distribution is a conjugate prior of a multinomial distribution in Bayesian inference.

Note: New code should use the *dirichlet* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

alpha
[sequence of floats, length k] Parameter of the distribution (length `k` for sample of length `k`).

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n)`, then `m * n * k` samples are drawn. Default is None, in which case a vector of length `k` is returned.

Returns

samples
[ndarray,] The drawn samples, of shape `(size, k)`.

Raises

ValueError
If any value in `alpha` is less than or equal to zero

See also:

random.Generator.dirichlet
which should be used for new code.

Notes

The Dirichlet distribution is a distribution over vectors x that fulfil the conditions $x_i > 0$ and $\sum_{i=1}^{k} x_i = 1$.

The probability density function p of a Dirichlet-distributed random vector X is proportional to

$$p(x) \propto \prod_{i=1}^{k} x_i^{\alpha_i - 1},$$

where α is a vector containing the positive concentration parameters.

The method uses the following property for computation: let Y be a random vector which has components that follow a standard gamma distribution, then $X = \frac{1}{\sum_{i=1}^{k} Y_i} Y$ is Dirichlet-distributed

References

[1], [2]

Examples

Taking an example cited in Wikipedia, this distribution can be used if one wanted to cut strings (each of initial length 1.0) into K pieces with different lengths, where each piece had, on average, a designated average length, but allowing some variation in the relative sizes of the pieces.

```
>>> s = np.random.dirichlet((10, 5, 3), 20).transpose()
```

```
>>> import matplotlib.pyplot as plt
>>> plt.barh(range(20), s[0])
>>> plt.barh(range(20), s[1], left=s[0], color='g')
>>> plt.barh(range(20), s[2], left=s[0]+s[1], color='r')
>>> plt.title("Lengths of Strings")
```

method

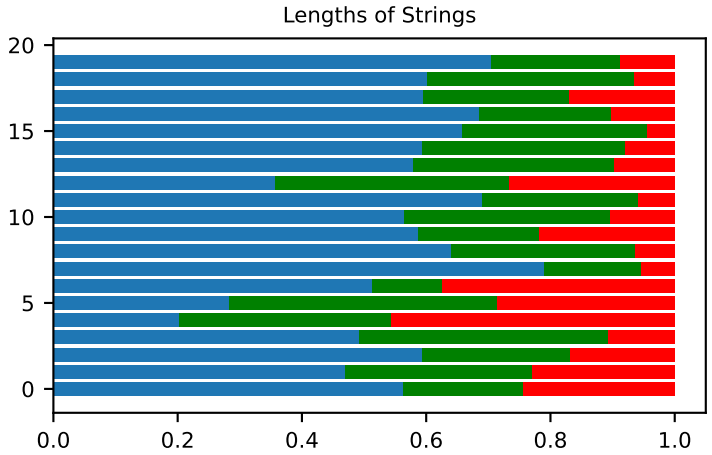
`random.RandomState.`**`exponential`**(*scale=1.0*, *size=None*)

Draw samples from an exponential distribution.

Its probability density function is

$$f(x; \frac{1}{\beta}) = \frac{1}{\beta} \exp(-\frac{x}{\beta}),$$

for `x > 0` and 0 elsewhere. β is the scale parameter, which is the inverse of the rate parameter $\lambda = 1/\beta$. The rate parameter is an alternative, widely used parameterization of the exponential distribution [3].



The exponential distribution is a continuous analogue of the geometric distribution. It describes many common situations, such as the size of raindrops measured over many rainstorms [1], or the time between page requests to Wikipedia [2].

Note: New code should use the `exponential` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

scale
[float or array_like of floats] The scale parameter, $\beta = 1/\lambda$. Must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `scale` is a scalar. Otherwise, `np.array(scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized exponential distribution.

See also:

random.Generator.exponential
which should be used for new code.

References

[1], [2], [3]

Examples

A real world example: Assume a company has 10000 customer support agents and the average time between customer calls is 4 minutes.

```
>>> n = 10000
>>> time_between_calls = np.random.default_rng().exponential(scale=4, size=n)
```

What is the probability that a customer will call in the next 4 to 5 minutes?

```
>>> x = ((time_between_calls < 5).sum())/n
>>> y = ((time_between_calls < 4).sum())/n
>>> x-y
0.08 # may vary
```

method

`random.RandomState.f`(*dfnum*, *dfden*, *size=None*)

Draw samples from an F distribution.

Samples are drawn from an F distribution with specified parameters, *dfnum* (degrees of freedom in numerator) and *dfden* (degrees of freedom in denominator), where both parameters must be greater than zero.

The random variate of the F distribution (also known as the Fisher distribution) is a continuous probability distribution that arises in ANOVA tests, and is the ratio of two chi-square variates.

Note: New code should use the `f` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

dfnum
[float or array_like of floats] Degrees of freedom in numerator, must be > 0.

dfden
[float or array_like of float] Degrees of freedom in denominator, must be > 0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `dfnum` and `dfden` are both scalars. Otherwise, `np.broadcast(dfnum, dfden).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Fisher distribution.

See also:

`scipy.stats.f`
probability density function, distribution or cumulative density function, etc.

random.Generator.f
which should be used for new code.

Notes

The F statistic is used to compare in-group variances to between-group variances. Calculating the distribution depends on the sampling, and so it is a function of the respective degrees of freedom in the problem. The variable *dfnum* is the number of samples minus one, the between-groups degrees of freedom, while *dfden* is the within-groups degrees of freedom, the sum of the number of samples in each group minus the number of groups.

References

[1], [2]

Examples

An example from Glantz[1], pp 47-40:

Two groups, children of diabetics (25 people) and children from people without diabetes (25 controls). Fasting blood glucose was measured, case group had a mean value of 86.1, controls had a mean value of 82.2. Standard deviations were 2.09 and 2.49 respectively. Are these data consistent with the null hypothesis that the parents diabetic status does not affect their children's blood glucose levels? Calculating the F statistic from the data gives a value of 36.01.

Draw samples from the distribution:

```
>>> dfnum = 1. # between group degrees of freedom
>>> dfden = 48. # within groups degrees of freedom
>>> s = np.random.f(dfnum, dfden, 1000)
```

The lower bound for the top 1% of the samples is :

```
>>> np.sort(s)[-10]
7.61988120985 # random
```

So there is about a 1% chance that the F statistic will exceed 7.62, the measured value is 36, so the null hypothesis is rejected at the 1% level.

method

`random.RandomState.`**`gamma`**(*shape*, *scale=1.0*, *size=None*)

Draw samples from a Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, *shape* (sometimes designated "k") and *scale* (sometimes designated "theta"), where both parameters are > 0.

Note: New code should use the *gamma* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

shape
[float or array_like of floats] The shape of the gamma distribution. Must be non-negative.

scale
: [float or array_like of floats, optional] The scale of the gamma distribution. Must be non-negative. Default is equal to 1.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `shape` and `scale` are both scalars. Otherwise, `np.broadcast(shape, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized gamma distribution.

See also:

`scipy.stats.gamma`
: probability density function, distribution or cumulative density function, etc.

`random.Generator.gamma`
: which should be used for new code.

Notes

The probability density for the Gamma distribution is

$$p(x) = x^{k-1}\frac{e^{-x/\theta}}{\theta^k\Gamma(k)},$$

where k is the shape and θ the scale, and Γ is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.

References

[1], [2]

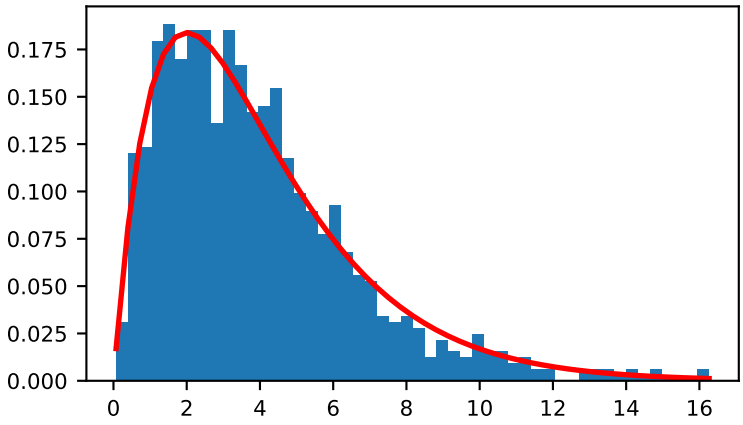
Examples

Draw samples from the distribution:

```
>>> shape, scale = 2., 2.  # mean=4, std=2*sqrt(2)
>>> s = np.random.gamma(shape, scale, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, ignored = plt.hist(s, 50, density=True)
>>> y = bins**(shape-1)*(np.exp(-bins/scale) /
...                      (sps.gamma(shape)*scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```



method

`random.RandomState.`**`geometric`**(*p*, *size=None*)

Draw samples from the geometric distribution.

Bernoulli trials are experiments with one of two outcomes: success or failure (an example of such an experiment is flipping a coin). The geometric distribution models the number of trials that must be run in order to achieve success. It is therefore supported on the positive integers, `k = 1, 2, ...`.

The probability mass function of the geometric distribution is

$$f(k) = (1-p)^{k-1}p$$

where *p* is the probability of success of an individual trial.

Note: New code should use the *`geometric`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

p
[float or array_like of floats] The probability of success of an individual trial.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `p` is a scalar. Otherwise, `np.array(p).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized geometric distribution.

See also:

`random.Generator.geometric`
which should be used for new code.

Examples

Draw ten thousand values from the geometric distribution, with the probability of an individual success equal to 0.35:

```
>>> z = np.random.geometric(p=0.35, size=10000)
```

How many trials succeeded after a single run?

```
>>> (z == 1).sum() / 10000.
0.34889999999999999 #random
```

method

`random.RandomState.`**`gumbel`**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw samples from a Gumbel distribution.

Draw samples from a Gumbel distribution with specified location and scale. For more information on the Gumbel distribution, see Notes and References below.

Note: New code should use the *`gumbel`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

loc
: [float or array_like of floats, optional] The location of the mode of the distribution. Default is 0.

scale
: [float or array_like of floats, optional] The scale parameter of the distribution. Default is 1. Must be non- negative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Gumbel distribution.

See also:

`scipy.stats.gumbel_l`
`scipy.stats.gumbel_r`
`scipy.stats.genextreme`
`weibull`
`random.Generator.gumbel`
: which should be used for new code.

Notes

The Gumbel (or Smallest Extreme Value (SEV) or the Smallest Extreme Value Type I) distribution is one of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems. The Gumbel is a special case of the Extreme Value Type I distribution for maximums from distributions with "exponential-like" tails.

The probability density for the Gumbel distribution is

$$p(x) = \frac{e^{-(x-\mu)/\beta}}{\beta} e^{-e^{-(x-\mu)/\beta}},$$

where μ is the mode, a location parameter, and β is the scale parameter.

The Gumbel (named for German mathematician Emil Julius Gumbel) was used very early in the hydrology literature, for modeling the occurrence of flood events. It is also used for modeling maximum wind speed and rainfall rates. It is a "fat-tailed" distribution - the probability of an event in the tail of the distribution is larger than if one used a Gaussian, hence the surprisingly frequent occurrence of 100-year floods. Floods were initially modeled as a Gaussian process, which underestimated the frequency of extreme events.

It is one of a class of extreme value distributions, the Generalized Extreme Value (GEV) distributions, which also includes the Weibull and Frechet.

The function has a mean of $\mu + 0.57721\beta$ and a variance of $\frac{\pi^2}{6}\beta^2$.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> mu, beta = 0, 0.1 # location and scale
>>> s = np.random.gumbel(mu, beta, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, density=True)
>>> plt.plot(bins, (1/beta)*np.exp(-(bins - mu)/beta)
...          * np.exp( -np.exp( -(bins - mu) /beta) ),
...          linewidth=2, color='r')
>>> plt.show()
```

Show how an extreme value distribution can arise from a Gaussian process and compare to a Gaussian:

```
>>> means = []
>>> maxima = []
>>> for i in range(0,1000) :
...    a = np.random.normal(mu, beta, 1000)
...    means.append(a.mean())
...    maxima.append(a.max())
>>> count, bins, ignored = plt.hist(maxima, 30, density=True)
>>> beta = np.std(maxima) * np.sqrt(6) / np.pi
>>> mu = np.mean(maxima) - 0.57721*beta
```

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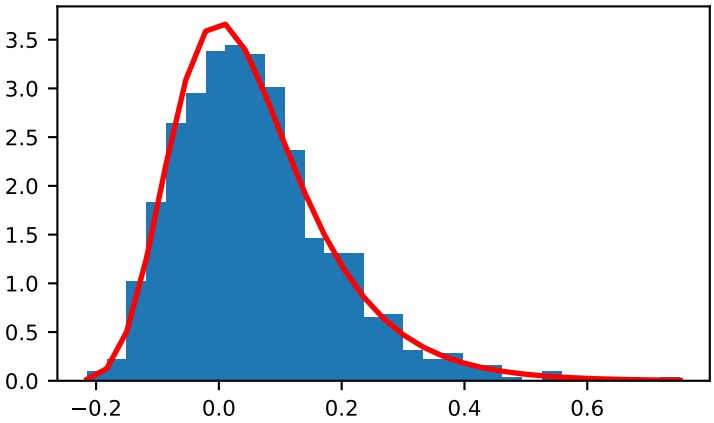

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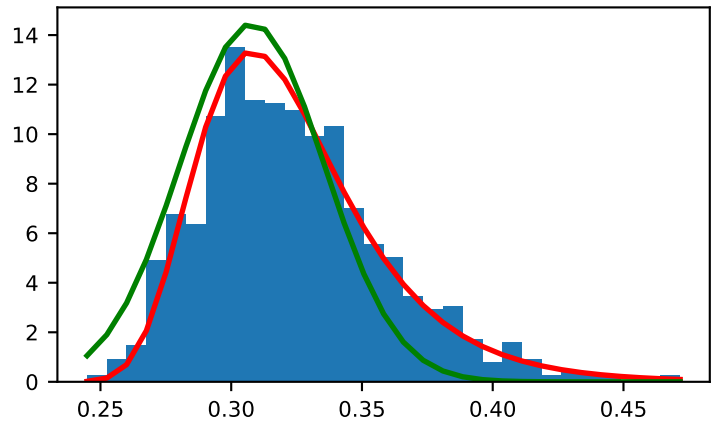
```
>>> plt.plot(bins, (1/beta)*np.exp(-(bins - mu)/beta)
...          * np.exp(-np.exp(-(bins - mu)/beta)),
...          linewidth=2, color='r')
>>> plt.plot(bins, 1/(beta * np.sqrt(2 * np.pi))
...          * np.exp(-(bins - mu)**2 / (2 * beta**2)),
...          linewidth=2, color='g')
>>> plt.show()
```



method

`random.RandomState.`**`hypergeometric`**(*ngood*, *nbad*, *nsample*, *size=None*)

Draw samples from a Hypergeometric distribution.

Samples are drawn from a hypergeometric distribution with specified parameters, *ngood* (ways to make a good selection), *nbad* (ways to make a bad selection), and *nsample* (number of items sampled, which is less than or equal

to the sum `ngood + nbad`).

Note: New code should use the *`hypergeometric`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

ngood
[int or array_like of ints] Number of ways to make a good selection. Must be nonnegative.

nbad
[int or array_like of ints] Number of ways to make a bad selection. Must be nonnegative.

nsample
[int or array_like of ints] Number of items sampled. Must be at least 1 and at most `ngood + nbad`.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if *ngood*, *nbad*, and *nsample* are all scalars. Otherwise, `np.broadcast(ngood, nbad, nsample).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized hypergeometric distribution. Each sample is the number of good items within a randomly selected subset of size *nsample* taken from a set of *ngood* good items and *nbad* bad items.

See also:

`scipy.stats.hypergeom`
probability density function, distribution or cumulative density function, etc.

`random.Generator.hypergeometric`
which should be used for new code.

Notes

The probability mass function (PMF) for the Hypergeometric distribution is

$$P(x) = \frac{\binom{g}{x}\binom{b}{n-x}}{\binom{g+b}{n}},$$

where $0 \leq x \leq n$ and $n - b \leq x \leq g$

for P(x) the probability of `x` good results in the drawn sample, g = *ngood*, b = *nbad*, and n = *nsample*.

Consider an urn with black and white marbles in it, *ngood* of them are black and *nbad* are white. If you draw *nsample* balls without replacement, then the hypergeometric distribution describes the distribution of black balls in the drawn sample.

Note that this distribution is very similar to the binomial distribution, except that in this case, samples are drawn without replacement, whereas in the Binomial case samples are drawn with replacement (or the sample space is infinite). As the sample space becomes large, this distribution approaches the binomial.

References

[1], [2], [3]

Examples

Draw samples from the distribution:

```
>>> ngood, nbad, nsamp = 100, 2, 10
# number of good, number of bad, and number of samples
>>> s = np.random.hypergeometric(ngood, nbad, nsamp, 1000)
>>> from matplotlib.pyplot import hist
>>> hist(s)
#   note that it is very unlikely to grab both bad items
```

Suppose you have an urn with 15 white and 15 black marbles. If you pull 15 marbles at random, how likely is it that 12 or more of them are one color?

```
>>> s = np.random.hypergeometric(15, 15, 15, 100000)
>>> sum(s>=12)/100000. + sum(s<=3)/100000.
#   answer = 0.003 ... pretty unlikely!
```

method

`random.RandomState.`**`laplace`**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw samples from the Laplace or double exponential distribution with specified location (or mean) and scale (decay).

The Laplace distribution is similar to the Gaussian/normal distribution, but is sharper at the peak and has fatter tails. It represents the difference between two independent, identically distributed exponential random variables.

Note: New code should use the *`laplace`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

loc
: [float or array_like of floats, optional] The position, μ, of the distribution peak. Default is 0.

scale
: [float or array_like of floats, optional] λ, the exponential decay. Default is 1. Must be non-negative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Laplace distribution.

See also:

random.Generator.laplace
which should be used for new code.

Notes

It has the probability density function

$$f(x; \mu, \lambda) = \frac{1}{2\lambda} \exp\left(-\frac{|x - \mu|}{\lambda}\right).$$

The first law of Laplace, from 1774, states that the frequency of an error can be expressed as an exponential function of the absolute magnitude of the error, which leads to the Laplace distribution. For many problems in economics and health sciences, this distribution seems to model the data better than the standard Gaussian distribution.

References

[1], [2], [3], [4]

Examples

Draw samples from the distribution

```
>>> loc, scale = 0., 1.
>>> s = np.random.laplace(loc, scale, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, density=True)
>>> x = np.arange(-8., 8., .01)
>>> pdf = np.exp(-abs(x-loc)/scale)/(2.*scale)
>>> plt.plot(x, pdf)
```

Plot Gaussian for comparison:

```
>>> g = (1/(scale * np.sqrt(2 * np.pi)) *
...      np.exp(-(x - loc)**2 / (2 * scale**2)))
>>> plt.plot(x,g)
```

method

`random.RandomState.`**`logistic`**(*loc=0.0*, *scale=1.0*, *size=None*)

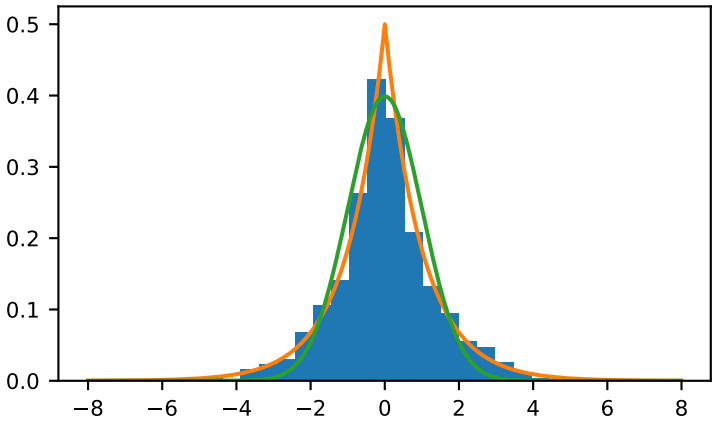
Draw samples from a logistic distribution.

Samples are drawn from a logistic distribution with specified parameters, loc (location or mean, also median), and scale (>0).

Note: New code should use the *logistic* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

loc
[float or array_like of floats, optional] Parameter of the distribution. Default is 0.



scale
: [float or array_like of floats, optional] Parameter of the distribution. Must be non-negative. Default is 1.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized logistic distribution.

See also:

`scipy.stats.logistic`
: probability density function, distribution or cumulative density function, etc.

`random.Generator.logistic`
: which should be used for new code.

Notes

The probability density for the Logistic distribution is

$$P(x) = P(x) = \frac{e^{-(x-\mu)/s}}{s(1+e^{-(x-\mu)/s})^2},$$

where μ = location and s = scale.

The Logistic distribution is used in Extreme Value problems where it can act as a mixture of Gumbel distributions, in Epidemiology, and by the World Chess Federation (FIDE) where it is used in the Elo ranking system, assuming the performance of each player is a logistically distributed random variable.

References

[1], [2], [3]

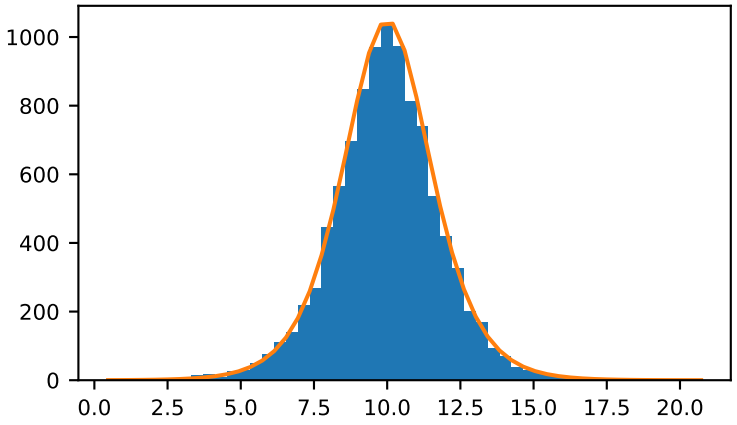
Examples

Draw samples from the distribution:

```
>>> loc, scale = 10, 1
>>> s = np.random.logistic(loc, scale, 10000)
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, bins=50)
```

plot against distribution

```
>>> def logist(x, loc, scale):
...     return np.exp((loc-x)/scale)/(scale*(1+np.exp((loc-x)/scale))**2)
>>> lgst_val = logist(bins, loc, scale)
>>> plt.plot(bins, lgst_val * count.max() / lgst_val.max())
>>> plt.show()
```



method

`random.RandomState.`**`lognormal`**(*mean=0.0*, *sigma=1.0*, *size=None*)

Draw samples from a log-normal distribution.

Draw samples from a log-normal distribution with specified mean, standard deviation, and array shape. Note that the mean and standard deviation are not the values for the distribution itself, but of the underlying normal distribution it is derived from.

Note: New code should use the *`lognormal`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

mean
: [float or array_like of floats, optional] Mean value of the underlying normal distribution. Default is 0.

sigma
: [float or array_like of floats, optional] Standard deviation of the underlying normal distribution. Must be non-negative. Default is 1.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `mean` and `sigma` are both scalars. Otherwise, `np.broadcast(mean, sigma).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized log-normal distribution.

See also:

`scipy.stats.lognorm`
: probability density function, distribution, cumulative density function, etc.

`random.Generator.lognormal`
: which should be used for new code.

Notes

A variable *x* has a log-normal distribution if *log(x)* is normally distributed. The probability density function for the log-normal distribution is:

$$p(x) = \frac{1}{\sigma x\sqrt{2\pi}} e^{(-\frac{(ln(x)-\mu)^2}{2\sigma^2})}$$

where μ is the mean and σ is the standard deviation of the normally distributed logarithm of the variable. A log-normal distribution results if a random variable is the *product* of a large number of independent, identically-distributed variables in the same way that a normal distribution results if the variable is the *sum* of a large number of independent, identically-distributed variables.

References

[1], [2]

Examples

Draw samples from the distribution:

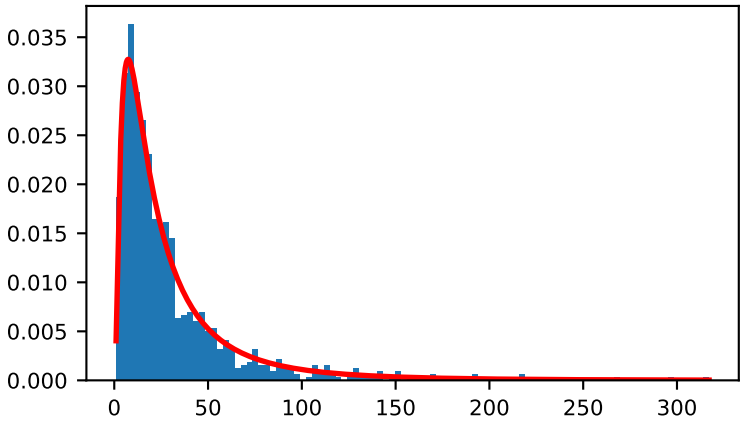
```
>>> mu, sigma = 3., 1. # mean and standard deviation
>>> s = np.random.lognormal(mu, sigma, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 100, density=True, align='mid')
```

```
>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
...        / (x * sigma * np.sqrt(2 * np.pi)))
```

```
>>> plt.plot(x, pdf, linewidth=2, color='r')
>>> plt.axis('tight')
>>> plt.show()
```



Demonstrate that taking the products of random samples from a uniform distribution can be fit well by a log-normal probability density function.

```
>>> # Generate a thousand samples: each is the product of 100 random
>>> # values, drawn from a normal distribution.
>>> b = []
>>> for i in range(1000):
...     a = 10. + np.random.standard_normal(100)
...     b.append(np.prod(a))
```

```
>>> b = np.array(b) / np.min(b) # scale values to be positive
>>> count, bins, ignored = plt.hist(b, 100, density=True, align='mid')
>>> sigma = np.std(np.log(b))
>>> mu = np.mean(np.log(b))
```

```
>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
...        / (x * sigma * np.sqrt(2 * np.pi)))
```

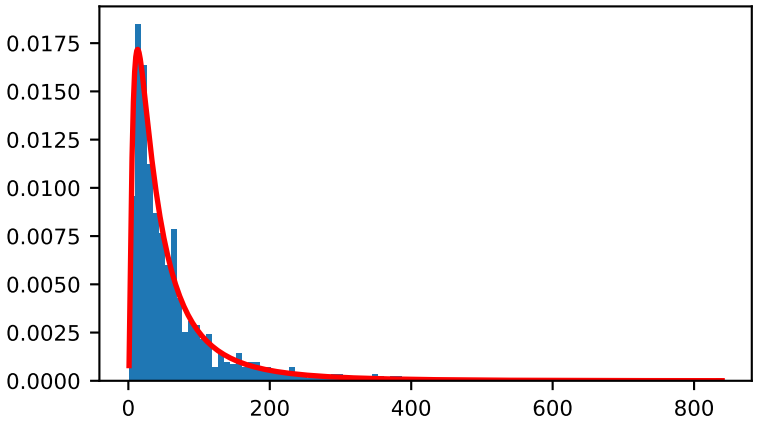
```
>>> plt.plot(x, pdf, color='r', linewidth=2)
>>> plt.show()
```

method

`random.RandomState.`**`logseries`**(*p*, *size=None*)

Draw samples from a logarithmic series distribution.

Samples are drawn from a log series distribution with specified shape parameter, 0 <= p < 1.



Note: New code should use the `logseries` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

p
[float or array_like of floats] Shape parameter for the distribution. Must be in the range [0, 1).

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `p` is a scalar. Otherwise, `np.array(p).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized logarithmic series distribution.

See also:

`scipy.stats.logser`
probability density function, distribution or cumulative density function, etc.

`random.Generator.logseries`
which should be used for new code.

Notes

The probability density for the Log Series distribution is

$$P(k) = \frac{-p^k}{k \ln(1-p)},$$

where p = probability.

The log series distribution is frequently used to represent species richness and occurrence, first proposed by Fisher, Corbet, and Williams in 1943 [2]. It may also be used to model the numbers of occupants seen in cars [3].

References

[1], [2], [3], [4]

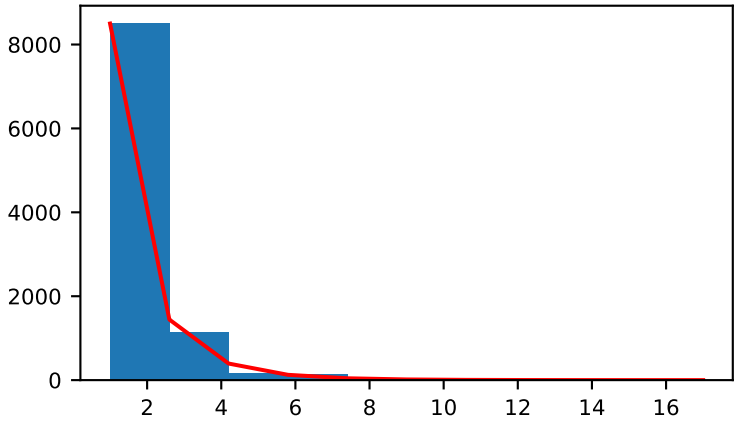
Examples

Draw samples from the distribution:

```
>>> a = .6
>>> s = np.random.logseries(a, 10000)
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s)
```

plot against distribution

```
>>> def logseries(k, p):
...     return -p**k/(k*np.log(1-p))
>>> plt.plot(bins, logseries(bins, a)*count.max()/
...          logseries(bins, a).max(), 'r')
>>> plt.show()
```



method

random.RandomState.**multinomial**(*n*, *pvals*, *size=None*)

Draw samples from a multinomial distribution.

The multinomial distribution is a multivariate generalization of the binomial distribution. Take an experiment with one of `p` possible outcomes. An example of such an experiment is throwing a dice, where the outcome can be 1 through 6. Each sample drawn from the distribution represents *n* such experiments. Its values, `X_i = [X_0, X_1, ..., X_p]`, represent the number of times the outcome was `i`.

Note: New code should use the *multinomial* method of a *Generator* instance instead; please see the *Quick start*.

Warning: This function defaults to the C-long dtype, which is 32bit on windows and otherwise 64bit on 64bit platforms (and 32bit on 32bit ones). Since NumPy 2.0, NumPy's default integer is 32bit on 32bit platforms and 64bit on 64bit platforms.

Parameters

n
: [int] Number of experiments.

pvals
: [sequence of floats, length p] Probabilities of each of the `p` different outcomes. These must sum to 1 (however, the last element is always assumed to account for the remaining probability, as long as `sum(pvals[:-1]) <= 1)`.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

out
: [ndarray] The drawn samples, of shape *size*, if that was provided. If not, the shape is `(N,)`.

  In other words, each entry `out[i,j,...,:]` is an N-dimensional value drawn from the distribution.

See also:

random.Generator.multinomial
: which should be used for new code.

Examples

Throw a dice 20 times:

```
>>> np.random.multinomial(20, [1/6.]*6, size=1)
array([[4, 1, 7, 5, 2, 1]]) # random
```

It landed 4 times on 1, once on 2, etc.

Now, throw the dice 20 times, and 20 times again:

```
>>> np.random.multinomial(20, [1/6.]*6, size=2)
array([[3, 4, 3, 3, 4, 3], # random
       [2, 4, 3, 4, 0, 7]])
```

For the first run, we threw 3 times 1, 4 times 2, etc. For the second, we threw 2 times 1, 4 times 2, etc.

A loaded die is more likely to land on number 6:

```
>>> np.random.multinomial(100, [1/7.]*5 + [2/7.])
array([11, 16, 14, 17, 16, 26]) # random
```

The probability inputs should be normalized. As an implementation detail, the value of the last entry is ignored and assumed to take up any leftover probability mass, but this should not be relied on. A biased coin which has twice as much weight on one side as on the other should be sampled like so:

```
>>> np.random.multinomial(100, [1.0 / 3, 2.0 / 3])  # RIGHT
array([38, 62]) # random
```

not like:

```
>>> np.random.multinomial(100, [1.0, 2.0])  # WRONG
Traceback (most recent call last):
ValueError: pvals < 0, pvals > 1 or pvals contains NaNs
```

method

`random.RandomState.`**`multivariate_normal`**(*mean*, *cov*, *size=None*, *check_valid='warn'*, *tol=1e-8*)

Draw random samples from a multivariate normal distribution.

The multivariate normal, multinormal or Gaussian distribution is a generalization of the one-dimensional normal distribution to higher dimensions. Such a distribution is specified by its mean and covariance matrix. These parameters are analogous to the mean (average or "center") and variance (standard deviation, or "width," squared) of the one-dimensional normal distribution.

Note: New code should use the *`multivariate_normal`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

mean
[1-D array_like, of length N] Mean of the N-dimensional distribution.

cov
[2-D array_like, of shape (N, N)] Covariance matrix of the distribution. It must be symmetric and positive-semidefinite for proper sampling.

size
[int or tuple of ints, optional] Given a shape of, for example, `(m,n,k)`, `m*n*k` samples are generated, and packed in an *m*-by-*n*-by-*k* arrangement. Because each sample is *N*-dimensional, the output shape is `(m,n,k,N)`. If no shape is specified, a single (*N*-D) sample is returned.

check_valid
[{ 'warn', 'raise', 'ignore' }, optional] Behavior when the covariance matrix is not positive semidefinite.

tol

[float, optional] Tolerance when checking the singular values in covariance matrix. cov is cast to double before the check.

Returns

out

[ndarray] The drawn samples, of shape *size*, if that was provided. If not, the shape is `(N,)`.

In other words, each entry `out[i,j,...,:]` is an N-dimensional value drawn from the distribution.

See also:

random.Generator.multivariate_normal
which should be used for new code.

Notes

The mean is a coordinate in N-dimensional space, which represents the location where samples are most likely to be generated. This is analogous to the peak of the bell curve for the one-dimensional or univariate normal distribution.

Covariance indicates the level to which two variables vary together. From the multivariate normal distribution, we draw N-dimensional samples, $X = [x_1, x_2, ...x_N]$. The covariance matrix element C_{ij} is the covariance of x_i and x_j. The element C_{ii} is the variance of x_i (i.e. its "spread").

Instead of specifying the full covariance matrix, popular approximations include:

- Spherical covariance (*cov* is a multiple of the identity matrix)
- Diagonal covariance (*cov* has non-negative elements, and only on the diagonal)

This geometrical property can be seen in two dimensions by plotting generated data-points:

```
>>> mean = [0, 0]
>>> cov = [[1, 0], [0, 100]]  # diagonal covariance
```

Diagonal covariance means that points are oriented along x or y-axis:

```
>>> import matplotlib.pyplot as plt
>>> x, y = np.random.multivariate_normal(mean, cov, 5000).T
>>> plt.plot(x, y, 'x')
>>> plt.axis('equal')
>>> plt.show()
```

Note that the covariance matrix must be positive semidefinite (a.k.a. nonnegative-definite). Otherwise, the behavior of this method is undefined and backwards compatibility is not guaranteed.

References

[1], [2]

Examples

```
>>> mean = (1, 2)
>>> cov = [[1, 0], [0, 1]]
>>> x = np.random.multivariate_normal(mean, cov, (3, 3))
>>> x.shape
(3, 3, 2)
```

Here we generate 800 samples from the bivariate normal distribution with mean [0, 0] and covariance matrix [[6, -3], [-3, 3.5]]. The expected variances of the first and second components of the sample are 6 and 3.5, respectively, and the expected correlation coefficient is -3/sqrt(6*3.5) ≈ -0.65465.

```
>>> cov = np.array([[6, -3], [-3, 3.5]])
>>> pts = np.random.multivariate_normal([0, 0], cov, size=800)
```

Check that the mean, covariance, and correlation coefficient of the sample are close to the expected values:

```
>>> pts.mean(axis=0)
array([ 0.0326911 , -0.01280782])  # may vary
>>> np.cov(pts.T)
array([[ 5.96202397, -2.85602287],
       [-2.85602287,  3.47613949]])  # may vary
>>> np.corrcoef(pts.T)[0, 1]
-0.6273591314603949  # may vary
```

We can visualize this data with a scatter plot. The orientation of the point cloud illustrates the negative correlation of the components of this sample.

```
>>> import matplotlib.pyplot as plt
>>> plt.plot(pts[:, 0], pts[:, 1], '.', alpha=0.5)
>>> plt.axis('equal')
>>> plt.grid()
>>> plt.show()
```

method

`random.RandomState.`**`negative_binomial`**(*n*, *p*, *size=None*)

Draw samples from a negative binomial distribution.

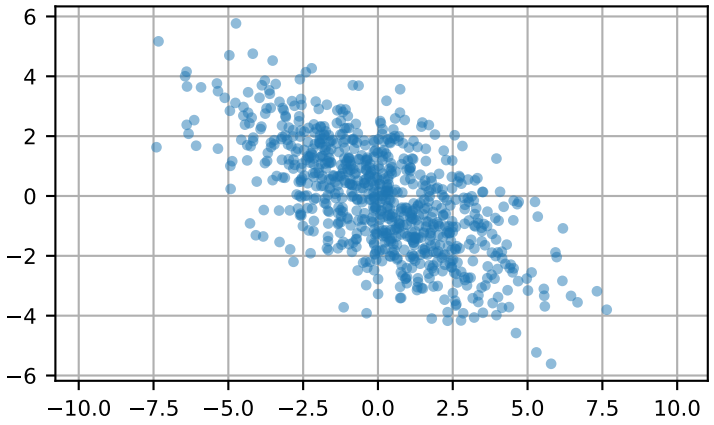
Samples are drawn from a negative binomial distribution with specified parameters, *n* successes and *p* probability of success where *n* is > 0 and *p* is in the interval [0, 1].

Note: New code should use the *`negative_binomial`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

n

[float or array_like of floats] Parameter of the distribution, > 0.



p
: [float or array_like of floats] Parameter of the distribution, >= 0 and <=1.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `n` and `p` are both scalars. Otherwise, `np.broadcast(n, p).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized negative binomial distribution, where each sample is equal to N, the number of failures that occurred before a total of n successes was reached.

> **Warning:** This function returns the C-long dtype, which is 32bit on windows and otherwise 64bit on 64bit platforms (and 32bit on 32bit ones). Since NumPy 2.0, NumPy's default integer is 32bit on 32bit platforms and 64bit on 64bit platforms.

See also:

`random.Generator.negative_binomial`
: which should be used for new code.

Notes

The probability mass function of the negative binomial distribution is

$$P(N;n,p) = \frac{\Gamma(N+n)}{N!\Gamma(n)}p^n(1-p)^N,$$

where n is the number of successes, p is the probability of success, $N+n$ is the number of trials, and Γ is the gamma function. When n is an integer, $\frac{\Gamma(N+n)}{N!\Gamma(n)} = \binom{N+n-1}{N}$, which is the more common form of this term in the pmf. The negative binomial distribution gives the probability of N failures given n successes, with a success on the last trial.

If one throws a die repeatedly until the third time a "1" appears, then the probability distribution of the number of non-"1"s that appear before the third "1" is a negative binomial distribution.

References

[1], [2]

Examples

Draw samples from the distribution:

A real world example. A company drills wild-cat oil exploration wells, each with an estimated probability of success of 0.1. What is the probability of having one success for each successive well, that is what is the probability of a single success after drilling 5 wells, after 6 wells, etc.?

```
>>> s = np.random.negative_binomial(1, 0.1, 100000)
>>> for i in range(1, 11):
...    probability = sum(s<i) / 100000.
...    print(i, "wells drilled, probability of one success =", probability)
```

method

`random.RandomState.`**`noncentral_chisquare`**(*df*, *nonc*, *size=None*)

Draw samples from a noncentral chi-square distribution.

The noncentral χ^2 distribution is a generalization of the χ^2 distribution.

Note: New code should use the *`noncentral_chisquare`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

df
: [float or array_like of floats] Degrees of freedom, must be > 0.

nonc
: [float or array_like of floats] Non-centrality, must be non-negative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `df` and `nonc` are both scalars. Otherwise, `np.broadcast(df, nonc).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized noncentral chi-square distribution.

See also:

random.Generator.noncentral_chisquare
which should be used for new code.

Notes

The probability density function for the noncentral Chi-square distribution is

$$P(x;df,nonc) = \sum_{i=0}^{\infty} \frac{e^{-nonc/2}(nonc/2)^i}{i!} P_{Y_{df+2i}}(x),$$

where Y_q is the Chi-square with q degrees of freedom.

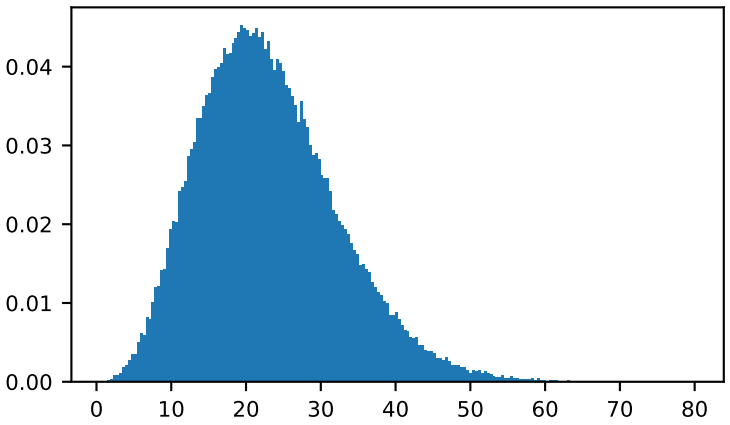
References

[1]

Examples

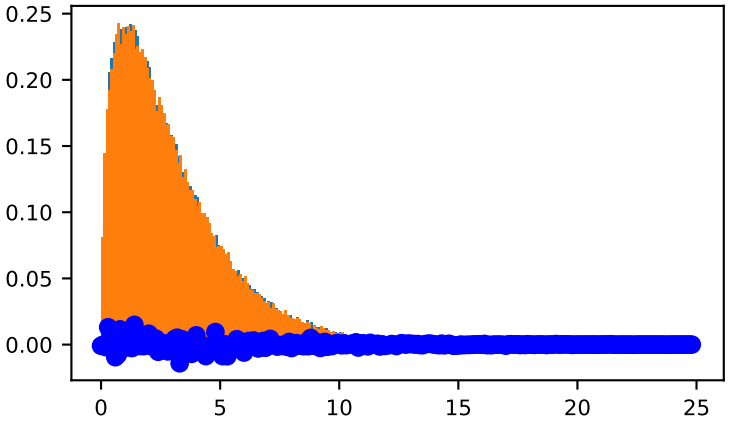
Draw values from the distribution and plot the histogram

```
>>> import matplotlib.pyplot as plt
>>> values = plt.hist(np.random.noncentral_chisquare(3, 20, 100000),
...                   bins=200, density=True)
>>> plt.show()
```



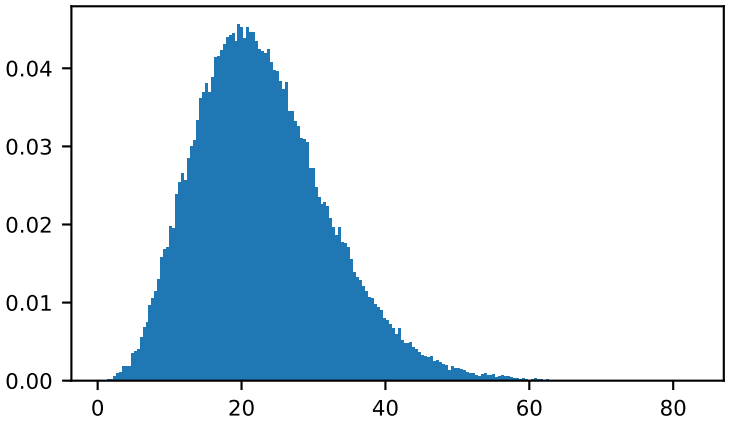
Draw values from a noncentral chisquare with very small noncentrality, and compare to a chisquare.

```
>>> plt.figure()
>>> values = plt.hist(np.random.noncentral_chisquare(3, .0000001, 100000),
...                   bins=np.arange(0., 25, .1), density=True)
>>> values2 = plt.hist(np.random.chisquare(3, 100000),
...                    bins=np.arange(0., 25, .1), density=True)
>>> plt.plot(values[1][0:-1], values[0]-values2[0], 'ob')
>>> plt.show()
```



Demonstrate how large values of non-centrality lead to a more symmetric distribution.

```
>>> plt.figure()
>>> values = plt.hist(np.random.noncentral_chisquare(3, 20, 100000),
...                   bins=200, density=True)
>>> plt.show()
```



method

random.RandomState.**noncentral_f**(*dfnum*, *dfden*, *nonc*, *size=None*)

Draw samples from the noncentral F distribution.

Samples are drawn from an F distribution with specified parameters, *dfnum* (degrees of freedom in numerator) and *dfden* (degrees of freedom in denominator), where both parameters > 1. *nonc* is the non-centrality parameter.

Note: New code should use the *noncentral_f* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

dfnum
[float or array_like of floats] Numerator degrees of freedom, must be > 0.

dfden
[float or array_like of floats] Denominator degrees of freedom, must be > 0.

nonc
[float or array_like of floats] Non-centrality parameter, the sum of the squares of the numerator means, must be >= 0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `dfnum`, `dfden`, and `nonc` are all scalars. Otherwise, `np.broadcast(dfnum, dfden, nonc).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized noncentral Fisher distribution.

See also:

random.Generator.noncentral_f
which should be used for new code.

Notes

When calculating the power of an experiment (power = probability of rejecting the null hypothesis when a specific alternative is true) the non-central F statistic becomes important. When the null hypothesis is true, the F statistic follows a central F distribution. When the null hypothesis is not true, then it follows a non-central F statistic.

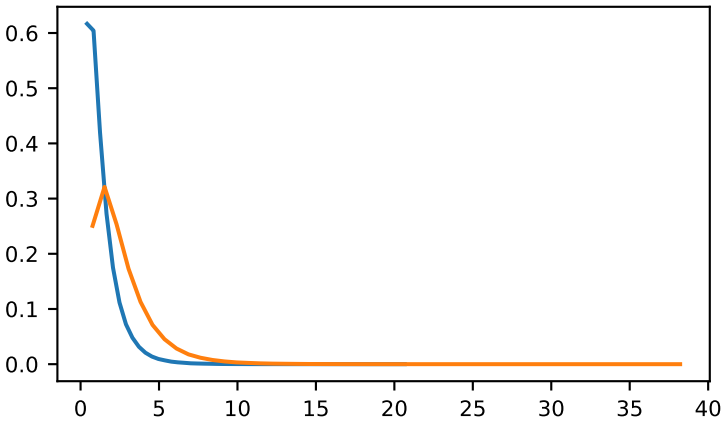
References

[1], [2]

Examples

In a study, testing for a specific alternative to the null hypothesis requires use of the Noncentral F distribution. We need to calculate the area in the tail of the distribution that exceeds the value of the F distribution for the null hypothesis. We'll plot the two probability distributions for comparison.

```
>>> dfnum = 3 # between group deg of freedom
>>> dfden = 20 # within groups degrees of freedom
>>> nonc = 3.0
>>> nc_vals = np.random.noncentral_f(dfnum, dfden, nonc, 1000000)
>>> NF = np.histogram(nc_vals, bins=50, density=True)
>>> c_vals = np.random.f(dfnum, dfden, 1000000)
>>> F = np.histogram(c_vals, bins=50, density=True)
>>> import matplotlib.pyplot as plt
>>> plt.plot(F[1][1:], F[0])
>>> plt.plot(NF[1][1:], NF[0])
>>> plt.show()
```



method

`random.RandomState.`**`normal`**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw random samples from a normal (Gaussian) distribution.

The probability density function of the normal distribution, first derived by De Moivre and 200 years later by both Gauss and Laplace independently [2], is often called the bell curve because of its characteristic shape (see the example below).

The normal distributions occurs often in nature. For example, it describes the commonly occurring distribution of samples influenced by a large number of tiny, random disturbances, each with its own unique distribution [2].

Note: New code should use the *`normal`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

loc

[float or array_like of floats] Mean ("centre") of the distribution.

scale
: [float or array_like of floats] Standard deviation (spread or "width") of the distribution. Must be non-negative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized normal distribution.

See also:

`scipy.stats.norm`
: probability density function, distribution or cumulative density function, etc.

`random.Generator.normal`
: which should be used for new code.

Notes

The probability density for the Gaussian distribution is

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}},$$

where μ is the mean and σ the standard deviation. The square of the standard deviation, σ^2, is called the variance.

The function has its peak at the mean, and its "spread" increases with the standard deviation (the function reaches 0.607 times its maximum at $x + \sigma$ and $x - \sigma$ [2]). This implies that normal is more likely to return samples lying close to the mean, rather than those far away.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> mu, sigma = 0, 0.1 # mean and standard deviation
>>> s = np.random.normal(mu, sigma, 1000)
```

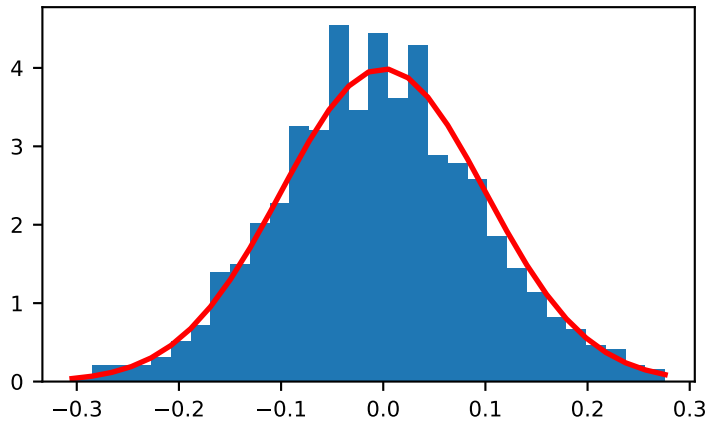
Verify the mean and the standard deviation:

```
>>> abs(mu - np.mean(s))
0.0  # may vary
```

```
>>> abs(sigma - np.std(s, ddof=1))
0.1  # may vary
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, density=True)
>>> plt.plot(bins, 1/(sigma * np.sqrt(2 * np.pi)) *
...                np.exp( - (bins - mu)**2 / (2 * sigma**2) ),
...          linewidth=2, color='r')
>>> plt.show()
```



Two-by-four array of samples from the normal distribution with mean 3 and standard deviation 2.5:

```
>>> np.random.normal(3, 2.5, size=(2, 4))
array([[-4.49401501,  4.00950034, -1.81814867,  7.29718677],   # random
       [ 0.39924804,  4.68456316,  4.99394529,  4.84057254]])  # random
```

method

`random.RandomState.`**`pareto`**(*a*, *size=None*)

Draw samples from a Pareto II or Lomax distribution with specified shape.

The Lomax or Pareto II distribution is a shifted Pareto distribution. The classical Pareto distribution can be obtained from the Lomax distribution by adding 1 and multiplying by the scale parameter `m` (see Notes). The smallest value of the Lomax distribution is zero while for the classical Pareto distribution it is `mu`, where the standard Pareto distribution has location `mu = 1`. Lomax can also be considered as a simplified version of the Generalized Pareto distribution (available in SciPy), with the scale set to one and the location set to zero.

The Pareto distribution must be greater than zero, and is unbounded above. It is also known as the "80-20 rule". In this distribution, 80 percent of the weights are in the lowest 20 percent of the range, while the other 20 percent fill the remaining 80 percent of the range.

Note: New code should use the *`pareto`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

a

[float or array_like of floats] Shape of the distribution. Must be positive.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Pareto distribution.

See also:

`scipy.stats.lomax`
: probability density function, distribution or cumulative density function, etc.

`scipy.stats.genpareto`
: probability density function, distribution or cumulative density function, etc.

`random.Generator.pareto`
: which should be used for new code.

Notes

The probability density for the Pareto distribution is

$$p(x) = \frac{am^a}{x^{a+1}}$$

where a is the shape and m the scale.

The Pareto distribution, named after the Italian economist Vilfredo Pareto, is a power law probability distribution useful in many real world problems. Outside the field of economics it is generally referred to as the Bradford distribution. Pareto developed the distribution to describe the distribution of wealth in an economy. It has also found use in insurance, web page access statistics, oil field sizes, and many other problems, including the download frequency for projects in Sourceforge [1]. It is one of the so-called "fat-tailed" distributions.

References

[1], [2], [3], [4]

Examples

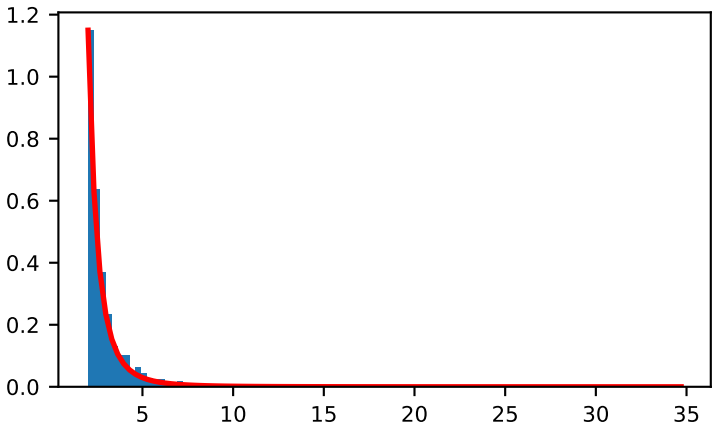
Draw samples from the distribution:

```
>>> a, m = 3., 2.  # shape and mode
>>> s = (np.random.pareto(a, 1000) + 1) * m
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, 100, density=True)
>>> fit = a*m**a / bins**(a+1)
>>> plt.plot(bins, max(count)*fit/max(fit), linewidth=2, color='r')
>>> plt.show()
```

method



`random.RandomState.`**`poisson`**(*lam=1.0*, *size=None*)

Draw samples from a Poisson distribution.

The Poisson distribution is the limit of the binomial distribution for large N.

Note: New code should use the *`poisson`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

lam
[float or array_like of floats] Expected number of events occurring in a fixed-time interval, must be >= 0. A sequence must be broadcastable over the requested size.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `lam` is a scalar. Otherwise, `np.array(lam).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Poisson distribution.

See also:

`random.Generator.poisson`
which should be used for new code.

Notes

The probability mass function (PMF) of Poisson distribution is

$$f(k; \lambda) = \frac{\lambda^k e^{-\lambda}}{k!}$$

For events with an expected separation λ the Poisson distribution $f(k; \lambda)$ describes the probability of k events occurring within the observed interval λ.

Because the output is limited to the range of the C int64 type, a ValueError is raised when *lam* is within 10 sigma of the maximum representable value.

References

[1], [2]

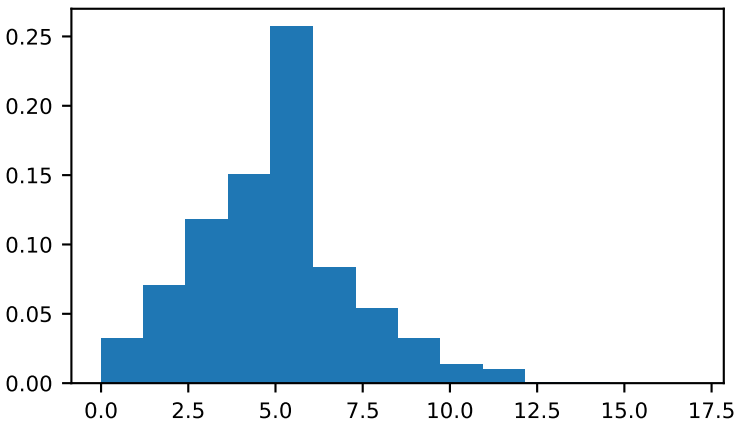
Examples

Draw samples from the distribution:

```
>>> import numpy as np
>>> s = np.random.poisson(5, 10000)
```

Display histogram of the sample:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 14, density=True)
>>> plt.show()
```



Draw each 100 values for lambda 100 and 500:

```
>>> s = np.random.poisson(lam=(100., 500.), size=(100, 2))
```

method

random.RandomState.**power**(*a*, *size=None*)

Draws samples in [0, 1] from a power distribution with positive exponent a - 1.

Also known as the power function distribution.

Note: New code should use the `power` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

a
[float or array_like of floats] Parameter of the distribution. Must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized power distribution.

Raises

ValueError
If a <= 0.

See also:

random.Generator.power
which should be used for new code.

Notes

The probability density function is

$$P(x; a) = ax^{a-1}, 0 \leq x \leq 1, a > 0.$$

The power function distribution is just the inverse of the Pareto distribution. It may also be seen as a special case of the Beta distribution.

It is used, for example, in modeling the over-reporting of insurance claims.

References

[1], [2]

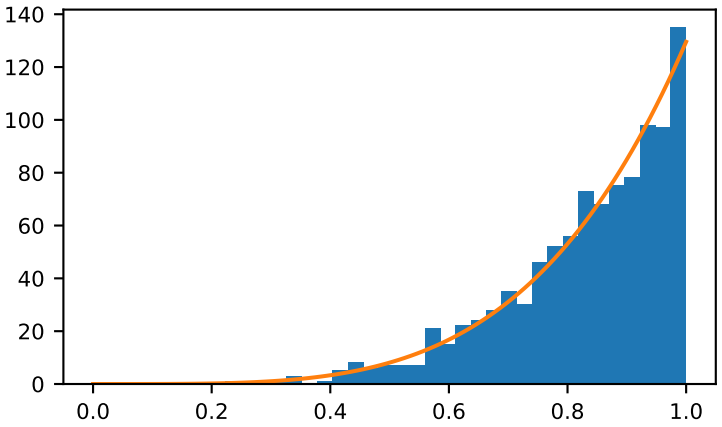
Examples

Draw samples from the distribution:

```
>>> a = 5. # shape
>>> samples = 1000
>>> s = np.random.power(a, samples)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, bins=30)
>>> x = np.linspace(0, 1, 100)
>>> y = a*x**(a-1.)
>>> normed_y = samples*np.diff(bins)[0]*y
>>> plt.plot(x, normed_y)
>>> plt.show()
```



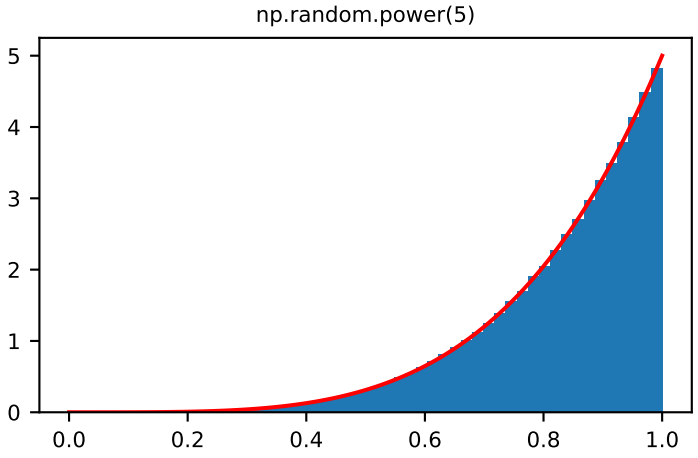
Compare the power function distribution to the inverse of the Pareto.

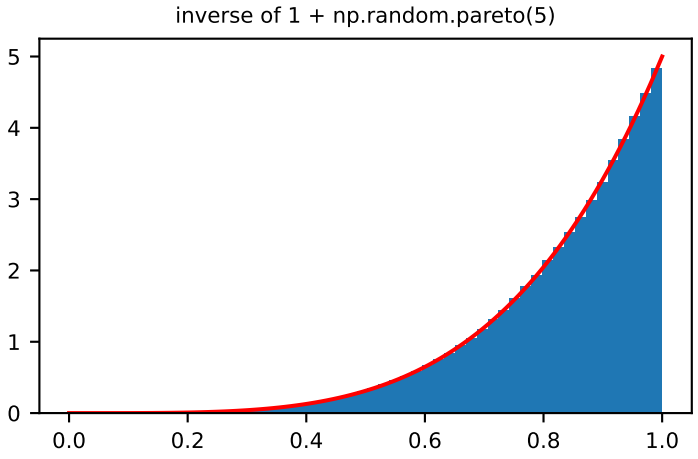
```
>>> from scipy import stats
>>> rvs = np.random.power(5, 1000000)
>>> rvsp = np.random.pareto(5, 1000000)
>>> xx = np.linspace(0,1,100)
>>> powpdf = stats.powerlaw.pdf(xx,5)
```

```
>>> plt.figure()
>>> plt.hist(rvs, bins=50, density=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('np.random.power(5)')
```

```
>>> plt.figure()
>>> plt.hist(1./(1.+rvsp), bins=50, density=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('inverse of 1 + np.random.pareto(5)')
```

```
>>> plt.figure()
>>> plt.hist(1./(1.+rvsp), bins=50, density=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('inverse of stats.pareto(5)')
```





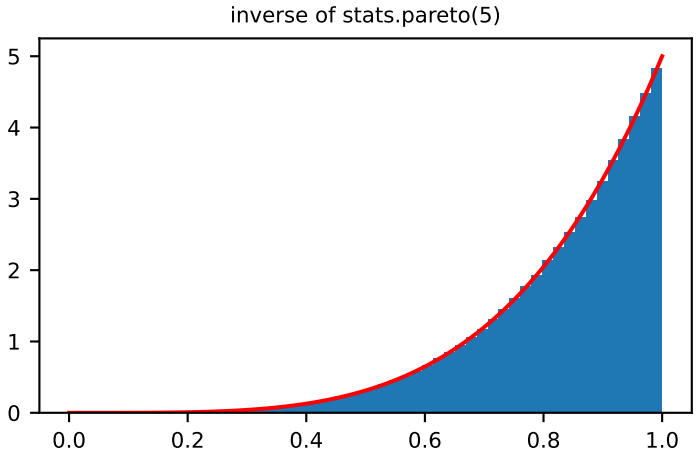
method

`random.RandomState.`**`rayleigh`**(*scale=1.0*, *size=None*)

Draw samples from a Rayleigh distribution.

The χ and Weibull distributions are generalizations of the Rayleigh.

Note: New code should use the *`rayleigh`* method of a *`Generator`* instance instead; please see the *Quick start*.



Parameters

scale
[float or array_like of floats, optional] Scale, also equals the mode. Must be non-negative. Default is 1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `scale` is a scalar. Otherwise, `np.array(scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Rayleigh distribution.

See also:

random.Generator.rayleigh
which should be used for new code.

Notes

The probability density function for the Rayleigh distribution is

$$P(x;scale) = \frac{x}{scale^2}e^{\frac{-x^2}{2\cdot scale^2}}$$

The Rayleigh distribution would arise, for example, if the East and North components of the wind velocity had identical zero-mean Gaussian distributions. Then the wind speed would have a Rayleigh distribution.

References

[1], [2]

Examples

Draw values from the distribution and plot the histogram

```
>>> from matplotlib.pyplot import hist
>>> values = hist(np.random.rayleigh(3, 100000), bins=200, density=True)
```

Wave heights tend to follow a Rayleigh distribution. If the mean wave height is 1 meter, what fraction of waves are likely to be larger than 3 meters?

```
>>> meanvalue = 1
>>> modevalue = np.sqrt(2 / np.pi) * meanvalue
>>> s = np.random.rayleigh(modevalue, 1000000)
```

The percentage of waves larger than 3 meters is:

```
>>> 100.*sum(s>3)/1000000.
0.08730000000000003 # random
```

method

`random.RandomState.`**`standard_cauchy`**(*size=None*)

Draw samples from a standard Cauchy distribution with mode = 0.

Also known as the Lorentz distribution.

Note: New code should use the *`standard_cauchy`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

samples
[ndarray or scalar] The drawn samples.

See also:

`random.Generator.standard_cauchy`
which should be used for new code.

Notes

The probability density function for the full Cauchy distribution is

$$P(x; x_0, \gamma) = \frac{1}{\pi\gamma\left[1 + \left(\frac{x-x_0}{\gamma}\right)^2\right]}$$

and the Standard Cauchy distribution just sets $x_0 = 0$ and $\gamma = 1$

The Cauchy distribution arises in the solution to the driven harmonic oscillator problem, and also describes spectral line broadening. It also describes the distribution of values at which a line tilted at a random angle will cut the x axis.

When studying hypothesis tests that assume normality, seeing how the tests perform on data from a Cauchy distribution is a good indicator of their sensitivity to a heavy-tailed distribution, since the Cauchy looks very much like a Gaussian distribution, but with heavier tails.

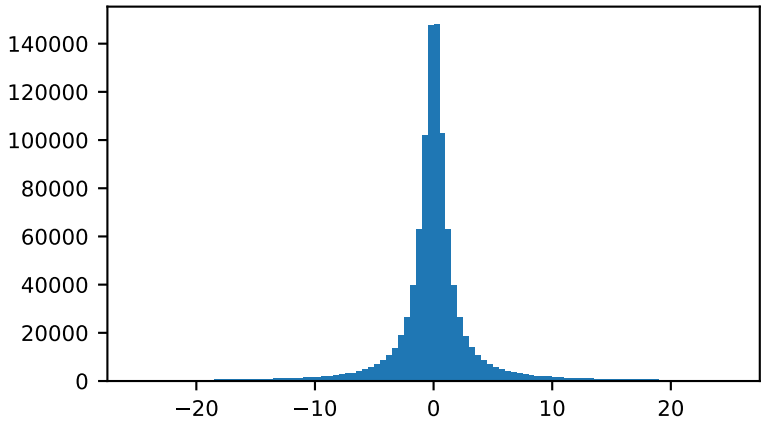
References

[1], [2], [3]

Examples

Draw samples and plot the distribution:

```
>>> import matplotlib.pyplot as plt
>>> s = np.random.standard_cauchy(1000000)
>>> s = s[(s>-25) & (s<25)]  # truncate distribution so it plots well
>>> plt.hist(s, bins=100)
>>> plt.show()
```



method

random.RandomState.**standard_exponential**(*size=None*)

Draw samples from the standard exponential distribution.

standard_exponential is identical to the exponential distribution with a scale parameter of 1.

Note: New code should use the *standard_exponential* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

out
[float or ndarray] Drawn samples.

See also:

random.Generator.standard_exponential
which should be used for new code.

Examples

Output a 3x8000 array:

```
>>> n = np.random.standard_exponential((3, 8000))
```

method

random.RandomState.**standard_gamma**(*shape*, *size=None*)

Draw samples from a standard Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, shape (sometimes designated "k") and scale=1.

Note: New code should use the *standard_gamma* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

shape
[float or array_like of floats] Parameter, must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `shape` is a scalar. Otherwise, `np.array(shape).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized standard gamma distribution.

See also:

`scipy.stats.gamma`
probability density function, distribution or cumulative density function, etc.

`random.Generator.standard_gamma`
which should be used for new code.

Notes

The probability density for the Gamma distribution is

$$p(x) = x^{k-1}\frac{e^{-x/\theta}}{\theta^k\Gamma(k)},$$

where k is the shape and θ the scale, and Γ is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> shape, scale = 2., 1. # mean and width
>>> s = np.random.standard_gamma(shape, 1000000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, ignored = plt.hist(s, 50, density=True)
>>> y = bins**(shape-1) * ((np.exp(-bins/scale))/
...                       (sps.gamma(shape) * scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```

method

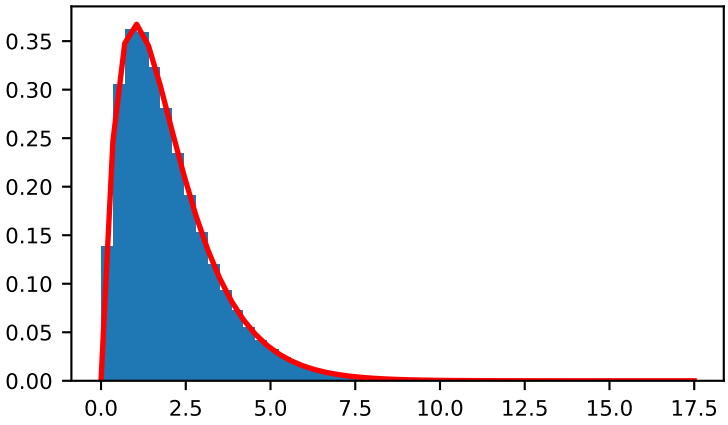
`random.RandomState.`**`standard_normal`**(*size=None*)

Draw samples from a standard Normal distribution (mean=0, stdev=1).

Note: New code should use the *`standard_normal`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.



Returns

out
: [float or ndarray] A floating-point array of shape `size` of drawn samples, or a single sample if `size` was not specified.

See also:

normal
: Equivalent function with additional `loc` and `scale` arguments for setting the mean and standard deviation.

random.Generator.standard_normal
: which should be used for new code.

Notes

For random samples from the normal distribution with mean `mu` and standard deviation `sigma`, use one of:

```
mu + sigma * np.random.standard_normal(size=...)
np.random.normal(mu, sigma, size=...)
```

Examples

```
>>> np.random.standard_normal()
2.1923875335537315 #random
```

```
>>> s = np.random.standard_normal(8000)
>>> s
array([ 0.6888893 ,  0.78096262, -0.89086505, ...,  0.49876311,  # random
       -0.38672696, -0.4685006 ])                                # random
>>> s.shape
(8000,)
>>> s = np.random.standard_normal(size=(3, 4, 2))
```

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```
>>> s.shape
(3, 4, 2)
```

Two-by-four array of samples from the normal distribution with mean 3 and standard deviation 2.5:

```
>>> 3 + 2.5 * np.random.standard_normal(size=(2, 4))
array([[-4.49401501,  4.00950034, -1.81814867,  7.29718677],   # random
       [ 0.39924804,  4.68456316,  4.99394529,  4.84057254]])  # random
```

method

random.RandomState.**standard_t**(*df*, *size=None*)

Draw samples from a standard Student's t distribution with *df* degrees of freedom.

A special case of the hyperbolic distribution. As *df* gets large, the result resembles that of the standard normal distribution (*standard_normal*).

Note: New code should use the *standard_t* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

df
[float or array_like of floats] Degrees of freedom, must be > 0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `df` is a scalar. Otherwise, `np.array(df).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized standard Student's t distribution.

See also:

random.Generator.standard_t
which should be used for new code.

Notes

The probability density function for the t distribution is

$$P(x, df) = \frac{\Gamma(\frac{df+1}{2})}{\sqrt{\pi df}\,\Gamma(\frac{df}{2})}\left(1+\frac{x^2}{df}\right)^{-(df+1)/2}$$

The t test is based on an assumption that the data come from a Normal distribution. The t test provides a way to test whether the sample mean (that is the mean calculated from the data) is a good estimate of the true mean.

The derivation of the t-distribution was first published in 1908 by William Gosset while working for the Guinness Brewery in Dublin. Due to proprietary issues, he had to publish under a pseudonym, and so he used the name Student.

References

[1], [2]

Examples

From Dalgaard page 83 [1], suppose the daily energy intake for 11 women in kilojoules (kJ) is:

```
>>> intake = np.array([5260., 5470, 5640, 6180, 6390, 6515, 6805, 7515, \
...                    7515, 8230, 8770])
```

Does their energy intake deviate systematically from the recommended value of 7725 kJ? Our null hypothesis will be the absence of deviation, and the alternate hypothesis will be the presence of an effect that could be either positive or negative, hence making our test 2-tailed.

Because we are estimating the mean and we have N=11 values in our sample, we have N-1=10 degrees of freedom. We set our significance level to 95% and compute the t statistic using the empirical mean and empirical standard deviation of our intake. We use a ddof of 1 to base the computation of our empirical standard deviation on an unbiased estimate of the variance (note: the final estimate is not unbiased due to the concave nature of the square root).

```
>>> np.mean(intake)
6753.636363636364
>>> intake.std(ddof=1)
1142.1232221373727
>>> t = (np.mean(intake)-7725)/(intake.std(ddof=1)/np.sqrt(len(intake)))
>>> t
-2.8207540608310198
```

We draw 1000000 samples from Student's t distribution with the adequate degrees of freedom.

```
>>> import matplotlib.pyplot as plt
>>> s = np.random.standard_t(10, size=1000000)
>>> h = plt.hist(s, bins=100, density=True)
```

Does our t statistic land in one of the two critical regions found at both tails of the distribution?

```
>>> np.sum(np.abs(t) < np.abs(s)) / float(len(s))
0.018318  #random < 0.05, statistic is in critical region
```

The probability value for this 2-tailed test is about 1.83%, which is lower than the 5% pre-determined significance threshold.

Therefore, the probability of observing values as extreme as our intake conditionally on the null hypothesis being true is too low, and we reject the null hypothesis of no deviation.

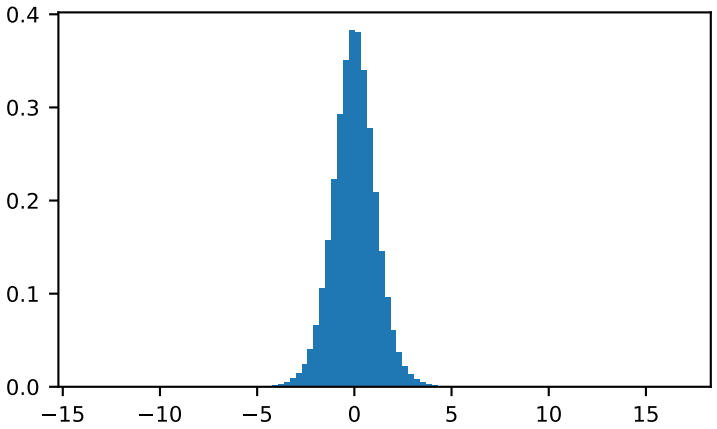
method

`random.RandomState.`**`triangular`**(*left*, *mode*, *right*, *size=None*)

Draw samples from the triangular distribution over the interval `[left, right]`.

The triangular distribution is a continuous probability distribution with lower limit left, peak at mode, and upper limit right. Unlike the other distributions, these parameters directly define the shape of the pdf.

Note: New code should use the *`triangular`* method of a *`Generator`* instance instead; please see the *Quick start*.



Parameters

left
[float or array_like of floats] Lower limit.

mode
[float or array_like of floats] The value where the peak of the distribution occurs. The value must fulfill the condition `left <= mode <= right`.

right
[float or array_like of floats] Upper limit, must be larger than *left*.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `left`, `mode`, and `right` are all scalars. Otherwise, `np.broadcast(left, mode, right).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized triangular distribution.

See also:

random.Generator.triangular
which should be used for new code.

Notes

The probability density function for the triangular distribution is

$$P(x;l,m,r) = \begin{cases} \frac{2(x-l)}{(r-l)(m-l)} & \text{for } l \leq x \leq m, \\ \frac{2(r-x)}{(r-l)(r-m)} & \text{for } m \leq x \leq r, \\ 0 & \text{otherwise.} \end{cases}$$

The triangular distribution is often used in ill-defined problems where the underlying distribution is not known, but some knowledge of the limits and mode exists. Often it is used in simulations.

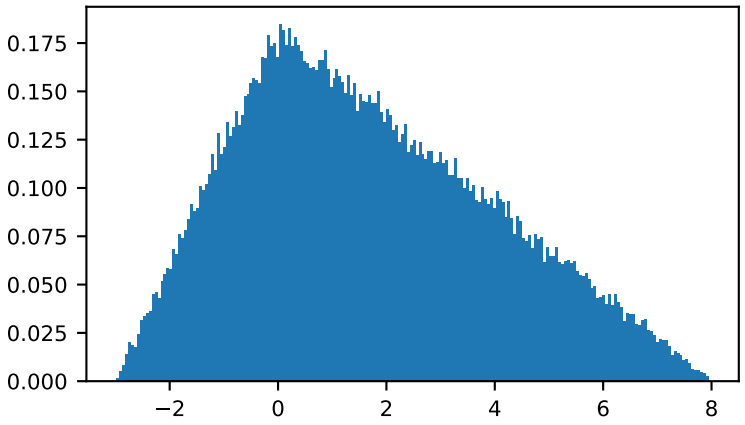
References

[1]

Examples

Draw values from the distribution and plot the histogram:

```
>>> import matplotlib.pyplot as plt
>>> h = plt.hist(np.random.triangular(-3, 0, 8, 100000), bins=200,
...              density=True)
>>> plt.show()
```



method

`random.RandomState.`**`uniform`**(*low=0.0*, *high=1.0*, *size=None*)

Draw samples from a uniform distribution.

Samples are uniformly distributed over the half-open interval `[low, high)` (includes low, but excludes high). In other words, any value within the given interval is equally likely to be drawn by *`uniform`*.

Note: New code should use the *`uniform`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

low
[float or array_like of floats, optional] Lower boundary of the output interval. All values generated will be greater than or equal to low. The default value is 0.

high
[float or array_like of floats] Upper boundary of the output interval. All values generated will be less than or equal to high. The high limit may be included in the returned array of floats due to floating-point rounding in the equation `low + (high-low) * random_sample()`. The default value is 1.0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `low` and `high` are both scalars. Otherwise, `np.broadcast(low, high).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized uniform distribution.

See also:

randint
Discrete uniform distribution, yielding integers.

random_integers
Discrete uniform distribution over the closed interval `[low, high]`.

random_sample
Floats uniformly distributed over `[0, 1)`.

random
Alias for *random_sample*.

rand
Convenience function that accepts dimensions as input, e.g., `rand(2,2)` would generate a 2-by-2 array of floats, uniformly distributed over `[0, 1)`.

random.Generator.uniform
which should be used for new code.

Notes

The probability density function of the uniform distribution is

$$p(x) = \frac{1}{b - a}$$

anywhere within the interval `[a, b)`, and zero elsewhere.

When `high` == `low`, values of `low` will be returned. If `high` < `low`, the results are officially undefined and may eventually raise an error, i.e. do not rely on this function to behave when passed arguments satisfying that inequality condition. The `high` limit may be included in the returned array of floats due to floating-point rounding in the equation `low + (high-low) * random_sample()`. For example:

```
>>> x = np.float32(5*0.99999999)
>>> x
np.float32(5.0)
```

Examples

Draw samples from the distribution:

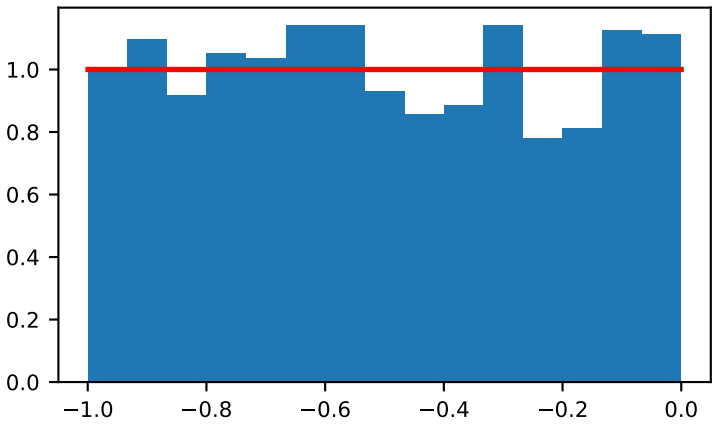
```
>>> s = np.random.uniform(-1,0,1000)
```

All values are within the given interval:

```
>>> np.all(s >= -1)
True
>>> np.all(s < 0)
True
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 15, density=True)
>>> plt.plot(bins, np.ones_like(bins), linewidth=2, color='r')
>>> plt.show()
```



method

`random.RandomState.`**`vonmises`**(*mu*, *kappa*, *size=None*)

Draw samples from a von Mises distribution.

Samples are drawn from a von Mises distribution with specified mode (mu) and concentration (kappa), on the interval [-pi, pi].

The von Mises distribution (also known as the circular normal distribution) is a continuous probability distribution on the unit circle. It may be thought of as the circular analogue of the normal distribution.

Note: New code should use the `vonmises` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

mu
[float or array_like of floats] Mode ("center") of the distribution.

kappa
[float or array_like of floats] Concentration of the distribution, has to be >=0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `mu` and `kappa` are both scalars. Otherwise, `np.broadcast(mu, kappa).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized von Mises distribution.

See also:

`scipy.stats.vonmises`
probability density function, distribution, or cumulative density function, etc.

`random.Generator.vonmises`
which should be used for new code.

Notes

The probability density for the von Mises distribution is

$$p(x) = \frac{e^{\kappa cos(x-\mu)}}{2\pi I_0(\kappa)},$$

where μ is the mode and κ the concentration, and $I_0(\kappa)$ is the modified Bessel function of order 0.

The von Mises is named for Richard Edler von Mises, who was born in Austria-Hungary, in what is now the Ukraine. He fled to the United States in 1939 and became a professor at Harvard. He worked in probability theory, aerodynamics, fluid mechanics, and philosophy of science.

References

[1], [2]

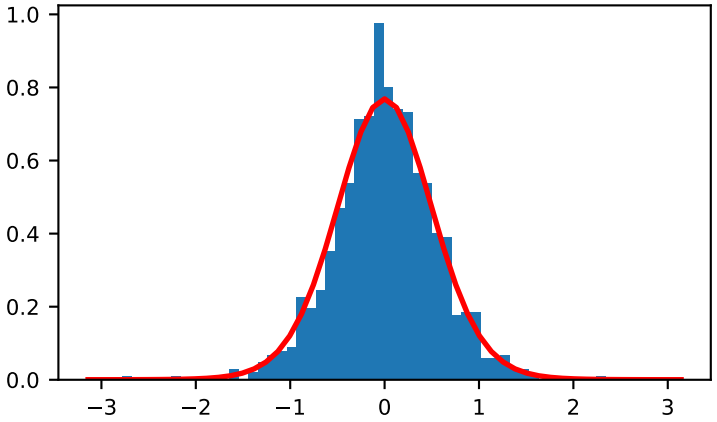
Examples

Draw samples from the distribution:

```
>>> mu, kappa = 0.0, 4.0 # mean and concentration
>>> s = np.random.vonmises(mu, kappa, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> from scipy.special import i0
>>> plt.hist(s, 50, density=True)
>>> x = np.linspace(-np.pi, np.pi, num=51)
>>> y = np.exp(kappa*np.cos(x-mu))/(2*np.pi*i0(kappa))
>>> plt.plot(x, y, linewidth=2, color='r')
>>> plt.show()
```



method

`random.RandomState.`**`wald`**(*mean*, *scale*, *size=None*)

Draw samples from a Wald, or inverse Gaussian, distribution.

As the scale approaches infinity, the distribution becomes more like a Gaussian. Some references claim that the Wald is an inverse Gaussian with mean equal to 1, but this is by no means universal.

The inverse Gaussian distribution was first studied in relationship to Brownian motion. In 1956 M.C.K. Tweedie used the name inverse Gaussian because there is an inverse relationship between the time to cover a unit distance and distance covered in unit time.

Note: New code should use the *`wald`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

mean
[float or array_like of floats] Distribution mean, must be > 0.

scale
: [float or array_like of floats] Scale parameter, must be > 0.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `mean` and `scale` are both scalars. Otherwise, `np.broadcast(mean, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Wald distribution.

See also:

random.Generator.wald
: which should be used for new code.

Notes

The probability density function for the Wald distribution is

$$P(x; mean, scale) = \sqrt{\frac{scale}{2\pi x^3}} e^{\frac{-scale(x-mean)^2}{2 \cdot mean^2 x}}$$

As noted above the inverse Gaussian distribution first arise from attempts to model Brownian motion. It is also a competitor to the Weibull for use in reliability modeling and modeling stock returns and interest rate processes.

References

[1], [2], [3]

Examples

Draw values from the distribution and plot the histogram:

```
>>> import matplotlib.pyplot as plt
>>> h = plt.hist(np.random.wald(3, 2, 100000), bins=200, density=True)
>>> plt.show()
```

method

`random.RandomState.`**`weibull`**(*a*, *size=None*)

Draw samples from a Weibull distribution.

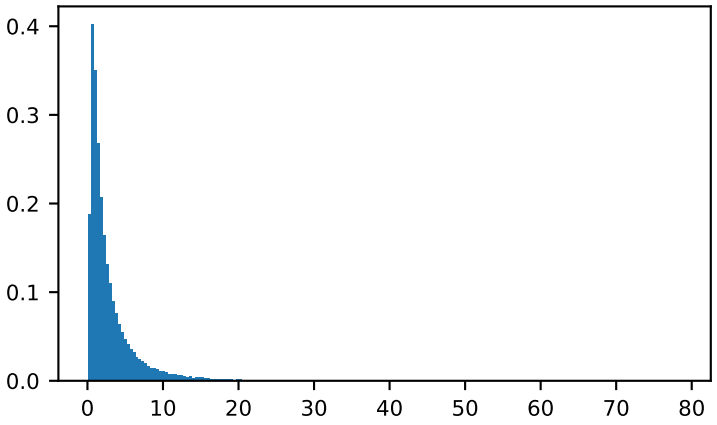
Draw samples from a 1-parameter Weibull distribution with the given shape parameter a.

$$X = (-ln(U))^{1/a}$$

Here, U is drawn from the uniform distribution over (0,1].

The more common 2-parameter Weibull, including a scale parameter λ is just $X = \lambda(-ln(U))^{1/a}$.

Note: New code should use the *`weibull`* method of a *`Generator`* instance instead; please see the *Quick start*.



Parameters

a
[float or array_like of floats] Shape parameter of the distribution. Must be nonnegative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Weibull distribution.

See also:

scipy.stats.weibull_max
scipy.stats.weibull_min
scipy.stats.genextreme
gumbel
random.Generator.weibull
which should be used for new code.

Notes

The Weibull (or Type III asymptotic extreme value distribution for smallest values, SEV Type III, or Rosin-Rammler distribution) is one of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems. This class includes the Gumbel and Frechet distributions.

The probability density for the Weibull distribution is

$$p(x) = \frac{a}{\lambda}(\frac{x}{\lambda})^{a-1}e^{-(x/\lambda)^a},$$

where a is the shape and λ the scale.

The function has its peak (the mode) at $\lambda(\frac{a-1}{a})^{1/a}$.

When `a = 1`, the Weibull distribution reduces to the exponential distribution.

References

[1], [2], [3]

Examples

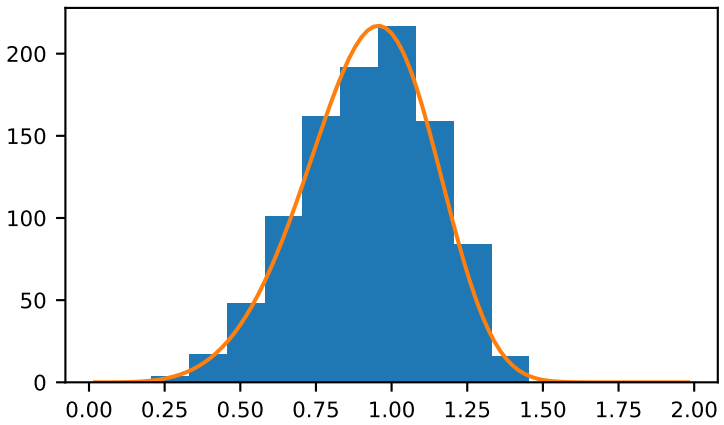
Draw samples from the distribution:

```
>>> a = 5. # shape
>>> s = np.random.weibull(a, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> x = np.arange(1,100.)/50.
>>> def weib(x,n,a):
...     return (a / n) * (x / n)**(a - 1) * np.exp(-(x / n)**a)
```

```
>>> count, bins, ignored = plt.hist(np.random.weibull(5.,1000))
>>> x = np.arange(1,100.)/50.
>>> scale = count.max()/weib(x, 1., 5.).max()
>>> plt.plot(x, weib(x, 1., 5.)*scale)
>>> plt.show()
```



method

`random.RandomState.`**`zipf`**(*a*, *size=None*)

Draw samples from a Zipf distribution.

Samples are drawn from a Zipf distribution with specified parameter $a > 1$.

The Zipf distribution (also known as the zeta distribution) is a discrete probability distribution that satisfies Zipf's law: the frequency of an item is inversely proportional to its rank in a frequency table.

Note: New code should use the *zipf* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

a
[float or array_like of floats] Distribution parameter. Must be greater than 1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Zipf distribution.

See also:

scipy.stats.zipf
probability density function, distribution, or cumulative density function, etc.

random.Generator.zipf
which should be used for new code.

Notes

The probability mass function (PMF) for the Zipf distribution is

$$p(k) = \frac{k^{-a}}{\zeta(a)},$$

for integers $k \geq 1$, where ζ is the Riemann Zeta function.

It is named for the American linguist George Kingsley Zipf, who noted that the frequency of any word in a sample of a language is inversely proportional to its rank in the frequency table.

References

[1]

Examples

Draw samples from the distribution:

```
>>> a = 4.0
>>> n = 20000
>>> s = np.random.zipf(a, n)
```

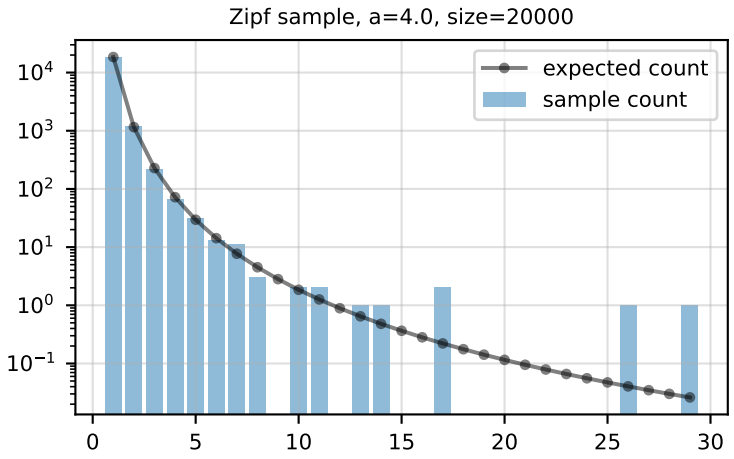
Display the histogram of the samples, along with the expected histogram based on the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> from scipy.special import zeta
```

bincount provides a fast histogram for small integers.

```
>>> count = np.bincount(s)
>>> k = np.arange(1, s.max() + 1)
```

```
>>> plt.bar(k, count[1:], alpha=0.5, label='sample count')
>>> plt.plot(k, n*(k**-a)/zeta(a), 'k.-', alpha=0.5,
...          label='expected count')
>>> plt.semilogy()
>>> plt.grid(alpha=0.4)
>>> plt.legend()
>>> plt.title(f'Zipf sample, a={a}, size={n}')
>>> plt.show()
```



Functions in `numpy.random`

Many of the RandomState methods above are exported as functions in *numpy.random* This usage is discouraged, as it is implemented via a global *RandomState* instance which is not advised on two counts:

- It uses global state, which means results will change as the code changes
- It uses a *RandomState* rather than the more modern *Generator*.

For backward compatible legacy reasons, we will not change this.

beta(a, b[, size])	Draw samples from a Beta distribution.
binomial(n, p[, size])	Draw samples from a binomial distribution.
bytes(length)	Return random bytes.
chisquare(df[, size])	Draw samples from a chi-square distribution.
choice(a[, size, replace, p])	Generates a random sample from a given 1-D array
dirichlet(alpha[, size])	Draw samples from the Dirichlet distribution.
exponential([scale, size])	Draw samples from an exponential distribution.
f(dfnum, dfden[, size])	Draw samples from an F distribution.
gamma(shape[, scale, size])	Draw samples from a Gamma distribution.

continues on next page

Table 3 – continued from previous page

geometric(p[, size])	Draw samples from the geometric distribution.
get_state([legacy])	Return a tuple representing the internal state of the generator.
gumbel([loc, scale, size])	Draw samples from a Gumbel distribution.
hypergeometric(ngood, nbad, nsample[, size])	Draw samples from a Hypergeometric distribution.
laplace([loc, scale, size])	Draw samples from the Laplace or double exponential distribution with specified location (or mean) and scale (decay).
logistic([loc, scale, size])	Draw samples from a logistic distribution.
lognormal([mean, sigma, size])	Draw samples from a log-normal distribution.
logseries(p[, size])	Draw samples from a logarithmic series distribution.
multinomial(n, pvals[, size])	Draw samples from a multinomial distribution.
multivariate_normal(mean, cov[, size, ...])	Draw random samples from a multivariate normal distribution.
negative_binomial(n, p[, size])	Draw samples from a negative binomial distribution.
noncentral_chisquare(df, nonc[, size])	Draw samples from a noncentral chi-square distribution.
noncentral_f(dfnum, dfden, nonc[, size])	Draw samples from the noncentral F distribution.
normal([loc, scale, size])	Draw random samples from a normal (Gaussian) distribution.
pareto(a[, size])	Draw samples from a Pareto II or Lomax distribution with specified shape.
permutation(x)	Randomly permute a sequence, or return a permuted range.
poisson([lam, size])	Draw samples from a Poisson distribution.
power(a[, size])	Draws samples in [0, 1] from a power distribution with positive exponent a - 1.
rand(d0, d1, ..., dn)	Random values in a given shape.
randint(low[, high, size, dtype])	Return random integers from *low* (inclusive) to *high* (exclusive).
randn(d0, d1, ..., dn)	Return a sample (or samples) from the "standard normal" distribution.
random([size])	Return random floats in the half-open interval [0.0, 1.0).
random_integers(low[, high, size])	Random integers of type *numpy.int_* between *low* and *high*, inclusive.
random_sample([size])	Return random floats in the half-open interval [0.0, 1.0).
ranf(*args, **kwargs)	This is an alias of *random_sample*.
rayleigh([scale, size])	Draw samples from a Rayleigh distribution.
sample(*args, **kwargs)	This is an alias of *random_sample*.
seed([seed])	Reseed the singleton RandomState instance.
set_state(state)	Set the internal state of the generator from a tuple.
shuffle(x)	Modify a sequence in-place by shuffling its contents.
standard_cauchy([size])	Draw samples from a standard Cauchy distribution with mode = 0.
standard_exponential([size])	Draw samples from the standard exponential distribution.
standard_gamma(shape[, size])	Draw samples from a standard Gamma distribution.
standard_normal([size])	Draw samples from a standard Normal distribution (mean=0, stdev=1).
standard_t(df[, size])	Draw samples from a standard Student's t distribution with *df* degrees of freedom.
triangular(left, mode, right[, size])	Draw samples from the triangular distribution over the interval `[left, right]`.
uniform([low, high, size])	Draw samples from a uniform distribution.

continues on next page

Table 3 – continued from previous page

vonmises(mu, kappa[, size])	Draw samples from a von Mises distribution.
wald(mean, scale[, size])	Draw samples from a Wald, or inverse Gaussian, distribution.
weibull(a[, size])	Draw samples from a Weibull distribution.
zipf(a[, size])	Draw samples from a Zipf distribution.

random.**beta**(*a*, *b*, *size=None*)

Draw samples from a Beta distribution.

The Beta distribution is a special case of the Dirichlet distribution, and is related to the Gamma distribution. It has the probability distribution function

$$f(x; a, b) = \frac{1}{B(\alpha, \beta)} x^{\alpha-1}(1-x)^{\beta-1},$$

where the normalization, B, is the beta function,

$$B(\alpha, \beta) = \int_0^1 t^{\alpha-1}(1-t)^{\beta-1} dt.$$

It is often seen in Bayesian inference and order statistics.

Note: New code should use the *beta* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

a
[float or array_like of floats] Alpha, positive (>0).

b
[float or array_like of floats] Beta, positive (>0).

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` and `b` are both scalars. Otherwise, `np.broadcast(a, b).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized beta distribution.

See also:

random.Generator.beta
which should be used for new code.

random.**binomial**(*n*, *p*, *size=None*)

Draw samples from a binomial distribution.

Samples are drawn from a binomial distribution with specified parameters, n trials and p probability of success where n an integer >= 0 and p is in the interval [0,1]. (n may be input as a float, but it is truncated to an integer in use)

Note: New code should use the *binomial* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

n
[int or array_like of ints] Parameter of the distribution, >= 0. Floats are also accepted, but they will be truncated to integers.

p
[float or array_like of floats] Parameter of the distribution, >= 0 and <=1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `n` and `p` are both scalars. Otherwise, `np.broadcast(n, p).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized binomial distribution, where each sample is equal to the number of successes over the n trials.

See also:

scipy.stats.binom
probability density function, distribution or cumulative density function, etc.

random.Generator.binomial
which should be used for new code.

Notes

The probability mass function (PMF) for the binomial distribution is

$$P(N) = \binom{n}{N} p^N (1-p)^{n-N},$$

where n is the number of trials, p is the probability of success, and N is the number of successes.

When estimating the standard error of a proportion in a population by using a random sample, the normal distribution works well unless the product p*n <=5, where p = population proportion estimate, and n = number of samples, in which case the binomial distribution is used instead. For example, a sample of 15 people shows 4 who are left handed, and 11 who are right handed. Then p = 4/15 = 27%. 0.27*15 = 4, so the binomial distribution should be used in this case.

References

[1], [2], [3], [4], [5]

Examples

Draw samples from the distribution:

```
>>> n, p = 10, .5  # number of trials, probability of each trial
>>> s = np.random.binomial(n, p, 1000)
# result of flipping a coin 10 times, tested 1000 times.
```

A real world example. A company drills 9 wild-cat oil exploration wells, each with an estimated probability of success of 0.1. All nine wells fail. What is the probability of that happening?

Let's do 20,000 trials of the model, and count the number that generate zero positive results.

```
>>> sum(np.random.binomial(9, 0.1, 20000) == 0)/20000.
# answer = 0.38885, or 38%.
```

random.**bytes**(*length*)

Return random bytes.

Note: New code should use the *bytes* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

length
[int] Number of random bytes.

Returns

out
[bytes] String of length *length*.

See also:

random.Generator.bytes
which should be used for new code.

Examples

```
>>> np.random.bytes(10)
b' eh\x85\x022SZ\xbf\xa4' #random
```

random.**chisquare**(*df*, *size=None*)

Draw samples from a chi-square distribution.

When *df* independent random variables, each with standard normal distributions (mean 0, variance 1), are squared and summed, the resulting distribution is chi-square (see Notes). This distribution is often used in hypothesis testing.

Note: New code should use the *chisquare* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

df
[float or array_like of floats] Number of degrees of freedom, must be > 0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `df` is a scalar. Otherwise, `np.array(df).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized chi-square distribution.

Raises

ValueError
When *df* <= 0 or when an inappropriate *size* (e.g. `size=-1`) is given.

See also:

random.Generator.chisquare
which should be used for new code.

Notes

The variable obtained by summing the squares of *df* independent, standard normally distributed random variables:

$$Q = \sum_{i=1}^{\mathtt{df}} X_i^2$$

is chi-square distributed, denoted

$$Q \sim \chi_k^2.$$

The probability density function of the chi-squared distribution is

$$p(x) = \frac{(1/2)^{k/2}}{\Gamma(k/2)} x^{k/2-1} e^{-x/2},$$

where Γ is the gamma function,

$$\Gamma(x) = \int_0^{-\infty} t^{x-1} e^{-t} dt.$$

References

[1]

Examples

```
>>> np.random.chisquare(2,4)
array([ 1.89920014,  9.00867716,  3.13710533,  5.62318272]) # random
```

random.**choice**(*a*, *size=None*, *replace=True*, *p=None*)

Generates a random sample from a given 1-D array

Note: New code should use the `choice` method of a `Generator` instance instead; please see the *Quick start*.

Warning: This function uses the C-long dtype, which is 32bit on windows and otherwise 64bit on 64bit platforms (and 32bit on 32bit ones). Since NumPy 2.0, NumPy's default integer is 32bit on 32bit platforms and 64bit on 64bit platforms.

Parameters

a
: [1-D array-like or int] If an ndarray, a random sample is generated from its elements. If an int, the random sample is generated as if it were `np.arange(a)`

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

replace
: [boolean, optional] Whether the sample is with or without replacement. Default is True, meaning that a value of `a` can be selected multiple times.

p
: [1-D array-like, optional] The probabilities associated with each entry in a. If not given, the sample assumes a uniform distribution over all entries in `a`.

Returns

samples
: [single item or ndarray] The generated random samples

Raises

ValueError
: If a is an int and less than zero, if a or p are not 1-dimensional, if a is an array-like of size 0, if p is not a vector of probabilities, if a and p have different lengths, or if replace=False and the sample size is greater than the population size

See also:

randint*, *shuffle*, *permutation
random.Generator.choice
: which should be used in new code

Notes

Setting user-specified probabilities through `p` uses a more general but less efficient sampler than the default. The general sampler produces a different sample than the optimized sampler even if each element of `p` is 1 / len(a).

Sampling random rows from a 2-D array is not possible with this function, but is possible with *Generator.choice* through its `axis` keyword.

Examples

Generate a uniform random sample from np.arange(5) of size 3:

```
>>> np.random.choice(5, 3)
array([0, 3, 4]) # random
>>> #This is equivalent to np.random.randint(0,5,3)
```

Generate a non-uniform random sample from np.arange(5) of size 3:

```
>>> np.random.choice(5, 3, p=[0.1, 0, 0.3, 0.6, 0])
array([3, 3, 0]) # random
```

Generate a uniform random sample from np.arange(5) of size 3 without replacement:

```
>>> np.random.choice(5, 3, replace=False)
array([3,1,0]) # random
>>> #This is equivalent to np.random.permutation(np.arange(5))[:3]
```

Generate a non-uniform random sample from np.arange(5) of size 3 without replacement:

```
>>> np.random.choice(5, 3, replace=False, p=[0.1, 0, 0.3, 0.6, 0])
array([2, 3, 0]) # random
```

Any of the above can be repeated with an arbitrary array-like instead of just integers. For instance:

```
>>> aa_milne_arr = ['pooh', 'rabbit', 'piglet', 'Christopher']
>>> np.random.choice(aa_milne_arr, 5, p=[0.5, 0.1, 0.1, 0.3])
array(['pooh', 'pooh', 'pooh', 'Christopher', 'piglet'], # random
      dtype='<U11')
```

`random.`**`dirichlet`**(*alpha*, *size=None*)

Draw samples from the Dirichlet distribution.

Draw *size* samples of dimension k from a Dirichlet distribution. A Dirichlet-distributed random variable can be seen as a multivariate generalization of a Beta distribution. The Dirichlet distribution is a conjugate prior of a multinomial distribution in Bayesian inference.

Note: New code should use the *dirichlet* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

alpha
: [sequence of floats, length k] Parameter of the distribution (length `k` for sample of length `k`).

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n)`, then `m * n * k` samples are drawn. Default is None, in which case a vector of length `k` is returned.

Returns

samples
[ndarray,] The drawn samples, of shape `(size, k)`.

Raises

ValueError
If any value in `alpha` is less than or equal to zero

See also:

random.Generator.dirichlet
which should be used for new code.

Notes

The Dirichlet distribution is a distribution over vectors x that fulfil the conditions $x_i > 0$ and $\sum_{i=1}^{k} x_i = 1$.

The probability density function p of a Dirichlet-distributed random vector X is proportional to

$$p(x) \propto \prod_{i=1}^{k} x_i^{\alpha_i - 1},$$

where α is a vector containing the positive concentration parameters.

The method uses the following property for computation: let Y be a random vector which has components that follow a standard gamma distribution, then $X = \frac{1}{\sum_{i=1}^{k} Y_i} Y$ is Dirichlet-distributed

References

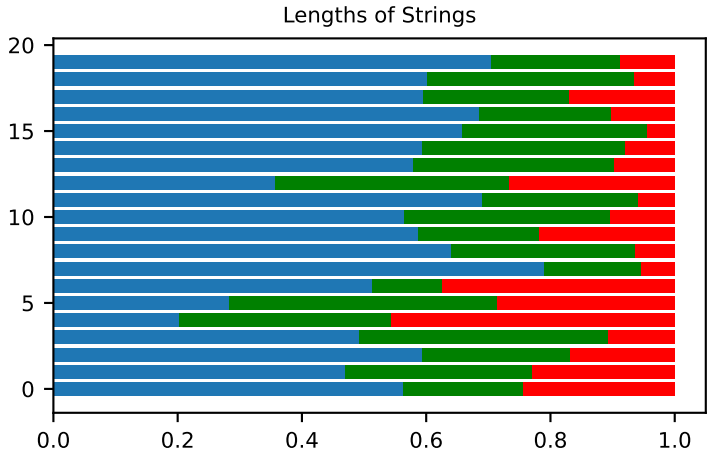
[1], [2]

Examples

Taking an example cited in Wikipedia, this distribution can be used if one wanted to cut strings (each of initial length 1.0) into K pieces with different lengths, where each piece had, on average, a designated average length, but allowing some variation in the relative sizes of the pieces.

```
>>> s = np.random.dirichlet((10, 5, 3), 20).transpose()
```

```
>>> import matplotlib.pyplot as plt
>>> plt.barh(range(20), s[0])
>>> plt.barh(range(20), s[1], left=s[0], color='g')
>>> plt.barh(range(20), s[2], left=s[0]+s[1], color='r')
>>> plt.title("Lengths of Strings")
```



random.**exponential**(*scale=1.0*, *size=None*)

Draw samples from an exponential distribution.

Its probability density function is

$$f(x; \frac{1}{\beta}) = \frac{1}{\beta} \exp(-\frac{x}{\beta}),$$

for `x > 0` and 0 elsewhere. β is the scale parameter, which is the inverse of the rate parameter $\lambda = 1/\beta$. The rate parameter is an alternative, widely used parameterization of the exponential distribution [3].

The exponential distribution is a continuous analogue of the geometric distribution. It describes many common situations, such as the size of raindrops measured over many rainstorms [1], or the time between page requests to Wikipedia [2].

Note: New code should use the `exponential` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

scale
[float or array_like of floats] The scale parameter, $\beta = 1/\lambda$. Must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `scale` is a scalar. Otherwise, `np.array(scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized exponential distribution.

See also:

random.Generator.exponential
which should be used for new code.

References

[1], [2], [3]

Examples

A real world example: Assume a company has 10000 customer support agents and the average time between customer calls is 4 minutes.

```
>>> n = 10000
>>> time_between_calls = np.random.default_rng().exponential(scale=4, size=n)
```

What is the probability that a customer will call in the next 4 to 5 minutes?

```
>>> x = ((time_between_calls < 5).sum())/n
>>> y = ((time_between_calls < 4).sum())/n
>>> x-y
0.08 # may vary
```

`random.f`(*dfnum*, *dfden*, *size=None*)

Draw samples from an F distribution.

Samples are drawn from an F distribution with specified parameters, *dfnum* (degrees of freedom in numerator) and *dfden* (degrees of freedom in denominator), where both parameters must be greater than zero.

The random variate of the F distribution (also known as the Fisher distribution) is a continuous probability distribution that arises in ANOVA tests, and is the ratio of two chi-square variates.

Note: New code should use the `f` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

dfnum
[float or array_like of floats] Degrees of freedom in numerator, must be > 0.

dfden
[float or array_like of float] Degrees of freedom in denominator, must be > 0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `dfnum` and `dfden` are both scalars. Otherwise, `np.broadcast(dfnum, dfden).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Fisher distribution.

See also:

`scipy.stats.f`
probability density function, distribution or cumulative density function, etc.

`random.Generator.f`
which should be used for new code.

Notes

The F statistic is used to compare in-group variances to between-group variances. Calculating the distribution depends on the sampling, and so it is a function of the respective degrees of freedom in the problem. The variable *dfnum* is the number of samples minus one, the between-groups degrees of freedom, while *dfden* is the within-groups degrees of freedom, the sum of the number of samples in each group minus the number of groups.

References

[1], [2]

Examples

An example from Glantz[1], pp 47-40:

Two groups, children of diabetics (25 people) and children from people without diabetes (25 controls). Fasting blood glucose was measured, case group had a mean value of 86.1, controls had a mean value of 82.2. Standard deviations were 2.09 and 2.49 respectively. Are these data consistent with the null hypothesis that the parents diabetic status does not affect their children's blood glucose levels? Calculating the F statistic from the data gives a value of 36.01.

Draw samples from the distribution:

```
>>> dfnum = 1. # between group degrees of freedom
>>> dfden = 48. # within groups degrees of freedom
>>> s = np.random.f(dfnum, dfden, 1000)
```

The lower bound for the top 1% of the samples is :

```
>>> np.sort(s)[-10]
7.61988120985 # random
```

So there is about a 1% chance that the F statistic will exceed 7.62, the measured value is 36, so the null hypothesis is rejected at the 1% level.

`random.`**`gamma`**(*shape*, *scale=1.0*, *size=None*)

Draw samples from a Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, `shape` (sometimes designated "k") and *scale* (sometimes designated "theta"), where both parameters are > 0.

Note: New code should use the `gamma` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

shape
[float or array_like of floats] The shape of the gamma distribution. Must be non-negative.

scale
[float or array_like of floats, optional] The scale of the gamma distribution. Must be non-negative. Default is equal to 1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `shape` and

`scale` are both scalars. Otherwise, `np.broadcast(shape, scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized gamma distribution.

See also:

`scipy.stats.gamma`
probability density function, distribution or cumulative density function, etc.

`random.Generator.gamma`
which should be used for new code.

Notes

The probability density for the Gamma distribution is

$$p(x) = x^{k-1}\frac{e^{-x/\theta}}{\theta^k\Gamma(k)},$$

where k is the shape and θ the scale, and Γ is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> shape, scale = 2., 2.  # mean=4, std=2*sqrt(2)
>>> s = np.random.gamma(shape, scale, 1000)
```

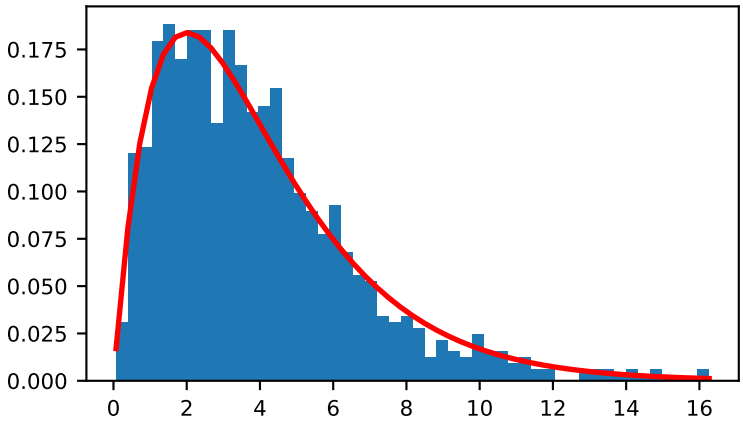
Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, ignored = plt.hist(s, 50, density=True)
>>> y = bins**(shape-1)*(np.exp(-bins/scale) /
...                      (sps.gamma(shape)*scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```

`random.`**`geometric`**(*p*, *size=None*)

Draw samples from the geometric distribution.

Bernoulli trials are experiments with one of two outcomes: success or failure (an example of such an experiment is flipping a coin). The geometric distribution models the number of trials that must be run in order to achieve success. It is therefore supported on the positive integers, `k = 1, 2, ...`.



The probability mass function of the geometric distribution is

$$f(k) = (1-p)^{k-1}p$$

where p is the probability of success of an individual trial.

Note: New code should use the `geometric` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

p
[float or array_like of floats] The probability of success of an individual trial.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `p` is a scalar. Otherwise, `np.array(p).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized geometric distribution.

See also:

random.Generator.geometric
which should be used for new code.

Examples

Draw ten thousand values from the geometric distribution, with the probability of an individual success equal to 0.35:

```
>>> z = np.random.geometric(p=0.35, size=10000)
```

How many trials succeeded after a single run?

```
>>> (z == 1).sum() / 10000.
0.34889999999999999 #random
```

random.**get_state**(*legacy=True*)

Return a tuple representing the internal state of the generator.

For more details, see *set_state*.

Parameters

legacy
[bool, optional] Flag indicating to return a legacy tuple state when the BitGenerator is MT19937, instead of a dict. Raises ValueError if the underlying bit generator is not an instance of MT19937.

Returns

out
[{tuple(str, ndarray of 624 uints, int, int, float), dict}] If legacy is True, the returned tuple has the following items:

1. the string 'MT19937'.
2. a 1-D array of 624 unsigned integer keys.
3. an integer `pos`.
4. an integer `has_gauss`.
5. a float `cached_gaussian`.

If *legacy* is False, or the BitGenerator is not MT19937, then state is returned as a dictionary.

See also:

set_state

Notes

set_state and *get_state* are not needed to work with any of the random distributions in NumPy. If the internal state is manually altered, the user should know exactly what he/she is doing.

random.**gumbel**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw samples from a Gumbel distribution.

Draw samples from a Gumbel distribution with specified location and scale. For more information on the Gumbel distribution, see Notes and References below.

Note: New code should use the *gumbel* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

loc
[float or array_like of floats, optional] The location of the mode of the distribution. Default is 0.

scale
[float or array_like of floats, optional] The scale parameter of the distribution. Default is 1. Must be non- negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Gumbel distribution.

See also:

scipy.stats.gumbel_l
scipy.stats.gumbel_r
scipy.stats.genextreme
weibull
random.Generator.gumbel
which should be used for new code.

Notes

The Gumbel (or Smallest Extreme Value (SEV) or the Smallest Extreme Value Type I) distribution is one of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems. The Gumbel is a special case of the Extreme Value Type I distribution for maximums from distributions with "exponential-like" tails.

The probability density for the Gumbel distribution is

$$p(x) = \frac{e^{-(x-\mu)/\beta}}{\beta} e^{-e^{-(x-\mu)/\beta}},$$

where μ is the mode, a location parameter, and β is the scale parameter.

The Gumbel (named for German mathematician Emil Julius Gumbel) was used very early in the hydrology literature, for modeling the occurrence of flood events. It is also used for modeling maximum wind speed and rainfall rates. It is a "fat-tailed" distribution - the probability of an event in the tail of the distribution is larger than if one used a Gaussian, hence the surprisingly frequent occurrence of 100-year floods. Floods were initially modeled as a Gaussian process, which underestimated the frequency of extreme events.

It is one of a class of extreme value distributions, the Generalized Extreme Value (GEV) distributions, which also includes the Weibull and Frechet.

The function has a mean of $\mu + 0.57721\beta$ and a variance of $\frac{\pi^2}{6}\beta^2$.

References

[1], [2]

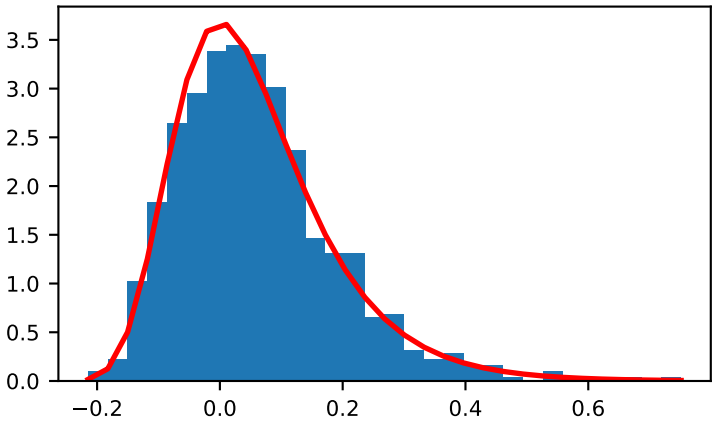
Examples

Draw samples from the distribution:

```
>>> mu, beta = 0, 0.1 # location and scale
>>> s = np.random.gumbel(mu, beta, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, density=True)
>>> plt.plot(bins, (1/beta)*np.exp(-(bins - mu)/beta)
...          * np.exp( -np.exp( -(bins - mu) /beta) ),
...          linewidth=2, color='r')
>>> plt.show()
```



Show how an extreme value distribution can arise from a Gaussian process and compare to a Gaussian:

```
>>> means = []
>>> maxima = []
>>> for i in range(0,1000) :
...    a = np.random.normal(mu, beta, 1000)
...    means.append(a.mean())
...    maxima.append(a.max())
>>> count, bins, ignored = plt.hist(maxima, 30, density=True)
>>> beta = np.std(maxima) * np.sqrt(6) / np.pi
>>> mu = np.mean(maxima) - 0.57721*beta
>>> plt.plot(bins, (1/beta)*np.exp(-(bins - mu)/beta)
...          * np.exp(-np.exp(-(bins - mu)/beta)),
...          linewidth=2, color='r')
>>> plt.plot(bins, 1/(beta * np.sqrt(2 * np.pi))
```

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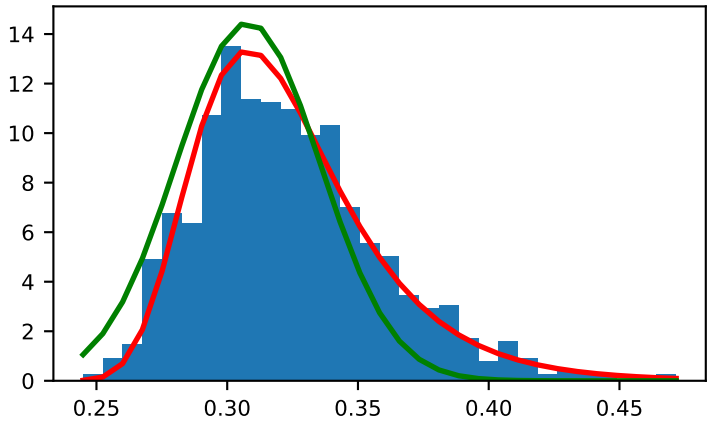
```
...           * np.exp(-(bins - mu)**2 / (2 * beta**2)),
...           linewidth=2, color='g')
>>> plt.show()
```



`random.`**`hypergeometric`**(*ngood*, *nbad*, *nsample*, *size=None*)

Draw samples from a Hypergeometric distribution.

Samples are drawn from a hypergeometric distribution with specified parameters, *ngood* (ways to make a good selection), *nbad* (ways to make a bad selection), and *nsample* (number of items sampled, which is less than or equal to the sum `ngood + nbad`).

Note: New code should use the *`hypergeometric`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

ngood
[int or array_like of ints] Number of ways to make a good selection. Must be nonnegative.

nbad
[int or array_like of ints] Number of ways to make a bad selection. Must be nonnegative.

nsample
[int or array_like of ints] Number of items sampled. Must be at least 1 and at most `ngood + nbad`.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if *ngood*, *nbad*, and *nsample* are all scalars. Otherwise, `np.broadcast(ngood, nbad, nsample).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized hypergeometric distribution. Each sample is the number of good items within a randomly selected subset of size *nsample* taken from a set of *ngood* good items and *nbad* bad items.

See also:

scipy.stats.hypergeom
: probability density function, distribution or cumulative density function, etc.

random.Generator.hypergeometric
: which should be used for new code.

Notes

The probability mass function (PMF) for the Hypergeometric distribution is

$$P(x) = \frac{\binom{g}{x}\binom{b}{n-x}}{\binom{g+b}{n}},$$

where $0 \leq x \leq n$ and $n - b \leq x \leq g$

for P(x) the probability of `x` good results in the drawn sample, g = *ngood*, b = *nbad*, and n = *nsample*.

Consider an urn with black and white marbles in it, *ngood* of them are black and *nbad* are white. If you draw *nsample* balls without replacement, then the hypergeometric distribution describes the distribution of black balls in the drawn sample.

Note that this distribution is very similar to the binomial distribution, except that in this case, samples are drawn without replacement, whereas in the Binomial case samples are drawn with replacement (or the sample space is infinite). As the sample space becomes large, this distribution approaches the binomial.

References

[1], [2], [3]

Examples

Draw samples from the distribution:

```
>>> ngood, nbad, nsamp = 100, 2, 10
# number of good, number of bad, and number of samples
>>> s = np.random.hypergeometric(ngood, nbad, nsamp, 1000)
>>> from matplotlib.pyplot import hist
>>> hist(s)
#   note that it is very unlikely to grab both bad items
```

Suppose you have an urn with 15 white and 15 black marbles. If you pull 15 marbles at random, how likely is it that 12 or more of them are one color?

```
>>> s = np.random.hypergeometric(15, 15, 15, 100000)
>>> sum(s>=12)/100000. + sum(s<=3)/100000.
#   answer = 0.003 ... pretty unlikely!
```

random.**laplace**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw samples from the Laplace or double exponential distribution with specified location (or mean) and scale (decay).

The Laplace distribution is similar to the Gaussian/normal distribution, but is sharper at the peak and has fatter tails. It represents the difference between two independent, identically distributed exponential random variables.

Note: New code should use the `laplace` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

loc
[float or array_like of floats, optional] The position, μ, of the distribution peak. Default is 0.

scale
[float or array_like of floats, optional] λ, the exponential decay. Default is 1. Must be non-negative.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Laplace distribution.

See also:

random.Generator.laplace
which should be used for new code.

Notes

It has the probability density function

$$f(x; \mu, \lambda) = \frac{1}{2\lambda} \exp\left(-\frac{|x - \mu|}{\lambda}\right).$$

The first law of Laplace, from 1774, states that the frequency of an error can be expressed as an exponential function of the absolute magnitude of the error, which leads to the Laplace distribution. For many problems in economics and health sciences, this distribution seems to model the data better than the standard Gaussian distribution.

References

[1], [2], [3], [4]

Examples

Draw samples from the distribution

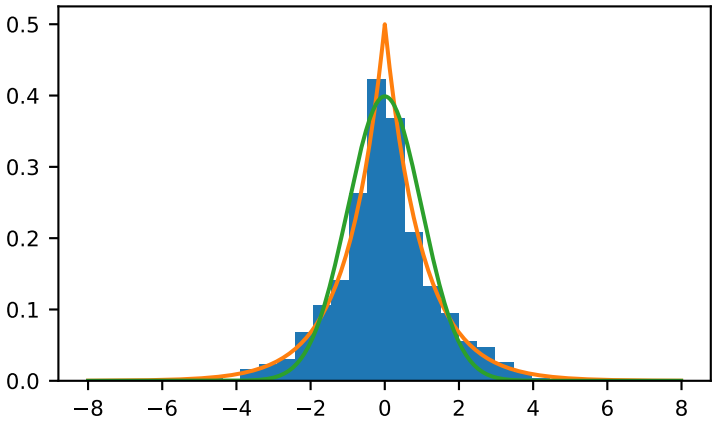
```
>>> loc, scale = 0., 1.
>>> s = np.random.laplace(loc, scale, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, density=True)
>>> x = np.arange(-8., 8., .01)
>>> pdf = np.exp(-abs(x-loc)/scale)/(2.*scale)
>>> plt.plot(x, pdf)
```

Plot Gaussian for comparison:

```
>>> g = (1/(scale * np.sqrt(2 * np.pi)) *
...      np.exp(-(x - loc)**2 / (2 * scale**2)))
>>> plt.plot(x,g)
```



`random.`**`logistic`**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw samples from a logistic distribution.

Samples are drawn from a logistic distribution with specified parameters, loc (location or mean, also median), and scale (>0).

Note: New code should use the *`logistic`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

loc

[float or array_like of floats, optional] Parameter of the distribution. Default is 0.

scale
: [float or array_like of floats, optional] Parameter of the distribution. Must be non-negative. Default is 1.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized logistic distribution.

See also:

`scipy.stats.logistic`
: probability density function, distribution or cumulative density function, etc.

`random.Generator.logistic`
: which should be used for new code.

Notes

The probability density for the Logistic distribution is

$$P(x) = P(x) = \frac{e^{-(x-\mu)/s}}{s(1+e^{-(x-\mu)/s})^2},$$

where μ = location and s = scale.

The Logistic distribution is used in Extreme Value problems where it can act as a mixture of Gumbel distributions, in Epidemiology, and by the World Chess Federation (FIDE) where it is used in the Elo ranking system, assuming the performance of each player is a logistically distributed random variable.

References

[1], [2], [3]

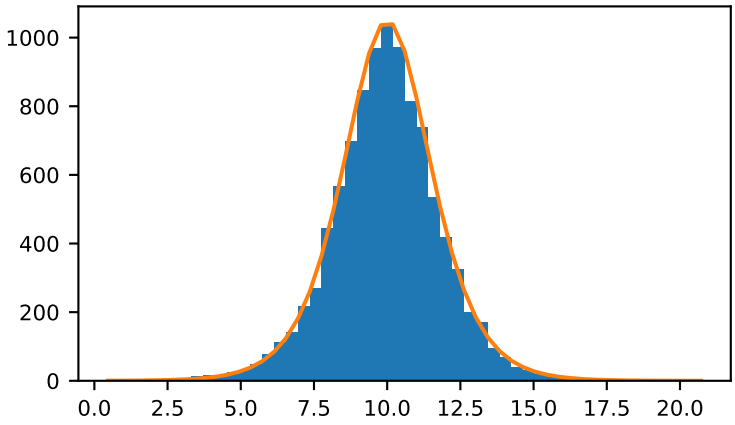
Examples

Draw samples from the distribution:

```
>>> loc, scale = 10, 1
>>> s = np.random.logistic(loc, scale, 10000)
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, bins=50)
```

plot against distribution

```
>>> def logist(x, loc, scale):
...     return np.exp((loc-x)/scale)/(scale*(1+np.exp((loc-x)/scale))**2)
>>> lgst_val = logist(bins, loc, scale)
>>> plt.plot(bins, lgst_val * count.max() / lgst_val.max())
>>> plt.show()
```



`random.`**`lognormal`**(*mean=0.0*, *sigma=1.0*, *size=None*)

Draw samples from a log-normal distribution.

Draw samples from a log-normal distribution with specified mean, standard deviation, and array shape. Note that the mean and standard deviation are not the values for the distribution itself, but of the underlying normal distribution it is derived from.

Note: New code should use the `lognormal` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

mean
[float or array_like of floats, optional] Mean value of the underlying normal distribution. Default is 0.

sigma
[float or array_like of floats, optional] Standard deviation of the underlying normal distribution. Must be non-negative. Default is 1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `mean` and `sigma` are both scalars. Otherwise, `np.broadcast(mean, sigma).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized log-normal distribution.

See also:

`scipy.stats.lognorm`
probability density function, distribution, cumulative density function, etc.

random.Generator.lognormal
which should be used for new code.

Notes

A variable *x* has a log-normal distribution if *log(x)* is normally distributed. The probability density function for the log-normal distribution is:

$$p(x) = \frac{1}{\sigma x\sqrt{2\pi}} e^{(-\frac{(ln(x)-\mu)^2}{2\sigma^2})}$$

where μ is the mean and σ is the standard deviation of the normally distributed logarithm of the variable. A log-normal distribution results if a random variable is the *product* of a large number of independent, identically-distributed variables in the same way that a normal distribution results if the variable is the *sum* of a large number of independent, identically-distributed variables.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> mu, sigma = 3., 1. # mean and standard deviation
>>> s = np.random.lognormal(mu, sigma, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 100, density=True, align='mid')
```

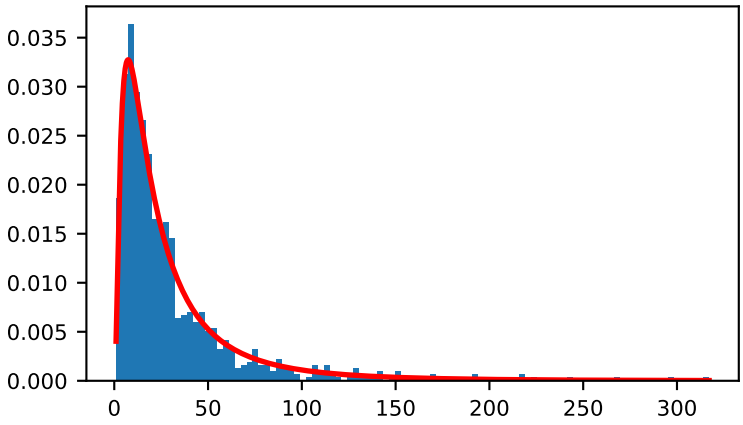
```
>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
...        / (x * sigma * np.sqrt(2 * np.pi)))
```

```
>>> plt.plot(x, pdf, linewidth=2, color='r')
>>> plt.axis('tight')
>>> plt.show()
```

Demonstrate that taking the products of random samples from a uniform distribution can be fit well by a log-normal probability density function.

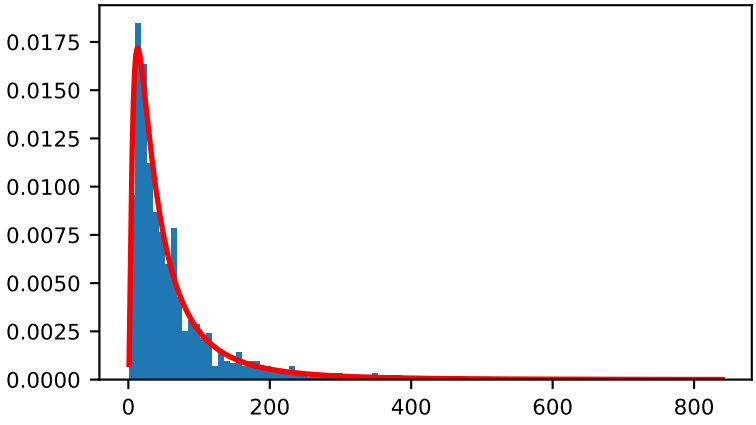
```
>>> # Generate a thousand samples: each is the product of 100 random
>>> # values, drawn from a normal distribution.
>>> b = []
>>> for i in range(1000):
...     a = 10. + np.random.standard_normal(100)
...     b.append(np.prod(a))
```

```
>>> b = np.array(b) / np.min(b) # scale values to be positive
>>> count, bins, ignored = plt.hist(b, 100, density=True, align='mid')
>>> sigma = np.std(np.log(b))
>>> mu = np.mean(np.log(b))
```




```
>>> x = np.linspace(min(bins), max(bins), 10000)
>>> pdf = (np.exp(-(np.log(x) - mu)**2 / (2 * sigma**2))
...        / (x * sigma * np.sqrt(2 * np.pi)))
```

```
>>> plt.plot(x, pdf, color='r', linewidth=2)
>>> plt.show()
```



`random.`**`logseries`**(*p*, *size=None*)

Draw samples from a logarithmic series distribution.

Samples are drawn from a log series distribution with specified shape parameter, 0 <= `p` < 1.

Note: New code should use the *`logseries`* method of a *`Generator`* instance instead; please see the *Quick*

start.

Parameters

p
[float or array_like of floats] Shape parameter for the distribution. Must be in the range [0, 1).

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `p` is a scalar. Otherwise, `np.array(p).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized logarithmic series distribution.

See also:

`scipy.stats.logser`
probability density function, distribution or cumulative density function, etc.

`random.Generator.logseries`
which should be used for new code.

Notes

The probability density for the Log Series distribution is

$$P(k) = \frac{-p^k}{k \ln(1-p)},$$

where p = probability.

The log series distribution is frequently used to represent species richness and occurrence, first proposed by Fisher, Corbet, and Williams in 1943 [2]. It may also be used to model the numbers of occupants seen in cars [3].

References

[1], [2], [3], [4]

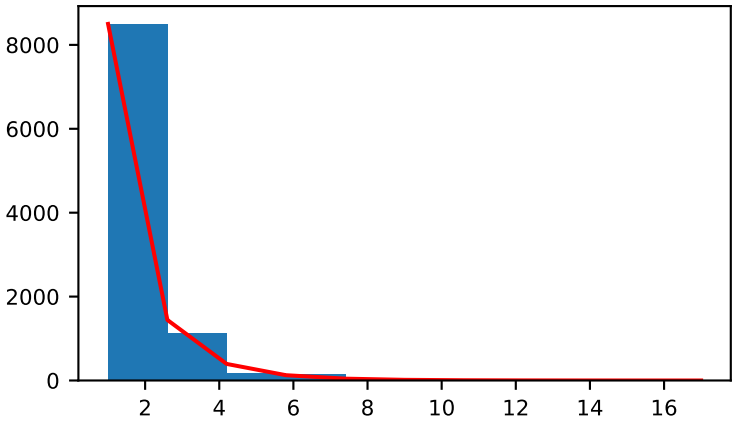
Examples

Draw samples from the distribution:

```
>>> a = .6
>>> s = np.random.logseries(a, 10000)
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s)
```

plot against distribution

```
>>> def logseries(k, p):
...     return -p**k/(k*np.log(1-p))
>>> plt.plot(bins, logseries(bins, a)*count.max()/
...          logseries(bins, a).max(), 'r')
>>> plt.show()
```



random.**multinomial**(*n*, *pvals*, *size=None*)

Draw samples from a multinomial distribution.

The multinomial distribution is a multivariate generalization of the binomial distribution. Take an experiment with one of `p` possible outcomes. An example of such an experiment is throwing a dice, where the outcome can be 1 through 6. Each sample drawn from the distribution represents *n* such experiments. Its values, `X_i = [X_0, X_1, ..., X_p]`, represent the number of times the outcome was `i`.

Note: New code should use the *`multinomial`* method of a *`Generator`* instance instead; please see the *Quick start*.

Warning: This function defaults to the C-long dtype, which is 32bit on windows and otherwise 64bit on 64bit platforms (and 32bit on 32bit ones). Since NumPy 2.0, NumPy's default integer is 32bit on 32bit platforms and 64bit on 64bit platforms.

Parameters

n
: [int] Number of experiments.

pvals
: [sequence of floats, length p] Probabilities of each of the `p` different outcomes. These must sum to 1 (however, the last element is always assumed to account for the remaining probability, as long as `sum(pvals[:-1]) <= 1)`.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m`

`* n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

out

[ndarray] The drawn samples, of shape *size*, if that was provided. If not, the shape is `(N,)`.

In other words, each entry `out[i,j,...,:]` is an N-dimensional value drawn from the distribution.

See also:

random.Generator.multinomial
which should be used for new code.

Examples

Throw a dice 20 times:

```
>>> np.random.multinomial(20, [1/6.]*6, size=1)
array([[4, 1, 7, 5, 2, 1]]) # random
```

It landed 4 times on 1, once on 2, etc.

Now, throw the dice 20 times, and 20 times again:

```
>>> np.random.multinomial(20, [1/6.]*6, size=2)
array([[3, 4, 3, 3, 4, 3], # random
       [2, 4, 3, 4, 0, 7]])
```

For the first run, we threw 3 times 1, 4 times 2, etc. For the second, we threw 2 times 1, 4 times 2, etc.

A loaded die is more likely to land on number 6:

```
>>> np.random.multinomial(100, [1/7.]*5 + [2/7.])
array([11, 16, 14, 17, 16, 26]) # random
```

The probability inputs should be normalized. As an implementation detail, the value of the last entry is ignored and assumed to take up any leftover probability mass, but this should not be relied on. A biased coin which has twice as much weight on one side as on the other should be sampled like so:

```
>>> np.random.multinomial(100, [1.0 / 3, 2.0 / 3])  # RIGHT
array([38, 62]) # random
```

not like:

```
>>> np.random.multinomial(100, [1.0, 2.0])  # WRONG
Traceback (most recent call last):
ValueError: pvals < 0, pvals > 1 or pvals contains NaNs
```

random.**multivariate_normal**(*mean*, *cov*, *size=None*, *check_valid='warn'*, *tol=1e-8*)

Draw random samples from a multivariate normal distribution.

The multivariate normal, multinormal or Gaussian distribution is a generalization of the one-dimensional normal distribution to higher dimensions. Such a distribution is specified by its mean and covariance matrix. These parameters are analogous to the mean (average or "center") and variance (standard deviation, or "width," squared) of the one-dimensional normal distribution.

Note: New code should use the *multivariate_normal* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

mean
[1-D array_like, of length N] Mean of the N-dimensional distribution.

cov
[2-D array_like, of shape (N, N)] Covariance matrix of the distribution. It must be symmetric and positive-semidefinite for proper sampling.

size
[int or tuple of ints, optional] Given a shape of, for example, `(m,n,k)`, `m*n*k` samples are generated, and packed in an *m*-by-*n*-by-*k* arrangement. Because each sample is *N*-dimensional, the output shape is `(m,n,k,N)`. If no shape is specified, a single (*N*-D) sample is returned.

check_valid
[{ 'warn', 'raise', 'ignore' }, optional] Behavior when the covariance matrix is not positive semidefinite.

tol
[float, optional] Tolerance when checking the singular values in covariance matrix. cov is cast to double before the check.

Returns

out
[ndarray] The drawn samples, of shape *size*, if that was provided. If not, the shape is `(N,)`.

In other words, each entry `out[i,j,...,:]` is an N-dimensional value drawn from the distribution.

See also:

random.Generator.multivariate_normal
which should be used for new code.

Notes

The mean is a coordinate in N-dimensional space, which represents the location where samples are most likely to be generated. This is analogous to the peak of the bell curve for the one-dimensional or univariate normal distribution.

Covariance indicates the level to which two variables vary together. From the multivariate normal distribution, we draw N-dimensional samples, $X = [x_1, x_2, ...x_N]$. The covariance matrix element C_{ij} is the covariance of x_i and x_j. The element C_{ii} is the variance of x_i (i.e. its "spread").

Instead of specifying the full covariance matrix, popular approximations include:

- Spherical covariance (*cov* is a multiple of the identity matrix)
- Diagonal covariance (*cov* has non-negative elements, and only on the diagonal)

This geometrical property can be seen in two dimensions by plotting generated data-points:

```
>>> mean = [0, 0]
>>> cov = [[1, 0], [0, 100]]  # diagonal covariance
```

Diagonal covariance means that points are oriented along x or y-axis:

```
>>> import matplotlib.pyplot as plt
>>> x, y = np.random.multivariate_normal(mean, cov, 5000).T
>>> plt.plot(x, y, 'x')
>>> plt.axis('equal')
>>> plt.show()
```

Note that the covariance matrix must be positive semidefinite (a.k.a. nonnegative-definite). Otherwise, the behavior of this method is undefined and backwards compatibility is not guaranteed.

References

[1], [2]

Examples

```
>>> mean = (1, 2)
>>> cov = [[1, 0], [0, 1]]
>>> x = np.random.multivariate_normal(mean, cov, (3, 3))
>>> x.shape
(3, 3, 2)
```

Here we generate 800 samples from the bivariate normal distribution with mean [0, 0] and covariance matrix [[6, -3], [-3, 3.5]]. The expected variances of the first and second components of the sample are 6 and 3.5, respectively, and the expected correlation coefficient is -3/sqrt(6*3.5) ≈ -0.65465.

```
>>> cov = np.array([[6, -3], [-3, 3.5]])
>>> pts = np.random.multivariate_normal([0, 0], cov, size=800)
```

Check that the mean, covariance, and correlation coefficient of the sample are close to the expected values:

```
>>> pts.mean(axis=0)
array([ 0.0326911 , -0.01280782])  # may vary
>>> np.cov(pts.T)
array([[ 5.96202397, -2.85602287],
       [-2.85602287,  3.47613949]])  # may vary
>>> np.corrcoef(pts.T)[0, 1]
-0.6273591314603949  # may vary
```

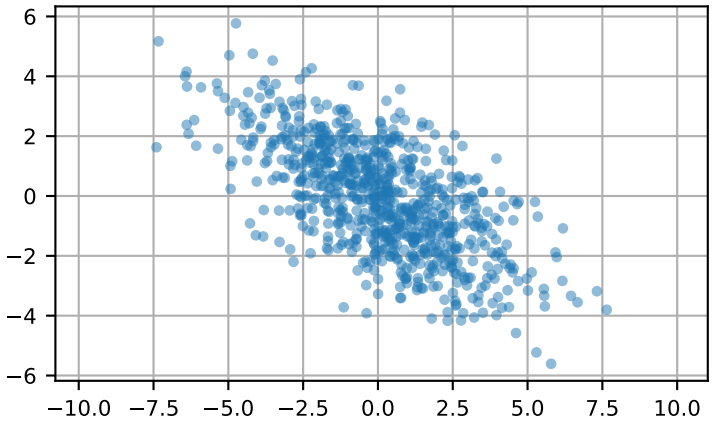
We can visualize this data with a scatter plot. The orientation of the point cloud illustrates the negative correlation of the components of this sample.

```
>>> import matplotlib.pyplot as plt
>>> plt.plot(pts[:, 0], pts[:, 1], '.', alpha=0.5)
>>> plt.axis('equal')
>>> plt.grid()
>>> plt.show()
```

random.**negative_binomial**(*n*, *p*, *size=None*)

Draw samples from a negative binomial distribution.

Samples are drawn from a negative binomial distribution with specified parameters, *n* successes and *p* probability of success where *n* is > 0 and *p* is in the interval [0, 1].



Note: New code should use the *negative_binomial* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

n
: [float or array_like of floats] Parameter of the distribution, > 0.

p
: [float or array_like of floats] Parameter of the distribution, >= 0 and <=1.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `n` and `p` are both scalars. Otherwise, `np.broadcast(n, p).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized negative binomial distribution, where each sample is equal to N, the number of failures that occurred before a total of n successes was reached.

Warning: This function returns the C-long dtype, which is 32bit on windows and otherwise 64bit on 64bit platforms (and 32bit on 32bit ones). Since NumPy 2.0, NumPy's default integer is 32bit on 32bit platforms and 64bit on 64bit platforms.

See also:

random.Generator.negative_binomial
: which should be used for new code.

Notes

The probability mass function of the negative binomial distribution is

$$P(N;n,p) = \frac{\Gamma(N+n)}{N!\Gamma(n)}p^n(1-p)^N,$$

where n is the number of successes, p is the probability of success, $N+n$ is the number of trials, and Γ is the gamma function. When n is an integer, $\frac{\Gamma(N+n)}{N!\Gamma(n)} = \binom{N+n-1}{N}$, which is the more common form of this term in the pmf. The negative binomial distribution gives the probability of N failures given n successes, with a success on the last trial.

If one throws a die repeatedly until the third time a "1" appears, then the probability distribution of the number of non-"1"s that appear before the third "1" is a negative binomial distribution.

References

[1], [2]

Examples

Draw samples from the distribution:

A real world example. A company drills wild-cat oil exploration wells, each with an estimated probability of success of 0.1. What is the probability of having one success for each successive well, that is what is the probability of a single success after drilling 5 wells, after 6 wells, etc.?

```
>>> s = np.random.negative_binomial(1, 0.1, 100000)
>>> for i in range(1, 11):
...    probability = sum(s<i) / 100000.
...    print(i, "wells drilled, probability of one success =", probability)
```

`random.`**`noncentral_chisquare`**(*df*, *nonc*, *size=None*)

Draw samples from a noncentral chi-square distribution.

The noncentral χ^2 distribution is a generalization of the χ^2 distribution.

Note: New code should use the *noncentral_chisquare* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

df
: [float or array_like of floats] Degrees of freedom, must be > 0.

nonc
: [float or array_like of floats] Non-centrality, must be non-negative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `df` and `nonc` are both scalars. Otherwise, `np.broadcast(df, nonc).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized noncentral chi-square distribution.

See also:

random.Generator.noncentral_chisquare
: which should be used for new code.

Notes

The probability density function for the noncentral Chi-square distribution is

$$P(x;df,nonc) = \sum_{i=0}^{\infty} \frac{e^{-nonc/2}(nonc/2)^i}{i!} P_{Y_{df+2i}}(x),$$

where Y_q is the Chi-square with q degrees of freedom.

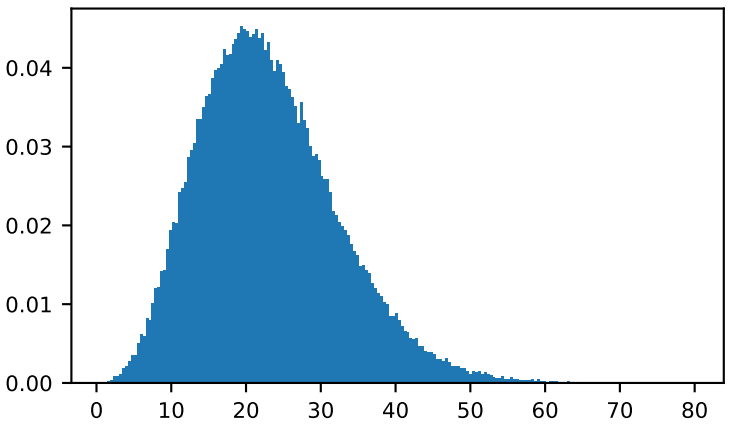
References

[1]

Examples

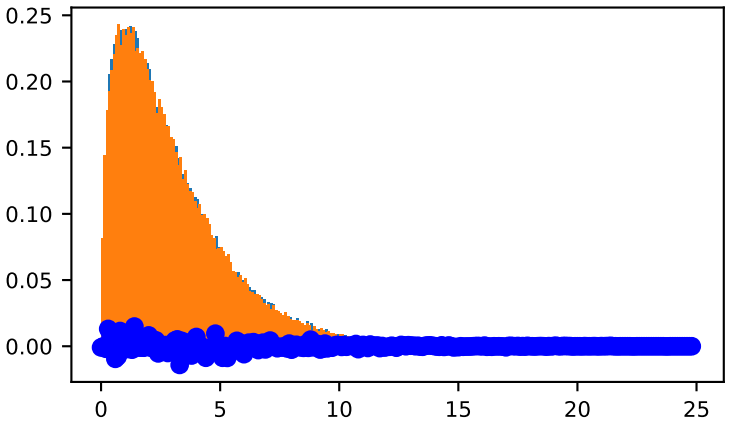
Draw values from the distribution and plot the histogram

```
>>> import matplotlib.pyplot as plt
>>> values = plt.hist(np.random.noncentral_chisquare(3, 20, 100000),
...                   bins=200, density=True)
>>> plt.show()
```



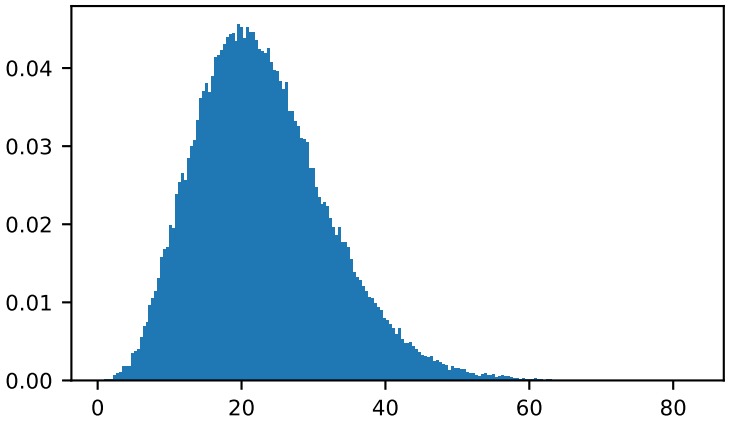
Draw values from a noncentral chisquare with very small noncentrality, and compare to a chisquare.

```
>>> plt.figure()
>>> values = plt.hist(np.random.noncentral_chisquare(3, .0000001, 100000),
...                   bins=np.arange(0., 25, .1), density=True)
>>> values2 = plt.hist(np.random.chisquare(3, 100000),
...                    bins=np.arange(0., 25, .1), density=True)
>>> plt.plot(values[1][0:-1], values[0]-values2[0], 'ob')
>>> plt.show()
```



Demonstrate how large values of non-centrality lead to a more symmetric distribution.

```
>>> plt.figure()
>>> values = plt.hist(np.random.noncentral_chisquare(3, 20, 100000),
...                   bins=200, density=True)
>>> plt.show()
```



random.**noncentral_f**(*dfnum*, *dfden*, *nonc*, *size=None*)

Draw samples from the noncentral F distribution.

Samples are drawn from an F distribution with specified parameters, *dfnum* (degrees of freedom in numerator) and *dfden* (degrees of freedom in denominator), where both parameters > 1. *nonc* is the non-centrality parameter.

Note: New code should use the `noncentral_f` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

dfnum
[float or array_like of floats] Numerator degrees of freedom, must be > 0.

dfden
[float or array_like of floats] Denominator degrees of freedom, must be > 0.

nonc
[float or array_like of floats] Non-centrality parameter, the sum of the squares of the numerator means, must be >= 0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `dfnum`, `dfden`, and `nonc` are all scalars. Otherwise, `np.broadcast(dfnum, dfden, nonc).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized noncentral Fisher distribution.

See also:

random.Generator.noncentral_f
which should be used for new code.

Notes

When calculating the power of an experiment (power = probability of rejecting the null hypothesis when a specific alternative is true) the non-central F statistic becomes important. When the null hypothesis is true, the F statistic follows a central F distribution. When the null hypothesis is not true, then it follows a non-central F statistic.

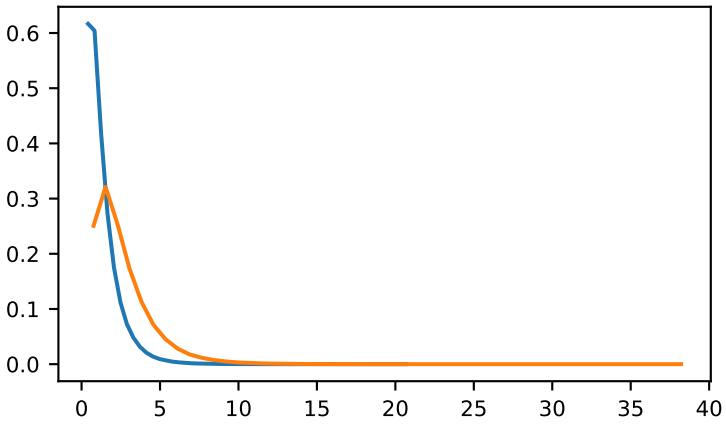
References

[1], [2]

Examples

In a study, testing for a specific alternative to the null hypothesis requires use of the Noncentral F distribution. We need to calculate the area in the tail of the distribution that exceeds the value of the F distribution for the null hypothesis. We'll plot the two probability distributions for comparison.

```
>>> dfnum = 3 # between group deg of freedom
>>> dfden = 20 # within groups degrees of freedom
>>> nonc = 3.0
>>> nc_vals = np.random.noncentral_f(dfnum, dfden, nonc, 1000000)
>>> NF = np.histogram(nc_vals, bins=50, density=True)
>>> c_vals = np.random.f(dfnum, dfden, 1000000)
>>> F = np.histogram(c_vals, bins=50, density=True)
>>> import matplotlib.pyplot as plt
>>> plt.plot(F[1][1:], F[0])
>>> plt.plot(NF[1][1:], NF[0])
>>> plt.show()
```



`random.`**`normal`**(*loc=0.0*, *scale=1.0*, *size=None*)

Draw random samples from a normal (Gaussian) distribution.

The probability density function of the normal distribution, first derived by De Moivre and 200 years later by both Gauss and Laplace independently [2], is often called the bell curve because of its characteristic shape (see the example below).

The normal distributions occurs often in nature. For example, it describes the commonly occurring distribution of samples influenced by a large number of tiny, random disturbances, each with its own unique distribution [2].

Note: New code should use the *`normal`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

loc
: [float or array_like of floats] Mean ("centre") of the distribution.

scale
: [float or array_like of floats] Standard deviation (spread or "width") of the distribution. Must be non-negative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `loc` and `scale` are both scalars. Otherwise, `np.broadcast(loc, scale).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized normal distribution.

See also:

`scipy.stats.norm`
: probability density function, distribution or cumulative density function, etc.

`random.Generator.normal`
: which should be used for new code.

Notes

The probability density for the Gaussian distribution is

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}},$$

where μ is the mean and σ the standard deviation. The square of the standard deviation, σ^2, is called the variance.

The function has its peak at the mean, and its "spread" increases with the standard deviation (the function reaches 0.607 times its maximum at $x + \sigma$ and $x - \sigma$ [2]). This implies that normal is more likely to return samples lying close to the mean, rather than those far away.

References

[1], [2]

Examples

Draw samples from the distribution:

```
>>> mu, sigma = 0, 0.1 # mean and standard deviation
>>> s = np.random.normal(mu, sigma, 1000)
```

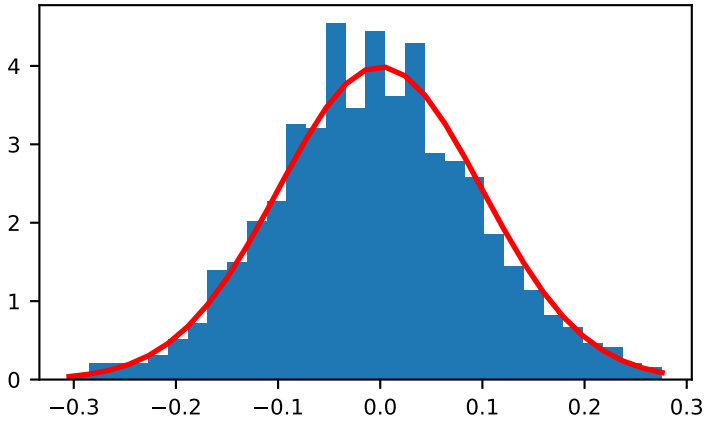
Verify the mean and the standard deviation:

```
>>> abs(mu - np.mean(s))
0.0  # may vary
```

```
>>> abs(sigma - np.std(s, ddof=1))
0.1  # may vary
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 30, density=True)
>>> plt.plot(bins, 1/(sigma * np.sqrt(2 * np.pi)) *
...                np.exp( - (bins - mu)**2 / (2 * sigma**2) ),
...          linewidth=2, color='r')
>>> plt.show()
```



Two-by-four array of samples from the normal distribution with mean 3 and standard deviation 2.5:

```
>>> np.random.normal(3, 2.5, size=(2, 4))
array([[-4.49401501,  4.00950034, -1.81814867,  7.29718677],   # random
       [ 0.39924804,  4.68456316,  4.99394529,  4.84057254]])  # random
```

random.**pareto**(*a*, *size=None*)

Draw samples from a Pareto II or Lomax distribution with specified shape.

The Lomax or Pareto II distribution is a shifted Pareto distribution. The classical Pareto distribution can be obtained from the Lomax distribution by adding 1 and multiplying by the scale parameter `m` (see Notes). The smallest value of the Lomax distribution is zero while for the classical Pareto distribution it is `mu`, where the standard Pareto distribution has location `mu = 1`. Lomax can also be considered as a simplified version of the Generalized Pareto distribution (available in SciPy), with the scale set to one and the location set to zero.

The Pareto distribution must be greater than zero, and is unbounded above. It is also known as the “80-20 rule”. In this distribution, 80 percent of the weights are in the lowest 20 percent of the range, while the other 20 percent fill the remaining 80 percent of the range.

Note: New code should use the *pareto* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

a

[float or array_like of floats] Shape of the distribution. Must be positive.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Pareto distribution.

See also:

`scipy.stats.lomax`
: probability density function, distribution or cumulative density function, etc.

`scipy.stats.genpareto`
: probability density function, distribution or cumulative density function, etc.

`random.Generator.pareto`
: which should be used for new code.

Notes

The probability density for the Pareto distribution is

$$p(x) = \frac{am^a}{x^{a+1}}$$

where a is the shape and m the scale.

The Pareto distribution, named after the Italian economist Vilfredo Pareto, is a power law probability distribution useful in many real world problems. Outside the field of economics it is generally referred to as the Bradford distribution. Pareto developed the distribution to describe the distribution of wealth in an economy. It has also found use in insurance, web page access statistics, oil field sizes, and many other problems, including the download frequency for projects in Sourceforge [1]. It is one of the so-called "fat-tailed" distributions.

References

[1], [2], [3], [4]

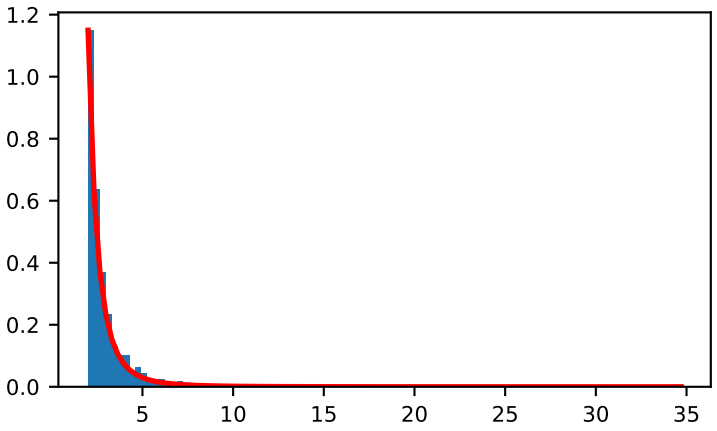
Examples

Draw samples from the distribution:

```
>>> a, m = 3., 2.  # shape and mode
>>> s = (np.random.pareto(a, 1000) + 1) * m
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, _ = plt.hist(s, 100, density=True)
>>> fit = a*m**a / bins**(a+1)
>>> plt.plot(bins, max(count)*fit/max(fit), linewidth=2, color='r')
>>> plt.show()
```



random.**permutation**(*x*)

Randomly permute a sequence, or return a permuted range.

If *x* is a multi-dimensional array, it is only shuffled along its first index.

Note: New code should use the *permutation* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

x

[int or array_like] If *x* is an integer, randomly permute `np.arange(x)`. If *x* is an array, make a copy and shuffle the elements randomly.

Returns

out

[ndarray] Permuted sequence or array range.

See also:

random.Generator.permutation
which should be used for new code.

Examples

```
>>> np.random.permutation(10)
array([1, 7, 4, 3, 0, 9, 2, 5, 8, 6]) # random
```

```
>>> np.random.permutation([1, 4, 9, 12, 15])
array([15,  1,  9,  4, 12]) # random
```

```
>>> arr = np.arange(9).reshape((3, 3))
>>> np.random.permutation(arr)
array([[6, 7, 8], # random
       [0, 1, 2],
       [3, 4, 5]])
```

random.**poisson**(*lam=1.0*, *size=None*)

Draw samples from a Poisson distribution.

The Poisson distribution is the limit of the binomial distribution for large N.

Note: New code should use the *poisson* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

lam
[float or array_like of floats] Expected number of events occurring in a fixed-time interval, must be >= 0. A sequence must be broadcastable over the requested size.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `lam` is a scalar. Otherwise, `np.array(lam).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Poisson distribution.

See also:

random.Generator.poisson
which should be used for new code.

Notes

The probability mass function (PMF) of Poisson distribution is

$$f(k;\lambda) = \frac{\lambda^k e^{-\lambda}}{k!}$$

For events with an expected separation λ the Poisson distribution $f(k;\lambda)$ describes the probability of k events occurring within the observed interval λ.

Because the output is limited to the range of the C int64 type, a ValueError is raised when *lam* is within 10 sigma of the maximum representable value.

References

[1], [2]

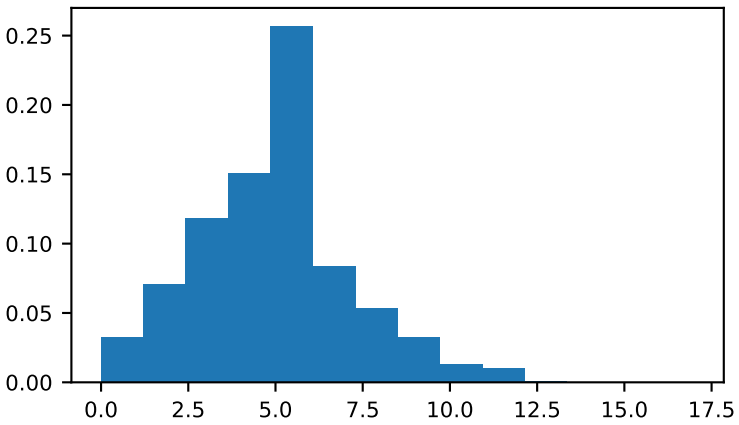
Examples

Draw samples from the distribution:

```
>>> import numpy as np
>>> s = np.random.poisson(5, 10000)
```

Display histogram of the sample:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 14, density=True)
>>> plt.show()
```



Draw each 100 values for lambda 100 and 500:

```
>>> s = np.random.poisson(lam=(100., 500.), size=(100, 2))
```

random.**power**(*a*, *size=None*)

Draws samples in [0, 1] from a power distribution with positive exponent a - 1.

Also known as the power function distribution.

Note: New code should use the *power* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

a

[float or array_like of floats] Parameter of the distribution. Must be non-negative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized power distribution.

Raises

ValueError
: If a <= 0.

See also:

random.Generator.power
: which should be used for new code.

Notes

The probability density function is

$$P(x; a) = ax^{a-1}, 0 \leq x \leq 1, a > 0.$$

The power function distribution is just the inverse of the Pareto distribution. It may also be seen as a special case of the Beta distribution.

It is used, for example, in modeling the over-reporting of insurance claims.

References

[1], [2]

Examples

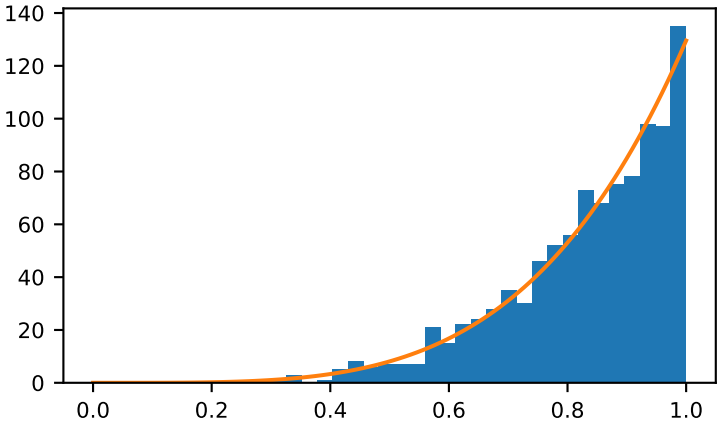
Draw samples from the distribution:

```
>>> a = 5. # shape
>>> samples = 1000
>>> s = np.random.power(a, samples)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, bins=30)
>>> x = np.linspace(0, 1, 100)
>>> y = a*x**(a-1.)
>>> normed_y = samples*np.diff(bins)[0]*y
>>> plt.plot(x, normed_y)
>>> plt.show()
```

Compare the power function distribution to the inverse of the Pareto.




```
>>> from scipy import stats
>>> rvs = np.random.power(5, 1000000)
>>> rvsp = np.random.pareto(5, 1000000)
>>> xx = np.linspace(0,1,100)
>>> powpdf = stats.powerlaw.pdf(xx,5)
```

```
>>> plt.figure()
>>> plt.hist(rvs, bins=50, density=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('np.random.power(5)')
```

```
>>> plt.figure()
>>> plt.hist(1./(1.+rvsp), bins=50, density=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('inverse of 1 + np.random.pareto(5)')
```

```
>>> plt.figure()
>>> plt.hist(1./(1.+rvsp), bins=50, density=True)
>>> plt.plot(xx,powpdf,'r-')
>>> plt.title('inverse of stats.pareto(5)')
```

random.**rand**(*d0*, *d1*, ..., *dn*)

Random values in a given shape.

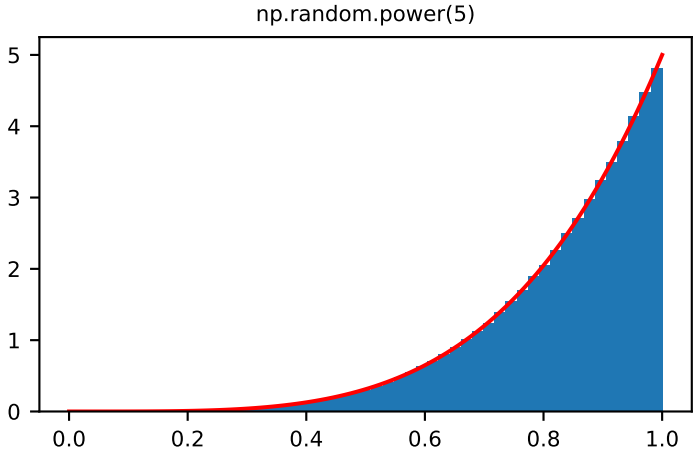
Note: This is a convenience function for users porting code from Matlab, and wraps *random_sample*. That function takes a tuple to specify the size of the output, which is consistent with other NumPy functions like *numpy.zeros* and *numpy.ones*.

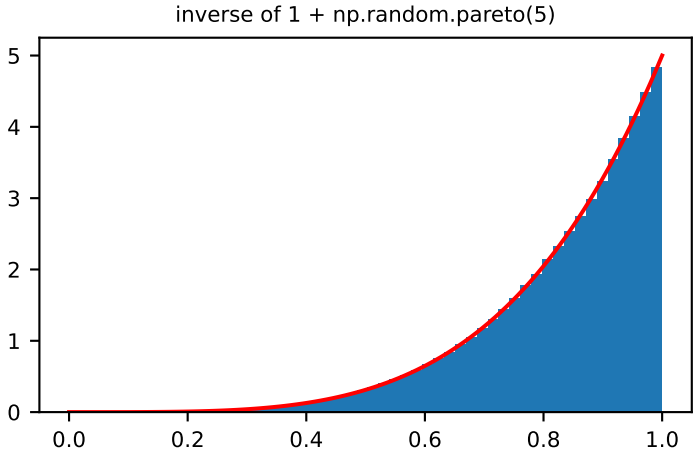
Create an array of the given shape and populate it with random samples from a uniform distribution over `[0, 1)`.

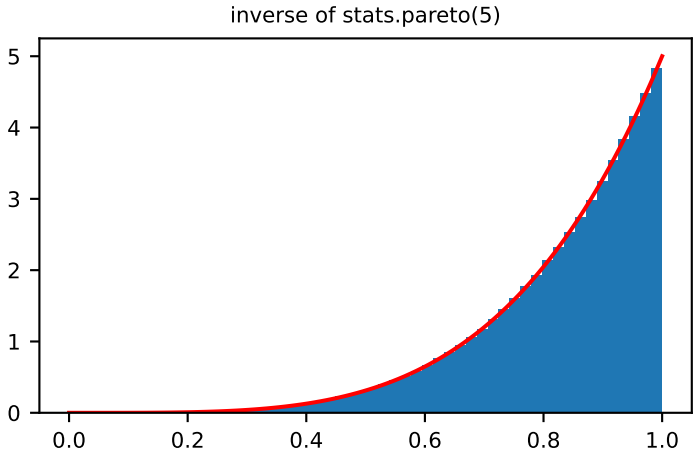
Parameters

d0, d1, …, dn

[int, optional] The dimensions of the returned array, must be non-negative. If no argument is


np.random.power(5)
5
4
3
2
1
0
0.0
0.2
0.4
0.6
0.8
1.0


inverse of 1 + np.random.pareto(5)
5
4
3
2
1
0
0.0
0.2
0.4
0.6
0.8
1.0



given a single Python float is returned.

Returns

out
[ndarray, shape `(d0, d1, ..., dn)`] Random values.

See also:

random

Examples

```
>>> np.random.rand(3,2)
array([[ 0.14022471,  0.96360618],  #random
       [ 0.37601032,  0.25528411],  #random
       [ 0.49313049,  0.94909878]]) #random
```

`random.`**`randint`**(*low*, *high=None*, *size=None*, *dtype=int*)

Return random integers from *low* (inclusive) to *high* (exclusive).

Return random integers from the "discrete uniform" distribution of the specified dtype in the "half-open" interval [*low*, *high*). If *high* is None (the default), then results are from [0, *low*).

Note: New code should use the *`integers`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

low
[int or array-like of ints] Lowest (signed) integers to be drawn from the distribution (unless `high=None`, in which case this parameter is one above the *highest* such integer).

high
[int or array-like of ints, optional] If provided, one above the largest (signed) integer to be

drawn from the distribution (see above for behavior if `high=None`). If array-like, must contain integer values

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

dtype
[dtype, optional] Desired dtype of the result. Byteorder must be native. The default value is long.

> **Warning:** This function defaults to the C-long dtype, which is 32bit on windows and otherwise 64bit on 64bit platforms (and 32bit on 32bit ones). Since NumPy 2.0, NumPy's default integer is 32bit on 32bit platforms and 64bit on 64bit platforms. Which corresponds to *np.intp*. (*dtype=int* is not the same as in most NumPy functions.)

Returns

out
[int or ndarray of ints] *size*-shaped array of random integers from the appropriate distribution, or a single such random int if *size* not provided.

See also:

random_integers
similar to *randint*, only for the closed interval [*low*, *high*], and 1 is the lowest value if *high* is omitted.

random.Generator.integers
which should be used for new code.

Examples

```
>>> np.random.randint(2, size=10)
array([1, 0, 0, 0, 1, 1, 0, 0, 1, 0]) # random
>>> np.random.randint(1, size=10)
array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0])
```

Generate a 2 x 4 array of ints between 0 and 4, inclusive:

```
>>> np.random.randint(5, size=(2, 4))
array([[4, 0, 2, 1], # random
       [3, 2, 2, 0]])
```

Generate a 1 x 3 array with 3 different upper bounds

```
>>> np.random.randint(1, [3, 5, 10])
array([2, 2, 9]) # random
```

Generate a 1 by 3 array with 3 different lower bounds

```
>>> np.random.randint([1, 5, 7], 10)
array([9, 8, 7]) # random
```

Generate a 2 by 4 array using broadcasting with dtype of uint8

```
>>> np.random.randint([1, 3, 5, 7], [[10], [20]], dtype=np.uint8)
array([[ 8,  6,  9,  7], # random
       [ 1, 16,  9, 12]], dtype=uint8)
```

random.**randn**(*d0*, *d1*, ..., *dn*)

Return a sample (or samples) from the "standard normal" distribution.

Note: This is a convenience function for users porting code from Matlab, and wraps *standard_normal*. That function takes a tuple to specify the size of the output, which is consistent with other NumPy functions like *numpy.zeros* and *numpy.ones*.

Note: New code should use the *standard_normal* method of a *Generator* instance instead; please see the *Quick start*.

If positive int_like arguments are provided, *randn* generates an array of shape `(d0, d1, ..., dn)`, filled with random floats sampled from a univariate "normal" (Gaussian) distribution of mean 0 and variance 1. A single float randomly sampled from the distribution is returned if no argument is provided.

Parameters

d0, d1, …, dn
[int, optional] The dimensions of the returned array, must be non-negative. If no argument is given a single Python float is returned.

Returns

Z
[ndarray or float] A `(d0, d1, ..., dn)`-shaped array of floating-point samples from the standard normal distribution, or a single such float if no parameters were supplied.

See also:

standard_normal
Similar, but takes a tuple as its argument.

normal
Also accepts mu and sigma arguments.

random.Generator.standard_normal
which should be used for new code.

Notes

For random samples from the normal distribution with mean `mu` and standard deviation `sigma`, use:

```
sigma * np.random.randn(...) + mu
```

Examples

```
>>> np.random.randn()
2.1923875335537315  # random
```

Two-by-four array of samples from the normal distribution with mean 3 and standard deviation 2.5:

```
>>> 3 + 2.5 * np.random.randn(2, 4)
array([[-4.49401501,  4.00950034, -1.81814867,  7.29718677],   # random
       [ 0.39924804,  4.68456316,  4.99394529,  4.84057254]])  # random
```

random.**random**(*size=None*)

Return random floats in the half-open interval [0.0, 1.0). Alias for *random_sample* to ease forward-porting to the new random API.

random.**random_integers**(*low*, *high=None*, *size=None*)

Random integers of type *numpy.int_* between *low* and *high*, inclusive.

Return random integers of type *numpy.int_* from the "discrete uniform" distribution in the closed interval [*low*, *high*]. If *high* is None (the default), then results are from [1, *low*]. The *numpy.int_* type translates to the C long integer type and its precision is platform dependent.

This function has been deprecated. Use randint instead.

Deprecated since version 1.11.0.

Parameters

low
: [int] Lowest (signed) integer to be drawn from the distribution (unless `high=None`, in which case this parameter is the *highest* such integer).

high
: [int, optional] If provided, the largest (signed) integer to be drawn from the distribution (see above for behavior if `high=None`).

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

out
: [int or ndarray of ints] *size*-shaped array of random integers from the appropriate distribution, or a single such random int if *size* not provided.

See also:

randint
: Similar to *random_integers*, only for the half-open interval [*low*, *high*), and 0 is the lowest value if *high* is omitted.

Notes

To sample from N evenly spaced floating-point numbers between a and b, use:

```
a + (b - a) * (np.random.random_integers(N) - 1) / (N - 1.)
```

Examples

```
>>> np.random.random_integers(5)
4 # random
>>> type(np.random.random_integers(5))
<class 'numpy.int64'>
>>> np.random.random_integers(5, size=(3,2))
array([[5, 4], # random
       [3, 3],
       [4, 5]])
```

Choose five random numbers from the set of five evenly-spaced numbers between 0 and 2.5, inclusive (*i.e.*, from the set $0, 5/8, 10/8, 15/8, 20/8$):

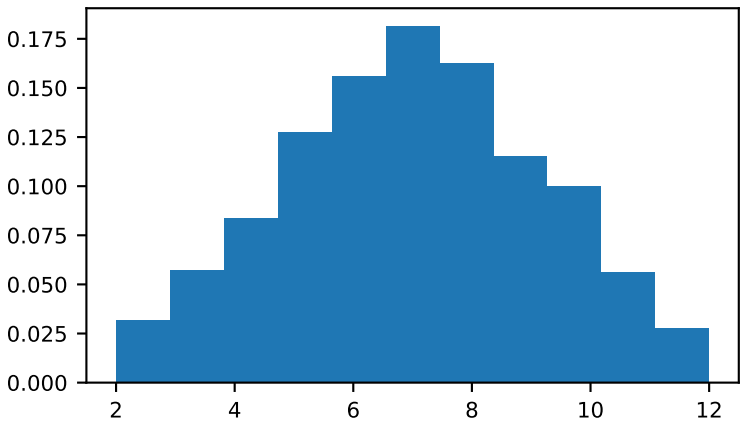
```
>>> 2.5 * (np.random.random_integers(5, size=(5,)) - 1) / 4.
array([ 0.625,  1.25 ,  0.625,  0.625,  2.5  ]) # random
```

Roll two six sided dice 1000 times and sum the results:

```
>>> d1 = np.random.random_integers(1, 6, 1000)
>>> d2 = np.random.random_integers(1, 6, 1000)
>>> dsums = d1 + d2
```

Display results as a histogram:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(dsums, 11, density=True)
>>> plt.show()
```



random.**random_sample**(*size=None*)

Return random floats in the half-open interval [0.0, 1.0).

Results are from the "continuous uniform" distribution over the stated interval. To sample $Unif[a, b), b > a$ multiply the output of *random_sample* by *(b-a)* and add a:

```
(b - a) * random_sample() + a
```

Note: New code should use the *random* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

size

[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

out

[float or ndarray of floats] Array of random floats of shape *size* (unless `size=None`, in which case a single float is returned).

See also:

random.Generator.random

which should be used for new code.

Examples

```
>>> np.random.random_sample()
0.47108547995356098 # random
>>> type(np.random.random_sample())
<class 'float'>
>>> np.random.random_sample((5,))
array([ 0.30220482,  0.86820401,  0.1654503 ,  0.11659149,  0.54323428]) # random
```

Three-by-two array of random numbers from [-5, 0):

```
>>> 5 * np.random.random_sample((3, 2)) - 5
array([[-3.99149989, -0.52338984], # random
       [-2.99091858, -0.79479508],
       [-1.23204345, -1.75224494]])
```

random.**ranf**(**args*, ***kwargs*)

This is an alias of *random_sample*. See *random_sample* for the complete documentation.

random.**rayleigh**(*scale=1.0*, *size=None*)

Draw samples from a Rayleigh distribution.

The χ and Weibull distributions are generalizations of the Rayleigh.

Note: New code should use the *rayleigh* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

scale
[float or array_like of floats, optional] Scale, also equals the mode. Must be non-negative. Default is 1.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `scale` is a scalar. Otherwise, `np.array(scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Rayleigh distribution.

See also:

random.Generator.rayleigh
which should be used for new code.

Notes

The probability density function for the Rayleigh distribution is

$$P(x;scale) = \frac{x}{scale^2}e^{\frac{-x^2}{2\cdot scale^2}}$$

The Rayleigh distribution would arise, for example, if the East and North components of the wind velocity had identical zero-mean Gaussian distributions. Then the wind speed would have a Rayleigh distribution.

References

[1], [2]

Examples

Draw values from the distribution and plot the histogram

```
>>> from matplotlib.pyplot import hist
>>> values = hist(np.random.rayleigh(3, 100000), bins=200, density=True)
```

Wave heights tend to follow a Rayleigh distribution. If the mean wave height is 1 meter, what fraction of waves are likely to be larger than 3 meters?

```
>>> meanvalue = 1
>>> modevalue = np.sqrt(2 / np.pi) * meanvalue
>>> s = np.random.rayleigh(modevalue, 1000000)
```

The percentage of waves larger than 3 meters is:

```
>>> 100.*sum(s>3)/1000000.
0.087300000000000003 # random
```

random.**sample**(**args*, ***kwargs*)

This is an alias of *random_sample*. See *random_sample* for the complete documentation.

random.**seed**(*seed=None*)

Reseed the singleton RandomState instance.

See also:

numpy.random.Generator

Notes

This is a convenience, legacy function that exists to support older code that uses the singleton RandomState. Best practice is to use a dedicated `Generator` instance rather than the random variate generation methods exposed directly in the random module.

random.**set_state**(*state*)

Set the internal state of the generator from a tuple.

For use if one has reason to manually (re-)set the internal state of the bit generator used by the RandomState instance. By default, RandomState uses the "Mersenne Twister"[1] pseudo-random number generating algorithm.

Parameters

state

[{tuple(str, ndarray of 624 uints, int, int, float), dict}] The *state* tuple has the following items:

1. the string 'MT19937', specifying the Mersenne Twister algorithm.
2. a 1-D array of 624 unsigned integers `keys`.
3. an integer `pos`.
4. an integer `has_gauss`.
5. a float `cached_gaussian`.

If state is a dictionary, it is directly set using the BitGenerators *state* property.

Returns

out

[None] Returns 'None' on success.

See also:

get_state

Notes

set_state and *get_state* are not needed to work with any of the random distributions in NumPy. If the internal state is manually altered, the user should know exactly what he/she is doing.

For backwards compatibility, the form (str, array of 624 uints, int) is also accepted although it is missing some information about the cached Gaussian value: `state = ('MT19937', keys, pos)`.

References

[1]

random.**shuffle**(*x*)

Modify a sequence in-place by shuffling its contents.

This function only shuffles the array along the first axis of a multi-dimensional array. The order of sub-arrays is changed but their contents remains the same.

Note: New code should use the *shuffle* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

x
[ndarray or MutableSequence] The array, list or mutable sequence to be shuffled.

Returns

None

See also:

random.Generator.shuffle
which should be used for new code.

Examples

```
>>> arr = np.arange(10)
>>> np.random.shuffle(arr)
>>> arr
[1 7 5 2 9 4 3 6 0 8] # random
```

Multi-dimensional arrays are only shuffled along the first axis:

```
>>> arr = np.arange(9).reshape((3, 3))
>>> np.random.shuffle(arr)
>>> arr
array([[3, 4, 5], # random
       [6, 7, 8],
       [0, 1, 2]])
```

random.**standard_cauchy**(*size=None*)

Draw samples from a standard Cauchy distribution with mode = 0.

Also known as the Lorentz distribution.

Note: New code should use the *standard_cauchy* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

samples
[ndarray or scalar] The drawn samples.

See also:

random.Generator.standard_cauchy
which should be used for new code.

Notes

The probability density function for the full Cauchy distribution is

$$P(x; x_0, \gamma) = \frac{1}{\pi\gamma\left[1 + \left(\frac{x-x_0}{\gamma}\right)^2\right]}$$

and the Standard Cauchy distribution just sets $x_0 = 0$ and $\gamma = 1$

The Cauchy distribution arises in the solution to the driven harmonic oscillator problem, and also describes spectral line broadening. It also describes the distribution of values at which a line tilted at a random angle will cut the x axis.

When studying hypothesis tests that assume normality, seeing how the tests perform on data from a Cauchy distribution is a good indicator of their sensitivity to a heavy-tailed distribution, since the Cauchy looks very much like a Gaussian distribution, but with heavier tails.

References

[1], [2], [3]

Examples

Draw samples and plot the distribution:

```
>>> import matplotlib.pyplot as plt
>>> s = np.random.standard_cauchy(1000000)
>>> s = s[(s>-25) & (s<25)]  # truncate distribution so it plots well
>>> plt.hist(s, bins=100)
>>> plt.show()
```

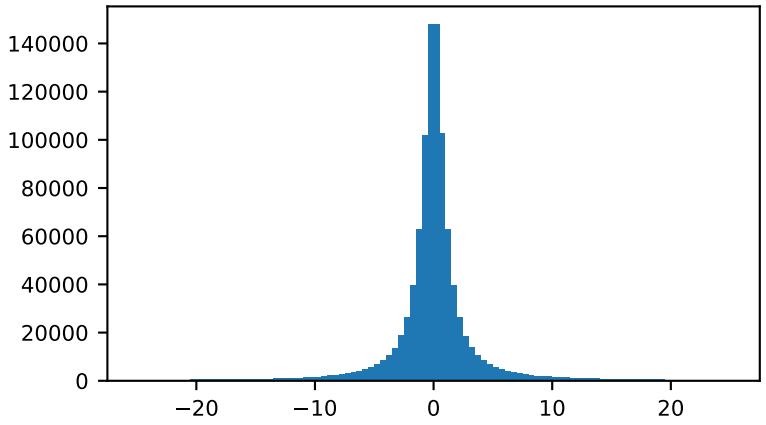
`random.`**`standard_exponential`**(*size=None*)

Draw samples from the standard exponential distribution.

standard_exponential is identical to the exponential distribution with a scale parameter of 1.

Note: New code should use the *standard_exponential* method of a *Generator* instance instead; please see the *Quick start*.

Parameters



size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

out
: [float or ndarray] Drawn samples.

See also:

`random.Generator.standard_exponential`
: which should be used for new code.

Examples

Output a 3x8000 array:

```
>>> n = np.random.standard_exponential((3, 8000))
```

`random.`**`standard_gamma`**(*shape*, *size=None*)

Draw samples from a standard Gamma distribution.

Samples are drawn from a Gamma distribution with specified parameters, shape (sometimes designated “k”) and scale=1.

Note: New code should use the *`standard_gamma`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

shape
: [float or array_like of floats] Parameter, must be non-negative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `shape` is a scalar. Otherwise, `np.array(shape).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized standard gamma distribution.

See also:

`scipy.stats.gamma`
: probability density function, distribution or cumulative density function, etc.

`random.Generator.standard_gamma`
: which should be used for new code.

Notes

The probability density for the Gamma distribution is

$$p(x) = x^{k-1}\frac{e^{-x/\theta}}{\theta^k\Gamma(k)},$$

where k is the shape and θ the scale, and Γ is the Gamma function.

The Gamma distribution is often used to model the times to failure of electronic components, and arises naturally in processes for which the waiting times between Poisson distributed events are relevant.

References

[1], [2]

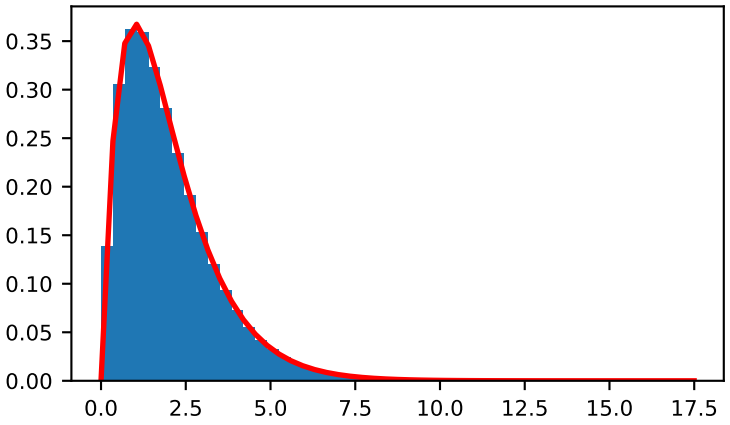
Examples

Draw samples from the distribution:

```
>>> shape, scale = 2., 1. # mean and width
>>> s = np.random.standard_gamma(shape, 1000000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> import scipy.special as sps
>>> count, bins, ignored = plt.hist(s, 50, density=True)
>>> y = bins**(shape-1) * ((np.exp(-bins/scale))/
...                        (sps.gamma(shape) * scale**shape))
>>> plt.plot(bins, y, linewidth=2, color='r')
>>> plt.show()
```



random.**standard_normal**(*size=None*)

Draw samples from a standard Normal distribution (mean=0, stdev=1).

Note: New code should use the *standard_normal* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

Returns

out
[float or ndarray] A floating-point array of shape `size` of drawn samples, or a single sample if `size` was not specified.

See also:

normal
Equivalent function with additional `loc` and `scale` arguments for setting the mean and standard deviation.

random.Generator.standard_normal
which should be used for new code.

Notes

For random samples from the normal distribution with mean `mu` and standard deviation `sigma`, use one of:

```
mu + sigma * np.random.standard_normal(size=...)
np.random.normal(mu, sigma, size=...)
```

Examples

```
>>> np.random.standard_normal()
2.1923875335537315 #random
```

```
>>> s = np.random.standard_normal(8000)
>>> s
array([ 0.6888893 ,  0.78096262, -0.89086505, ...,  0.49876311,  # random
       -0.38672696, -0.4685006 ])                                # random
>>> s.shape
(8000,)
>>> s = np.random.standard_normal(size=(3, 4, 2))
>>> s.shape
(3, 4, 2)
```

Two-by-four array of samples from the normal distribution with mean 3 and standard deviation 2.5:

```
>>> 3 + 2.5 * np.random.standard_normal(size=(2, 4))
array([[-4.49401501,  4.00950034, -1.81814867,  7.29718677],   # random
       [ 0.39924804,  4.68456316,  4.99394529,  4.84057254]])  # random
```

`random.`**`standard_t`**(*df*, *size=None*)

Draw samples from a standard Student's t distribution with *df* degrees of freedom.

A special case of the hyperbolic distribution. As *df* gets large, the result resembles that of the standard normal distribution (*`standard_normal`*).

Note: New code should use the *`standard_t`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

df
: [float or array_like of floats] Degrees of freedom, must be > 0.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `df` is a scalar. Otherwise, `np.array(df).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized standard Student's t distribution.

See also:

random.Generator.standard_t
which should be used for new code.

Notes

The probability density function for the t distribution is

$$P(x, df) = \frac{\Gamma(\frac{df+1}{2})}{\sqrt{\pi df}\,\Gamma(\frac{df}{2})}\left(1+\frac{x^2}{df}\right)^{-(df+1)/2}$$

The t test is based on an assumption that the data come from a Normal distribution. The t test provides a way to test whether the sample mean (that is the mean calculated from the data) is a good estimate of the true mean.

The derivation of the t-distribution was first published in 1908 by William Gosset while working for the Guinness Brewery in Dublin. Due to proprietary issues, he had to publish under a pseudonym, and so he used the name Student.

References

[1], [2]

Examples

From Dalgaard page 83 [1], suppose the daily energy intake for 11 women in kilojoules (kJ) is:

```
>>> intake = np.array([5260., 5470, 5640, 6180, 6390, 6515, 6805, 7515, \
...                    7515, 8230, 8770])
```

Does their energy intake deviate systematically from the recommended value of 7725 kJ? Our null hypothesis will be the absence of deviation, and the alternate hypothesis will be the presence of an effect that could be either positive or negative, hence making our test 2-tailed.

Because we are estimating the mean and we have N=11 values in our sample, we have N-1=10 degrees of freedom. We set our significance level to 95% and compute the t statistic using the empirical mean and empirical standard deviation of our intake. We use a ddof of 1 to base the computation of our empirical standard deviation on an unbiased estimate of the variance (note: the final estimate is not unbiased due to the concave nature of the square root).

```
>>> np.mean(intake)
6753.636363636364
>>> intake.std(ddof=1)
1142.1232221373727
>>> t = (np.mean(intake)-7725)/(intake.std(ddof=1)/np.sqrt(len(intake)))
>>> t
-2.8207540608310198
```

We draw 1000000 samples from Student's t distribution with the adequate degrees of freedom.

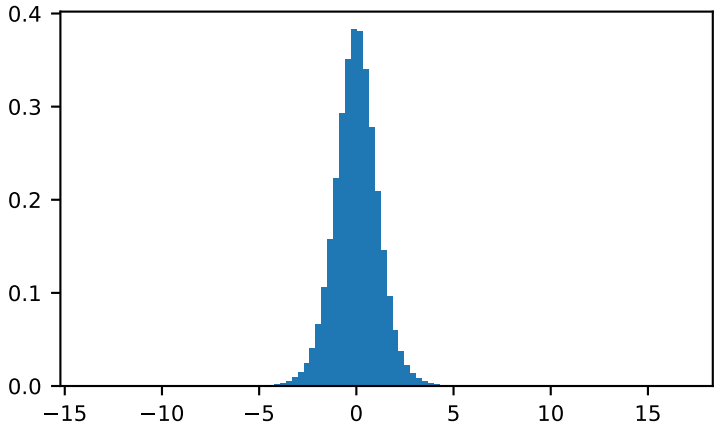
```
>>> import matplotlib.pyplot as plt
>>> s = np.random.standard_t(10, size=1000000)
>>> h = plt.hist(s, bins=100, density=True)
```

Does our t statistic land in one of the two critical regions found at both tails of the distribution?

```
>>> np.sum(np.abs(t) < np.abs(s)) / float(len(s))
0.018318  #random < 0.05, statistic is in critical region
```

The probability value for this 2-tailed test is about 1.83%, which is lower than the 5% pre-determined significance threshold.

Therefore, the probability of observing values as extreme as our intake conditionally on the null hypothesis being true is too low, and we reject the null hypothesis of no deviation.



`random.`**`triangular`**(*left*, *mode*, *right*, *size=None*)

Draw samples from the triangular distribution over the interval `[left, right]`.

The triangular distribution is a continuous probability distribution with lower limit left, peak at mode, and upper limit right. Unlike the other distributions, these parameters directly define the shape of the pdf.

Note: New code should use the *`triangular`* method of a *`Generator`* instance instead; please see the *Quick start*.

Parameters

left
[float or array_like of floats] Lower limit.

mode
[float or array_like of floats] The value where the peak of the distribution occurs. The value must fulfill the condition `left <= mode <= right`.

right
[float or array_like of floats] Upper limit, must be larger than *left*.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `left`, `mode`, and `right` are all scalars. Otherwise, `np.broadcast(left, mode, right).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized triangular distribution.

See also:

random.Generator.triangular
which should be used for new code.

Notes

The probability density function for the triangular distribution is

$$P(x;l,m,r) = \begin{cases} \frac{2(x-l)}{(r-l)(m-l)} & \text{for } l \leq x \leq m, \\ \frac{2(r-x)}{(r-l)(r-m)} & \text{for } m \leq x \leq r, \\ 0 & \text{otherwise.} \end{cases}$$

The triangular distribution is often used in ill-defined problems where the underlying distribution is not known, but some knowledge of the limits and mode exists. Often it is used in simulations.

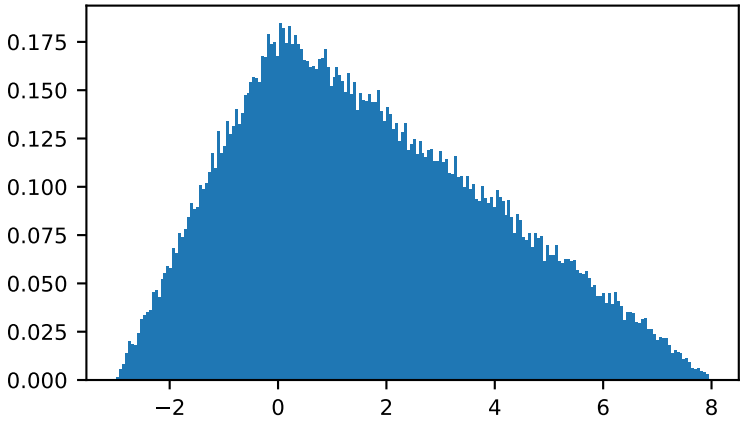
References

[1]

Examples

Draw values from the distribution and plot the histogram:

```
>>> import matplotlib.pyplot as plt
>>> h = plt.hist(np.random.triangular(-3, 0, 8, 100000), bins=200,
...              density=True)
>>> plt.show()
```



random.**uniform**(*low=0.0*, *high=1.0*, *size=None*)

Draw samples from a uniform distribution.

Samples are uniformly distributed over the half-open interval `[low, high)` (includes low, but excludes high). In other words, any value within the given interval is equally likely to be drawn by *uniform*.

Note: New code should use the *uniform* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

low
[float or array_like of floats, optional] Lower boundary of the output interval. All values generated will be greater than or equal to low. The default value is 0.

high
[float or array_like of floats] Upper boundary of the output interval. All values generated will be less than or equal to high. The high limit may be included in the returned array of floats due to floating-point rounding in the equation `low + (high-low) * random_sample()`. The default value is 1.0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `low` and `high` are both scalars. Otherwise, `np.broadcast(low, high).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized uniform distribution.

See also:

randint
Discrete uniform distribution, yielding integers.

random_integers
Discrete uniform distribution over the closed interval `[low, high]`.

random_sample
Floats uniformly distributed over `[0, 1)`.

random
Alias for *random_sample*.

rand
Convenience function that accepts dimensions as input, e.g., `rand(2,2)` would generate a 2-by-2 array of floats, uniformly distributed over `[0, 1)`.

random.Generator.uniform
which should be used for new code.

Notes

The probability density function of the uniform distribution is

$$p(x) = \frac{1}{b - a}$$

anywhere within the interval `[a, b)`, and zero elsewhere.

When `high` == `low`, values of `low` will be returned. If `high` < `low`, the results are officially undefined and may eventually raise an error, i.e. do not rely on this function to behave when passed arguments satisfying that inequality condition. The `high` limit may be included in the returned array of floats due to floating-point rounding in the equation `low + (high-low) * random_sample()`. For example:

```
>>> x = np.float32(5*0.99999999)
>>> x
np.float32(5.0)
```

Examples

Draw samples from the distribution:

```
>>> s = np.random.uniform(-1,0,1000)
```

All values are within the given interval:

```
>>> np.all(s >= -1)
True
>>> np.all(s < 0)
True
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> count, bins, ignored = plt.hist(s, 15, density=True)
>>> plt.plot(bins, np.ones_like(bins), linewidth=2, color='r')
>>> plt.show()
```

`random.`**`vonmises`**(*mu*, *kappa*, *size=None*)

Draw samples from a von Mises distribution.

Samples are drawn from a von Mises distribution with specified mode (mu) and concentration (kappa), on the interval [-pi, pi].

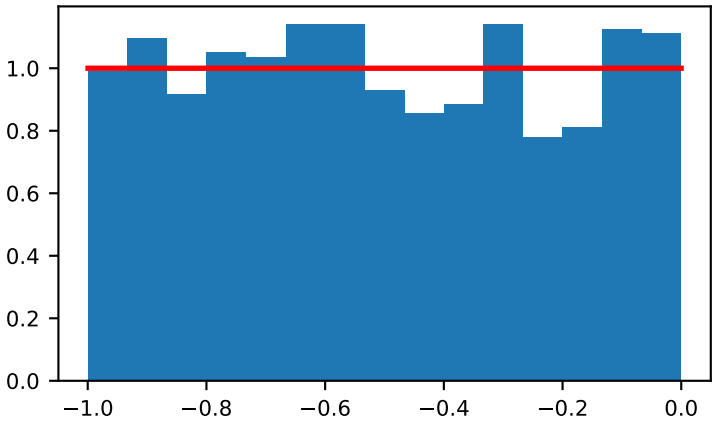
The von Mises distribution (also known as the circular normal distribution) is a continuous probability distribution on the unit circle. It may be thought of as the circular analogue of the normal distribution.

Note: New code should use the *vonmises* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

mu

[float or array_like of floats] Mode (“center”) of the distribution.



kappa
: [float or array_like of floats] Concentration of the distribution, has to be >=0.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `mu` and `kappa` are both scalars. Otherwise, `np.broadcast(mu, kappa).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized von Mises distribution.

See also:

`scipy.stats.vonmises`
: probability density function, distribution, or cumulative density function, etc.

`random.Generator.vonmises`
: which should be used for new code.

Notes

The probability density for the von Mises distribution is

$$p(x) = \frac{e^{\kappa cos(x-\mu)}}{2\pi I_0(\kappa)},$$

where μ is the mode and κ the concentration, and $I_0(\kappa)$ is the modified Bessel function of order 0.

The von Mises is named for Richard Edler von Mises, who was born in Austria-Hungary, in what is now the Ukraine. He fled to the United States in 1939 and became a professor at Harvard. He worked in probability theory, aerodynamics, fluid mechanics, and philosophy of science.

References

[1], [2]

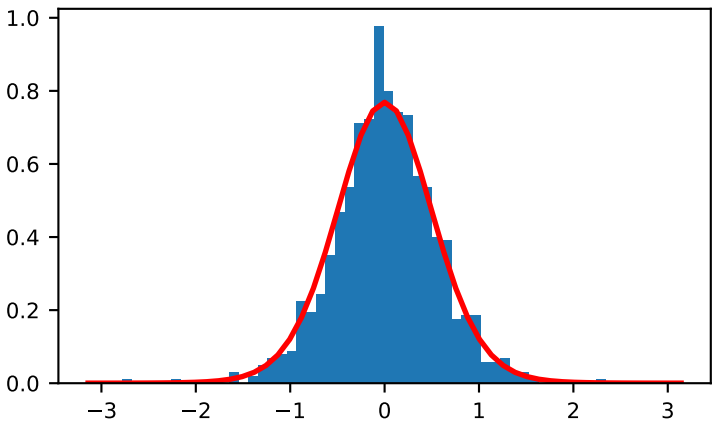
Examples

Draw samples from the distribution:

```
>>> mu, kappa = 0.0, 4.0 # mean and concentration
>>> s = np.random.vonmises(mu, kappa, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> from scipy.special import i0
>>> plt.hist(s, 50, density=True)
>>> x = np.linspace(-np.pi, np.pi, num=51)
>>> y = np.exp(kappa*np.cos(x-mu))/(2*np.pi*i0(kappa))
>>> plt.plot(x, y, linewidth=2, color='r')
>>> plt.show()
```



random.**wald**(*mean*, *scale*, *size=None*)

Draw samples from a Wald, or inverse Gaussian, distribution.

As the scale approaches infinity, the distribution becomes more like a Gaussian. Some references claim that the Wald is an inverse Gaussian with mean equal to 1, but this is by no means universal.

The inverse Gaussian distribution was first studied in relationship to Brownian motion. In 1956 M.C.K. Tweedie used the name inverse Gaussian because there is an inverse relationship between the time to cover a unit distance and distance covered in unit time.

Note: New code should use the *wald* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

mean
[float or array_like of floats] Distribution mean, must be > 0.

scale
[float or array_like of floats] Scale parameter, must be > 0.

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `mean` and `scale` are both scalars. Otherwise, `np.broadcast(mean, scale).size` samples are drawn.

Returns

out
[ndarray or scalar] Drawn samples from the parameterized Wald distribution.

See also:

random.Generator.wald
which should be used for new code.

Notes

The probability density function for the Wald distribution is

$$P(x; mean, scale) = \sqrt{\frac{scale}{2\pi x^3}} e^{\frac{-scale(x-mean)^2}{2 \cdot mean^2 x}}$$

As noted above the inverse Gaussian distribution first arise from attempts to model Brownian motion. It is also a competitor to the Weibull for use in reliability modeling and modeling stock returns and interest rate processes.

References

[1], [2], [3]

Examples

Draw values from the distribution and plot the histogram:

```
>>> import matplotlib.pyplot as plt
>>> h = plt.hist(np.random.wald(3, 2, 100000), bins=200, density=True)
>>> plt.show()
```

`random.`**`weibull`**(*a*, *size=None*)

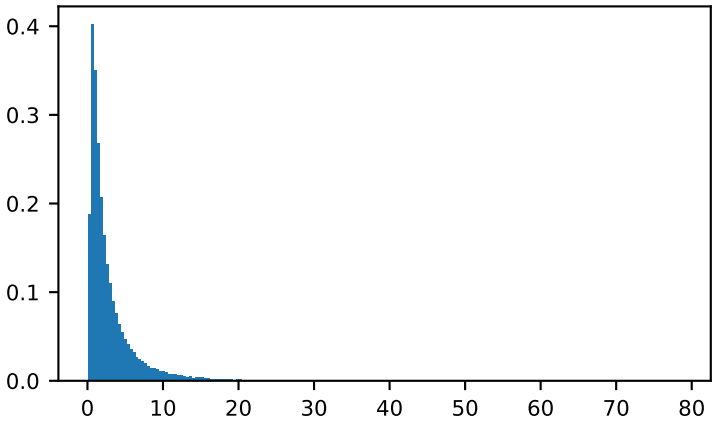
Draw samples from a Weibull distribution.

Draw samples from a 1-parameter Weibull distribution with the given shape parameter *a*.

$$X = (-ln(U))^{1/a}$$

Here, U is drawn from the uniform distribution over (0,1].

The more common 2-parameter Weibull, including a scale parameter λ is just $X = \lambda(-ln(U))^{1/a}$.



Note: New code should use the `weibull` method of a `Generator` instance instead; please see the *Quick start*.

Parameters

a
: [float or array_like of floats] Shape parameter of the distribution. Must be nonnegative.

size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Weibull distribution.

See also:

scipy.stats.weibull_max
scipy.stats.weibull_min
scipy.stats.genextreme
gumbel
random.Generator.weibull
: which should be used for new code.

Notes

The Weibull (or Type III asymptotic extreme value distribution for smallest values, SEV Type III, or Rosin-Rammler distribution) is one of a class of Generalized Extreme Value (GEV) distributions used in modeling extreme value problems. This class includes the Gumbel and Frechet distributions.

The probability density for the Weibull distribution is

$$p(x) = \frac{a}{\lambda}(\frac{x}{\lambda})^{a-1}e^{-(x/\lambda)^a},$$

where a is the shape and λ the scale.

The function has its peak (the mode) at $\lambda(\frac{a-1}{a})^{1/a}$.

When `a = 1`, the Weibull distribution reduces to the exponential distribution.

References

[1], [2], [3]

Examples

Draw samples from the distribution:

```
>>> a = 5. # shape
>>> s = np.random.weibull(a, 1000)
```

Display the histogram of the samples, along with the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> x = np.arange(1,100.)/50.
>>> def weib(x,n,a):
...     return (a / n) * (x / n)**(a - 1) * np.exp(-(x / n)**a)
```

```
>>> count, bins, ignored = plt.hist(np.random.weibull(5.,1000))
>>> x = np.arange(1,100.)/50.
>>> scale = count.max()/weib(x, 1., 5.).max()
>>> plt.plot(x, weib(x, 1., 5.)*scale)
>>> plt.show()
```

random.**zipf**(*a*, *size=None*)

Draw samples from a Zipf distribution.

Samples are drawn from a Zipf distribution with specified parameter $a > 1$.

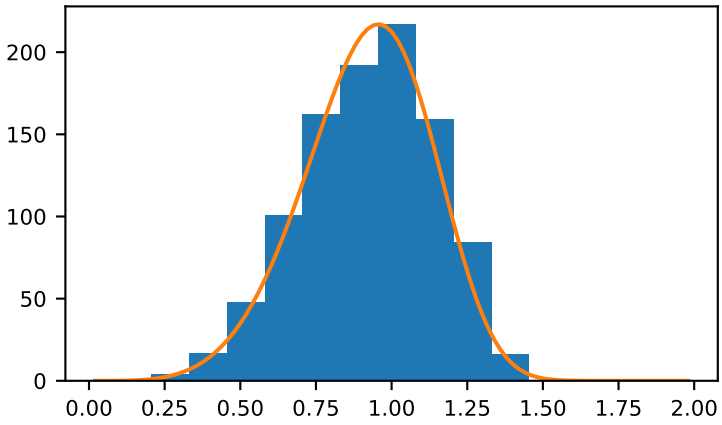
The Zipf distribution (also known as the zeta distribution) is a discrete probability distribution that satisfies Zipf's law: the frequency of an item is inversely proportional to its rank in a frequency table.

Note: New code should use the *zipf* method of a *Generator* instance instead; please see the *Quick start*.

Parameters

a

[float or array_like of floats] Distribution parameter. Must be greater than 1.



size
: [int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. If size is `None` (default), a single value is returned if `a` is a scalar. Otherwise, `np.array(a).size` samples are drawn.

Returns

out
: [ndarray or scalar] Drawn samples from the parameterized Zipf distribution.

See also:

`scipy.stats.zipf`
: probability density function, distribution, or cumulative density function, etc.

`random.Generator.zipf`
: which should be used for new code.

Notes

The probability mass function (PMF) for the Zipf distribution is

$$p(k) = \frac{k^{-a}}{\zeta(a)},$$

for integers $k \geq 1$, where ζ is the Riemann Zeta function.

It is named for the American linguist George Kingsley Zipf, who noted that the frequency of any word in a sample of a language is inversely proportional to its rank in the frequency table.

References

[1]

Examples

Draw samples from the distribution:

```
>>> a = 4.0
>>> n = 20000
>>> s = np.random.zipf(a, n)
```

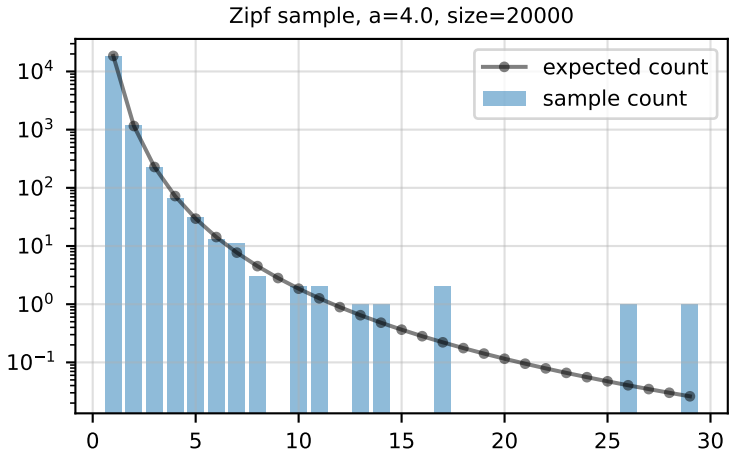
Display the histogram of the samples, along with the expected histogram based on the probability density function:

```
>>> import matplotlib.pyplot as plt
>>> from scipy.special import zeta
```

bincount provides a fast histogram for small integers.

```
>>> count = np.bincount(s)
>>> k = np.arange(1, s.max() + 1)
```

```
>>> plt.bar(k, count[1:], alpha=0.5, label='sample count')
>>> plt.plot(k, n*(k**-a)/zeta(a), 'k.-', alpha=0.5,
...          label='expected count')
>>> plt.semilogy()
>>> plt.grid(alpha=0.4)
>>> plt.legend()
>>> plt.title(f'Zipf sample, a={a}, size={n}')
>>> plt.show()
```



Bit generators

The random values produced by *Generator* originate in a BitGenerator. The BitGenerators do not directly provide random numbers and only contains methods used for seeding, getting or setting the state, jumping or advancing the state, and for accessing low-level wrappers for consumption by code that can efficiently access the functions provided, e.g., numba.

Supported BitGenerators

The included BitGenerators are:

- PCG-64 - The default. A fast generator that can be advanced by an arbitrary amount. See the documentation for *advance*. PCG-64 has a period of 2^{128}. See the PCG author's page for more details about this class of PRNG.
- PCG-64 DXSM - An upgraded version of PCG-64 with better statistical properties in parallel contexts. See *Upgrading PCG64 with PCG64DXSM* for more information on these improvements.
- MT19937 - The standard Python BitGenerator. Adds a *MT19937.jumped* function that returns a new generator with state as-if 2^{128} draws have been made.
- Philox - A counter-based generator capable of being advanced an arbitrary number of steps or generating independent streams. See the Random123 page for more details about this class of bit generators.
- SFC64 - A fast generator based on random invertible mappings. Usually the fastest generator of the four. See the SFC author's page for (a little) more detail.

BitGenerator([seed])	Base Class for generic BitGenerators, which provide a stream of random bits based on different algorithms.

class numpy.random.**BitGenerator**(*seed=None*)

Base Class for generic BitGenerators, which provide a stream of random bits based on different algorithms. Must be overridden.

Parameters

seed

[{None, int, array_like[ints], SeedSequence}, optional] A seed to initialize the *BitGenerator*. If None, then fresh, unpredictable entropy will be pulled from the OS. If an `int` or `array_like[ints]` is passed, then it will be passed to *SeedSequence* to derive the initial *BitGenerator* state. One may also pass in a *SeedSequence* instance. All integer values must be non-negative.

See also:

SeedSequence

Attributes

lock

[threading.Lock] Lock instance that is shared so that the same BitGenerator can be used in multiple Generators without corrupting the state. Code that generates values from a bit generator should hold the bit generator's lock.

Methods

random_raw(self[, size])	Return randoms as generated by the underlying BitGenerator
spawn(n_children)	Create new independent child bit generators.

method

random.BitGenerator.**random_raw**(*self*, *size=None*)

Return randoms as generated by the underlying BitGenerator

Parameters

size
[int or tuple of ints, optional] Output shape. If the given shape is, e.g., `(m, n, k)`, then `m * n * k` samples are drawn. Default is None, in which case a single value is returned.

output
[bool, optional] Output values. Used for performance testing since the generated values are not returned.

Returns

out
[uint or ndarray] Drawn samples.

Notes

This method directly exposes the raw underlying pseudo-random number generator. All values are returned as unsigned 64-bit values irrespective of the number of bits produced by the PRNG.

See the class docstring for the number of bits returned.

method

random.BitGenerator.**spawn**(*n_children*)

Create new independent child bit generators.

See *SeedSequence spawning* for additional notes on spawning children. Some bit generators also implement `jumped` as a different approach for creating independent streams.

New in version 1.25.0.

Parameters

n_children
[int]

Returns

child_bit_generators
[list of BitGenerators]

Raises

TypeError
When the underlying SeedSequence does not implement spawning.

See also:

random.Generator.spawn*, *random.SeedSequence.spawn
Equivalent method on the generator and seed sequence.

Mersenne Twister (MT19937)

class numpy.random.**MT19937**(*seed=None*)

Container for the Mersenne Twister pseudo-random number generator.

Parameters

seed
[{None, int, array_like[ints], SeedSequence}, optional] A seed to initialize the *BitGenerator*. If None, then fresh, unpredictable entropy will be pulled from the OS. If an `int` or `array_like[ints]` is passed, then it will be passed to *SeedSequence* to derive the initial *BitGenerator* state. One may also pass in a *SeedSequence* instance.

Notes

MT19937 provides a capsule containing function pointers that produce doubles, and unsigned 32 and 64- bit integers [1]. These are not directly consumable in Python and must be consumed by a *Generator* or similar object that supports low-level access.

The Python stdlib module "random" also contains a Mersenne Twister pseudo-random number generator.

State and Seeding

The *MT19937* state vector consists of a 624-element array of 32-bit unsigned integers plus a single integer value between 0 and 624 that indexes the current position within the main array.

The input seed is processed by *SeedSequence* to fill the whole state. The first element is reset such that only its most significant bit is set.

Parallel Features

The preferred way to use a BitGenerator in parallel applications is to use the *SeedSequence.spawn* method to obtain entropy values, and to use these to generate new BitGenerators:

```
>>> from numpy.random import Generator, MT19937, SeedSequence
>>> sg = SeedSequence(1234)
>>> rg = [Generator(MT19937(s)) for s in sg.spawn(10)]
```

Another method is to use *MT19937.jumped* which advances the state as-if 2^{128} random numbers have been generated ([1], [2]). This allows the original sequence to be split so that distinct segments can be used in each worker process. All generators should be chained to ensure that the segments come from the same sequence.

```
>>> from numpy.random import Generator, MT19937, SeedSequence
>>> sg = SeedSequence(1234)
>>> bit_generator = MT19937(sg)
>>> rg = []
>>> for _ in range(10):
...     rg.append(Generator(bit_generator))
...     # Chain the BitGenerators
...     bit_generator = bit_generator.jumped()
```

Compatibility Guarantee

MT19937 makes a guarantee that a fixed seed will always produce the same random integer stream.

References

[1], [2]

Attributes

lock: threading.Lock
Lock instance that is shared so that the same bit git generator can be used in multiple Generators without corrupting the state. Code that generates values from a bit generator should hold the bit generator's lock.

State

state	Get or set the PRNG state

attribute

random.MT19937.**state**

Get or set the PRNG state

Returns

state
[dict] Dictionary containing the information required to describe the state of the PRNG

Parallel generation

jumped([jumps])	Returns a new bit generator with the state jumped

method

random.MT19937.**jumped**(*jumps=1*)

Returns a new bit generator with the state jumped

The state of the returned bit generator is jumped as-if 2**(128 * jumps) random numbers have been generated.

Parameters

jumps
[integer, positive] Number of times to jump the state of the bit generator returned

Returns

bit_generator
[MT19937] New instance of generator jumped iter times

Notes

The jump step is computed using a modified version of Matsumoto's implementation of Horner's method. The step polynomial is precomputed to perform 2**128 steps. The jumped state has been verified to match the state produced using Matsumoto's original code.

References

[1], [2]

Extending

cffi	CFFI interface
ctypes	ctypes interface

attribute

random.MT19937.**cffi**

CFFI interface

Returns

interface
[namedtuple] Named tuple containing CFFI wrapper

- state_address - Memory address of the state struct
- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers
- next_uint32 - function pointer to produce 32 bit integers
- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

attribute

random.MT19937.**ctypes**

ctypes interface

Returns

interface
[namedtuple] Named tuple containing ctypes wrapper

- state_address - Memory address of the state struct
- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers
- next_uint32 - function pointer to produce 32 bit integers
- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

Permuted congruential generator (64-bit, PCG64)

class numpy.random.**PCG64**(*seed=None*)

BitGenerator for the PCG-64 pseudo-random number generator.

Parameters

seed

[{None, int, array_like[ints], SeedSequence}, optional] A seed to initialize the *BitGenerator*. If None, then fresh, unpredictable entropy will be pulled from the OS. If an `int` or `array_like[ints]` is passed, then it will be passed to *SeedSequence* to derive the initial *BitGenerator* state. One may also pass in a *SeedSequence* instance.

Notes

PCG-64 is a 128-bit implementation of O'Neill's permutation congruential generator ([1], [2]). PCG-64 has a period of 2^{128} and supports advancing an arbitrary number of steps as well as 2^{127} streams. The specific member of the PCG family that we use is PCG XSL RR 128/64 as described in the paper ([2]).

PCG64 provides a capsule containing function pointers that produce doubles, and unsigned 32 and 64- bit integers. These are not directly consumable in Python and must be consumed by a *Generator* or similar object that supports low-level access.

Supports the method *advance* to advance the RNG an arbitrary number of steps. The state of the PCG-64 RNG is represented by 2 128-bit unsigned integers.

State and Seeding

The *PCG64* state vector consists of 2 unsigned 128-bit values, which are represented externally as Python ints. One is the state of the PRNG, which is advanced by a linear congruential generator (LCG). The second is a fixed odd increment used in the LCG.

The input seed is processed by *SeedSequence* to generate both values. The increment is not independently settable.

Parallel Features

The preferred way to use a BitGenerator in parallel applications is to use the *SeedSequence.spawn* method to obtain entropy values, and to use these to generate new BitGenerators:

```
>>> from numpy.random import Generator, PCG64, SeedSequence
>>> sg = SeedSequence(1234)
>>> rg = [Generator(PCG64(s)) for s in sg.spawn(10)]
```

Compatibility Guarantee

PCG64 makes a guarantee that a fixed seed will always produce the same random integer stream.

References

[1], [2]

State

state	Get or set the PRNG state

attribute

random.PCG64.**state**

Get or set the PRNG state

Returns

state
[dict] Dictionary containing the information required to describe the state of the PRNG

Parallel generation

advance(delta)	Advance the underlying RNG as-if delta draws have occurred.
jumped([jumps])	Returns a new bit generator with the state jumped.

method

random.PCG64.**advance**(*delta*)

Advance the underlying RNG as-if delta draws have occurred.

Parameters

delta
[integer, positive] Number of draws to advance the RNG. Must be less than the size state variable in the underlying RNG.

Returns

self
[PCG64] RNG advanced delta steps

Notes

Advancing a RNG updates the underlying RNG state as-if a given number of calls to the underlying RNG have been made. In general there is not a one-to-one relationship between the number output random values from a particular distribution and the number of draws from the core RNG. This occurs for two reasons:

- The random values are simulated using a rejection-based method and so, on average, more than one value from the underlying RNG is required to generate an single draw.
- The number of bits required to generate a simulated value differs from the number of bits generated by the underlying RNG. For example, two 16-bit integer values can be simulated from a single draw of a 32-bit RNG.

Advancing the RNG state resets any pre-computed random numbers. This is required to ensure exact reproducibility.

method

random.PCG64.**jumped**(*jumps=1*)

Returns a new bit generator with the state jumped.

Jumps the state as-if jumps * 210306068529402873165736369884012333109 random numbers have been generated.

Parameters

jumps
[integer, positive] Number of times to jump the state of the bit generator returned

Returns

bit_generator
[PCG64] New instance of generator jumped iter times

Notes

The step size is phi-1 when multiplied by 2**128 where phi is the golden ratio.

Extending

cffi	CFFI interface
ctypes	ctypes interface

attribute

random.PCG64.**cffi**

CFFI interface

Returns

interface
[namedtuple] Named tuple containing CFFI wrapper

- state_address - Memory address of the state struct
- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers
- next_uint32 - function pointer to produce 32 bit integers
- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

attribute

random.PCG64.**ctypes**

ctypes interface

Returns

interface
[namedtuple] Named tuple containing ctypes wrapper

- state_address - Memory address of the state struct
- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers
- next_uint32 - function pointer to produce 32 bit integers
- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

Permuted congruential generator (64-bit, PCG64 DXSM)

class numpy.random.**PCG64DXSM**(*seed=None*)

BitGenerator for the PCG-64 DXSM pseudo-random number generator.

Parameters

seed
[{None, int, array_like[ints], SeedSequence}, optional] A seed to initialize the *BitGenerator*. If None, then fresh, unpredictable entropy will be pulled from the OS. If an `int` or `array_like[ints]` is passed, then it will be passed to *SeedSequence* to derive the initial *BitGenerator* state. One may also pass in a *SeedSequence* instance.

Notes

PCG-64 DXSM is a 128-bit implementation of O'Neill's permutation congruential generator ([1], [2]). PCG-64 DXSM has a period of 2^{128} and supports advancing an arbitrary number of steps as well as 2^{127} streams. The specific member of the PCG family that we use is PCG CM DXSM 128/64. It differs from *PCG64* in that it uses the stronger DXSM output function, a 64-bit "cheap multiplier" in the LCG, and outputs from the state before advancing it rather than advance-then-output.

PCG64DXSM provides a capsule containing function pointers that produce doubles, and unsigned 32 and 64- bit integers. These are not directly consumable in Python and must be consumed by a *Generator* or similar object that supports low-level access.

Supports the method *advance* to advance the RNG an arbitrary number of steps. The state of the PCG-64 DXSM RNG is represented by 2 128-bit unsigned integers.

State and Seeding

The *PCG64DXSM* state vector consists of 2 unsigned 128-bit values, which are represented externally as Python ints. One is the state of the PRNG, which is advanced by a linear congruential generator (LCG). The second is a fixed odd increment used in the LCG.

The input seed is processed by *SeedSequence* to generate both values. The increment is not independently settable.

Parallel Features

The preferred way to use a BitGenerator in parallel applications is to use the *SeedSequence.spawn* method to obtain entropy values, and to use these to generate new BitGenerators:

```
>>> from numpy.random import Generator, PCG64DXSM, SeedSequence
>>> sg = SeedSequence(1234)
>>> rg = [Generator(PCG64DXSM(s)) for s in sg.spawn(10)]
```

Compatibility Guarantee

PCG64DXSM makes a guarantee that a fixed seed will always produce the same random integer stream.

References

[1], [2]

State

state	Get or set the PRNG state

attribute

random.PCG64DXSM.**state**

Get or set the PRNG state

Returns

state
[dict] Dictionary containing the information required to describe the state of the PRNG

Parallel generation

advance(delta)	Advance the underlying RNG as-if delta draws have occurred.
jumped([jumps])	Returns a new bit generator with the state jumped.

method

random.PCG64DXSM.**advance**(*delta*)

Advance the underlying RNG as-if delta draws have occurred.

Parameters

delta
[integer, positive] Number of draws to advance the RNG. Must be less than the size state variable in the underlying RNG.

Returns

self
[PCG64] RNG advanced delta steps

Notes

Advancing a RNG updates the underlying RNG state as-if a given number of calls to the underlying RNG have been made. In general there is not a one-to-one relationship between the number output random values from a particular distribution and the number of draws from the core RNG. This occurs for two reasons:

- The random values are simulated using a rejection-based method and so, on average, more than one value from the underlying RNG is required to generate an single draw.
- The number of bits required to generate a simulated value differs from the number of bits generated by the underlying RNG. For example, two 16-bit integer values can be simulated from a single draw of a 32-bit RNG.

Advancing the RNG state resets any pre-computed random numbers. This is required to ensure exact reproducibility.

method

random.PCG64DXSM.**jumped**(*jumps=1*)

Returns a new bit generator with the state jumped.

Jumps the state as-if jumps * 210306068529402873165736369884012333109 random numbers have been generated.

Parameters

jumps
[integer, positive] Number of times to jump the state of the bit generator returned

Returns

bit_generator
[PCG64DXSM] New instance of generator jumped iter times

Notes

The step size is phi-1 when multiplied by 2**128 where phi is the golden ratio.

Extending

cffi	CFFI interface
ctypes	ctypes interface

attribute

random.PCG64DXSM.**cffi**

CFFI interface

Returns

interface
[namedtuple] Named tuple containing CFFI wrapper

- state_address - Memory address of the state struct
- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers

- next_uint32 - function pointer to produce 32 bit integers
- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

attribute

`random.PCG64DXSM.`**`ctypes`**

ctypes interface

Returns

interface

[namedtuple] Named tuple containing ctypes wrapper

- state_address - Memory address of the state struct
- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers
- next_uint32 - function pointer to produce 32 bit integers
- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

Philox counter-based RNG

`class` `numpy.random.`**`Philox`**(*seed=None*, *counter=None*, *key=None*)

Container for the Philox (4x64) pseudo-random number generator.

Parameters

seed

[{None, int, array_like[ints], SeedSequence}, optional] A seed to initialize the *`BitGenerator`*. If None, then fresh, unpredictable entropy will be pulled from the OS. If an `int` or `array_like[ints]` is passed, then it will be passed to *`SeedSequence`* to derive the initial *`BitGenerator`* state. One may also pass in a *`SeedSequence`* instance.

counter

[{None, int, array_like}, optional] Counter to use in the Philox state. Can be either a Python int (long in 2.x) in [0, 2**256) or a 4-element uint64 array. If not provided, the RNG is initialized at 0.

key

[{None, int, array_like}, optional] Key to use in the Philox state. Unlike `seed`, the value in key is directly set. Can be either a Python int in [0, 2**128) or a 2-element uint64 array. *key* and `seed` cannot both be used.

Notes

Philox is a 64-bit PRNG that uses a counter-based design based on weaker (and faster) versions of cryptographic functions [1]. Instances using different values of the key produce independent sequences. Philox has a period of $2^{256} - 1$ and supports arbitrary advancing and jumping the sequence in increments of 2^{128}. These features allow multiple non-overlapping sequences to be generated.

Philox provides a capsule containing function pointers that produce doubles, and unsigned 32 and 64- bit integers. These are not directly consumable in Python and must be consumed by a *Generator* or similar object that supports low-level access.

State and Seeding

The *Philox* state vector consists of a 256-bit value encoded as a 4-element uint64 array and a 128-bit value encoded as a 2-element uint64 array. The former is a counter which is incremented by 1 for every 4 64-bit randoms produced. The second is a key which determined the sequence produced. Using different keys produces independent sequences.

The input `seed` is processed by *SeedSequence* to generate the key. The counter is set to 0.

Alternately, one can omit the `seed` parameter and set the `key` and `counter` directly.

Parallel Features

The preferred way to use a BitGenerator in parallel applications is to use the *SeedSequence.spawn* method to obtain entropy values, and to use these to generate new BitGenerators:

```
>>> from numpy.random import Generator, Philox, SeedSequence
>>> sg = SeedSequence(1234)
>>> rg = [Generator(Philox(s)) for s in sg.spawn(10)]
```

Philox can be used in parallel applications by calling the *jumped* method to advance the state as-if 2^{128} random numbers have been generated. Alternatively, *advance* can be used to advance the counter for any positive step in [0, 2**256). When using *jumped*, all generators should be chained to ensure that the segments come from the same sequence.

```
>>> from numpy.random import Generator, Philox
>>> bit_generator = Philox(1234)
>>> rg = []
>>> for _ in range(10):
...     rg.append(Generator(bit_generator))
...     bit_generator = bit_generator.jumped()
```

Alternatively, *Philox* can be used in parallel applications by using a sequence of distinct keys where each instance uses different key.

```
>>> key = 2**96 + 2**33 + 2**17 + 2**9
>>> rg = [Generator(Philox(key=key+i)) for i in range(10)]
```

Compatibility Guarantee

Philox makes a guarantee that a fixed `seed` will always produce the same random integer stream.

References

[1]

Examples

```
>>> from numpy.random import Generator, Philox
>>> rg = Generator(Philox(1234))
>>> rg.standard_normal()
0.123  # random
```

Attributes

lock: threading.Lock
Lock instance that is shared so that the same bit git generator can be used in multiple Generators without corrupting the state. Code that generates values from a bit generator should hold the bit generator's lock.

State

state	Get or set the PRNG state

attribute

random.Philox.**state**
Get or set the PRNG state

Returns

state
[dict] Dictionary containing the information required to describe the state of the PRNG

Parallel generation

advance(delta)	Advance the underlying RNG as-if delta draws have occurred.
jumped([jumps])	Returns a new bit generator with the state jumped

method

random.Philox.**advance**(*delta*)
Advance the underlying RNG as-if delta draws have occurred.

Parameters

delta
[integer, positive] Number of draws to advance the RNG. Must be less than the size state variable in the underlying RNG.

Returns

self
[Philox] RNG advanced delta steps

Notes

Advancing a RNG updates the underlying RNG state as-if a given number of calls to the underlying RNG have been made. In general there is not a one-to-one relationship between the number output random values from a particular distribution and the number of draws from the core RNG. This occurs for two reasons:

- The random values are simulated using a rejection-based method and so, on average, more than one value from the underlying RNG is required to generate an single draw.
- The number of bits required to generate a simulated value differs from the number of bits generated by the underlying RNG. For example, two 16-bit integer values can be simulated from a single draw of a 32-bit RNG.

Advancing the RNG state resets any pre-computed random numbers. This is required to ensure exact reproducibility.

method

random.Philox.**jumped**(*jumps=1*)

Returns a new bit generator with the state jumped

The state of the returned bit generator is jumped as-if (2**128) * jumps random numbers have been generated.

Parameters

jumps
[integer, positive] Number of times to jump the state of the bit generator returned

Returns

bit_generator
[Philox] New instance of generator jumped iter times

Extending

cffi	CFFI interface
ctypes	ctypes interface

attribute

random.Philox.**cffi**

CFFI interface

Returns

interface
[namedtuple] Named tuple containing CFFI wrapper

- state_address - Memory address of the state struct
- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers
- next_uint32 - function pointer to produce 32 bit integers

- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

attribute

random.Philox.**ctypes**

ctypes interface

Returns

interface

[namedtuple] Named tuple containing ctypes wrapper

- state_address - Memory address of the state struct
- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers
- next_uint32 - function pointer to produce 32 bit integers
- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

SFC64 Small Fast Chaotic PRNG

class numpy.random.**SFC64**(*seed=None*)

BitGenerator for Chris Doty-Humphrey's Small Fast Chaotic PRNG.

Parameters

seed

[{None, int, array_like[ints], SeedSequence}, optional] A seed to initialize the *BitGenerator*. If None, then fresh, unpredictable entropy will be pulled from the OS. If an `int` or `array_like[ints]` is passed, then it will be passed to *SeedSequence* to derive the initial *BitGenerator* state. One may also pass in a *SeedSequence* instance.

Notes

SFC64 is a 256-bit implementation of Chris Doty-Humphrey's Small Fast Chaotic PRNG ([1]). *SFC64* has a few different cycles that one might be on, depending on the seed; the expected period will be about 2^{255} ([2]). *SFC64* incorporates a 64-bit counter which means that the absolute minimum cycle length is 2^{64} and that distinct seeds will not run into each other for at least 2^{64} iterations.

SFC64 provides a capsule containing function pointers that produce doubles, and unsigned 32 and 64- bit integers. These are not directly consumable in Python and must be consumed by a *Generator* or similar object that supports low-level access.

State and Seeding

The *SFC64* state vector consists of 4 unsigned 64-bit values. The last is a 64-bit counter that increments by 1 each iteration.

The input seed is processed by *SeedSequence* to generate the first 3 values, then the *SFC64* algorithm is iterated a small number of times to mix.

Compatibility Guarantee

SFC64 makes a guarantee that a fixed seed will always produce the same random integer stream.

References

[1], [2]

State

state	Get or set the PRNG state

attribute

random.SFC64.**state**

Get or set the PRNG state

Returns

state

[dict] Dictionary containing the information required to describe the state of the PRNG

Extending

cffi	CFFI interface
ctypes	ctypes interface

attribute

random.SFC64.**cffi**

CFFI interface

Returns

interface

[namedtuple] Named tuple containing CFFI wrapper

- state_address - Memory address of the state struct
- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers
- next_uint32 - function pointer to produce 32 bit integers
- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

attribute

random.SFC64.**ctypes**

ctypes interface

Returns

interface

[namedtuple] Named tuple containing ctypes wrapper

- state_address - Memory address of the state struct

- state - pointer to the state struct
- next_uint64 - function pointer to produce 64 bit integers
- next_uint32 - function pointer to produce 32 bit integers
- next_double - function pointer to produce doubles
- bitgen - pointer to the bit generator struct

Seeding and entropy

A BitGenerator provides a stream of random values. In order to generate reproducible streams, BitGenerators support setting their initial state via a seed. All of the provided BitGenerators will take an arbitrary-sized non-negative integer, or a list of such integers, as a seed. BitGenerators need to take those inputs and process them into a high-quality internal state for the BitGenerator. All of the BitGenerators in numpy delegate that task to *SeedSequence*, which uses hashing techniques to ensure that even low-quality seeds generate high-quality initial states.

```
from numpy.random import PCG64

bg = PCG64(12345678903141592653589793)
```

SeedSequence is designed to be convenient for implementing best practices. We recommend that a stochastic program defaults to using entropy from the OS so that each run is different. The program should print out or log that entropy. In order to reproduce a past value, the program should allow the user to provide that value through some mechanism, a command-line argument is common, so that the user can then re-enter that entropy to reproduce the result. *SeedSequence* can take care of everything except for communicating with the user, which is up to you.

```
from numpy.random import PCG64, SeedSequence

# Get the user's seed somehow, maybe through `argparse`.
# If the user did not provide a seed, it should return `None`.
seed = get_user_seed()
ss = SeedSequence(seed)
print('seed = {}'.format(ss.entropy))
bg = PCG64(ss)
```

We default to using a 128-bit integer using entropy gathered from the OS. This is a good amount of entropy to initialize all of the generators that we have in numpy. We do not recommend using small seeds below 32 bits for general use. Using just a small set of seeds to instantiate larger state spaces means that there are some initial states that are impossible to reach. This creates some biases if everyone uses such values.

There will not be anything *wrong* with the results, per se; even a seed of 0 is perfectly fine thanks to the processing that *SeedSequence* does. If you just need *some* fixed value for unit tests or debugging, feel free to use whatever seed you like. But if you want to make inferences from the results or publish them, drawing from a larger set of seeds is good practice.

If you need to generate a good seed "offline", then `SeedSequence().entropy` or using `secrets.randbits(128)` from the standard library are both convenient ways.

If you need to run several stochastic simulations in parallel, best practice is to construct a random generator instance for each simulation. To make sure that the random streams have distinct initial states, you can use the *spawn* method of *SeedSequence*. For instance, here we construct a list of 12 instances:

```
from numpy.random import PCG64, SeedSequence

# High quality initial entropy
```

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```
entropy = 0x87351080e25cb0fad77a44a3be03b491
base_seq = SeedSequence(entropy)
child_seqs = base_seq.spawn(12)     # a list of 12 SeedSequences
generators = [PCG64(seq) for seq in child_seqs]
```

If you already have an initial random generator instance, you can shorten the above by using the *spawn* method:

```
from numpy.random import PCG64, SeedSequence
# High quality initial entropy
entropy = 0x87351080e25cb0fad77a44a3be03b491
base_bitgen = PCG64(entropy)
generators = base_bitgen.spawn(12)
```

An alternative way is to use the fact that a *SeedSequence* can be initialized by a tuple of elements. Here we use a base entropy value and an integer `worker_id`

```
from numpy.random import PCG64, SeedSequence

# High quality initial entropy
entropy = 0x87351080e25cb0fad77a44a3be03b491
sequences = [SeedSequence((entropy, worker_id)) for worker_id in range(12)]
generators = [PCG64(seq) for seq in sequences]
```

Note that the sequences produced by the latter method will be distinct from those constructed via *spawn*.

SeedSequence([entropy, spawn_key, pool_size])	SeedSequence mixes sources of entropy in a reproducible way to set the initial state for independent and very probably non-overlapping BitGenerators.

class numpy.random.**SeedSequence**(*entropy=None*, ***, *spawn_key=()*, *pool_size=4*)

SeedSequence mixes sources of entropy in a reproducible way to set the initial state for independent and very probably non-overlapping BitGenerators.

Once the SeedSequence is instantiated, you can call the *generate_state* method to get an appropriately sized seed. Calling *spawn(n)* will create `n` SeedSequences that can be used to seed independent BitGenerators, i.e. for different threads.

Parameters

entropy
[{None, int, sequence[int]}, optional] The entropy for creating a *SeedSequence*. All integer values must be non-negative.

spawn_key
[{(), sequence[int]}, optional] An additional source of entropy based on the position of this *SeedSequence* in the tree of such objects created with the *SeedSequence.spawn* method. Typically, only *SeedSequence.spawn* will set this, and users will not.

pool_size
[{int}, optional] Size of the pooled entropy to store. Default is 4 to give a 128-bit entropy pool. 8 (for 256 bits) is another reasonable choice if working with larger PRNGs, but there is very little to be gained by selecting another value.

n_children_spawned
[{int}, optional] The number of children already spawned. Only pass this if reconstructing a *SeedSequence* from a serialized form.

Notes

Best practice for achieving reproducible bit streams is to use the default `None` for the initial entropy, and then use `SeedSequence.entropy` to log/pickle the `entropy` for reproducibility:

```
>>> sq1 = np.random.SeedSequence()
>>> sq1.entropy
243799254704924441050048792905230269161  # random
>>> sq2 = np.random.SeedSequence(sq1.entropy)
>>> np.all(sq1.generate_state(10) == sq2.generate_state(10))
True
```

Attributes

entropy
n_children_spawned
pool
pool_size
spawn_key
state

Methods

generate_state(n_words[, dtype])	Return the requested number of words for PRNG seeding.
spawn(n_children)	Spawn a number of child *SeedSequence* s by extending the `spawn_key`.

method

`random.SeedSequence.`**`generate_state`**(*n_words*, *dtype=np.uint32*)

Return the requested number of words for PRNG seeding.

A BitGenerator should call this method in its constructor with an appropriate *n_words* parameter to properly seed itself.

Parameters

n_words
[int]

dtype
[np.uint32 or np.uint64, optional] The size of each word. This should only be either *uint32* or *uint64*. Strings (*'uint32'*, *'uint64'*) are fine. Note that requesting *uint64* will draw twice as many bits as *uint32* for the same *n_words*. This is a convenience for *BitGenerator*s that express their states as *uint64* arrays.

Returns

state
[uint32 or uint64 array, shape=(n_words,)]

method

random.SeedSequence.**spawn**(*n_children*)

Spawn a number of child *SeedSequence* s by extending the `spawn_key`.

See *SeedSequence spawning* for additional notes on spawning children.

Parameters

n_children
[int]

Returns

seqs
[list of *SeedSequence* s]

See also:

random.Generator.spawn*, *random.BitGenerator.spawn
Equivalent method on the generator and bit generator.

Upgrading `PCG64` with `PCG64DXSM`

Uses of the *`PCG64` `BitGenerator`* in a massively-parallel context have been shown to have statistical weaknesses that were not apparent at the first release in numpy 1.17. Most users will never observe this weakness and are safe to continue to use *`PCG64`*. We have introduced a new *`PCG64DXSM` `BitGenerator`* that will eventually become the new default *`BitGenerator`* implementation used by *`default_rng`* in future releases. *`PCG64DXSM`* solves the statistical weakness while preserving the performance and the features of *`PCG64`*.

Does this affect me?

If you

1. only use a single *`Generator`* instance,
2. only use *`RandomState`* or the functions in *`numpy.random`*,
3. only use the *`PCG64.jumped`* method to generate parallel streams,
4. explicitly use a *`BitGenerator`* other than *`PCG64`*,

then this weakness does not affect you at all. Carry on.

If you use moderate numbers of parallel streams created with *`default_rng`* or *`SeedSequence.spawn`*, in the 1000s, then the chance of observing this weakness is negligibly small. You can continue to use *`PCG64`* comfortably.

If you use very large numbers of parallel streams, in the millions, and draw large amounts of numbers from each, then the chance of observing this weakness can become non-negligible, if still small. An example of such a use case would be a very large distributed reinforcement learning problem with millions of long Monte Carlo playouts each generating billions of random number draws. Such use cases should consider using *`PCG64DXSM`* explicitly or another modern *`BitGenerator`* like *`SFC64`* or *`Philox`*, but it is unlikely that any old results you may have calculated are invalid. In any case, the weakness is a kind of Birthday Paradox collision. That is, a single pair of parallel streams out of the millions, considered together, might fail a stringent set of statistical tests of randomness. The remaining millions of streams would all be perfectly fine, and the effect of the bad pair in the whole calculation is very likely to be swamped by the remaining streams in most applications.

Technical details

Like many PRNG algorithms, *PCG64* is constructed from a transition function, which advances a 128-bit state, and an output function, that mixes the 128-bit state into a 64-bit integer to be output. One of the guiding design principles of the PCG family of PRNGs is to balance the computational cost (and pseudorandomness strength) between the transition function and the output function. The transition function is a 128-bit linear congruential generator (LCG), which consists of multiplying the 128-bit state with a fixed multiplication constant and then adding a user-chosen increment, in 128-bit modular arithmetic. LCGs are well-analyzed PRNGs with known weaknesses, though 128-bit LCGs are large enough to pass stringent statistical tests on their own, with only the trivial output function. The output function of *PCG64* is intended to patch up some of those known weaknesses by doing "just enough" scrambling of the bits to assist in the statistical properties without adding too much computational cost.

One of these known weaknesses is that advancing the state of the LCG by steps numbering a power of two (`bg.advance(2**N)`) will leave the lower `N` bits identical to the state that was just left. For a single stream drawn from sequentially, this is of little consequence. The remaining $128 - N$ bits provide plenty of pseudorandomness that will be mixed in for any practical `N` that can be observed in a single stream, which is why one does not need to worry about this if you only use a single stream in your application. Similarly, the *PCG64.jumped* method uses a carefully chosen number of steps to avoid creating these collisions. However, once you start creating "randomly-initialized" parallel streams, either using OS entropy by calling *default_rng* repeatedly or using *SeedSequence.spawn*, then we need to consider how many lower bits need to "collide" in order to create a bad pair of streams, and then evaluate the probability of creating such a collision. Empirically, it has been determined that if one shares the lower 58 bits of state and shares an increment, then the pair of streams, when interleaved, will fail PractRand in a reasonable amount of time, after drawing a few gigabytes of data. Following the standard Birthday Paradox calculations for a collision of 58 bits, we can see that we can create 2^{29}, or about half a billion, streams which is when the probability of such a collision becomes high. Half a billion streams is quite high, and the amount of data each stream needs to draw before the statistical correlations become apparent to even the strict `PractRand` tests is in the gigabytes. But this is on the horizon for very large applications like distributed reinforcement learning. There are reasons to expect that even in these applications a collision probably will not have a practical effect in the total result, since the statistical problem is constrained to just the colliding pair.

Now, let us consider the case when the increment is not constrained to be the same. Our implementation of *PCG64* seeds both the state and the increment; that is, two calls to *default_rng* (almost certainly) have different states and increments. Upon our first release, we believed that having the seeded increment would provide a certain amount of extra protection, that one would have to be "close" in both the state space and increment space in order to observe correlations (`PractRand` failures) in a pair of streams. If that were true, then the "bottleneck" for collisions would be the 128-bit entropy pool size inside of *SeedSequence* (and 128-bit collisions are in the "preposterously unlikely" category). Unfortunately, this is not true.

One of the known properties of an LCG is that different increments create *distinct* streams, but with a known relationship. Each LCG has an orbit that traverses all 2^{128} different 128-bit states. Two LCGs with different increments are related in that one can "rotate" the orbit of the first LCG (advance it by a number of steps that we can compute from the two increments) such that then both LCGs will always then have the same state, up to an additive constant and maybe an inversion of the bits. If you then iterate both streams in lockstep, then the states will *always* remain related by that same additive constant (and the inversion, if present). Recall that *PCG64* is constructed from both a transition function (the LCG) and an output function. It was expected that the scrambling effect of the output function would have been strong enough to make the distinct streams practically independent (i.e. "passing the `PractRand` tests") unless the two increments were pathologically related to each other (e.g. 1 and 3). The output function XSL-RR of the then-standard PCG algorithm that we implemented in *PCG64* turns out to be too weak to cover up for the 58-bit collision of the underlying LCG that we described above. For any given pair of increments, the size of the "colliding" space of states is the same, so for this weakness, the extra distinctness provided by the increments does not translate into extra protection from statistical correlations that `PractRand` can detect.

Fortunately, strengthening the output function is able to correct this weakness and *does* turn the extra distinctness provided by differing increments into additional protection from these low-bit collisions. To the PCG author's credit, she had developed a stronger output function in response to related discussions during the long birth of the new *BitGenerator* system. We NumPy developers chose to be "conservative" and use the XSL-RR variant that had undergone a longer period of testing at that time. The DXSM output function adopts a "xorshift-multiply" construction used in strong integer

hashes that has much better avalanche properties than the XSL-RR output function. While there are "pathological" pairs of increments that induce "bad" additive constants that relate the two streams, the vast majority of pairs induce "good" additive constants that make the merely-distinct streams of LCG states into practically-independent output streams. Indeed, now the claim we once made about *PCG64* is actually true of *PCG64DXSM*: collisions are possible, but both streams have to simultaneously be both "close" in the 128 bit state space *and* "close" in the 127-bit increment space, so that would be less likely than the negligible chance of colliding in the 128-bit internal *SeedSequence* pool. The DXSM output function is more computationally intensive than XSL-RR, but some optimizations in the LCG more than make up for the performance hit on most machines, so *PCG64DXSM* is a good, safe upgrade. There are, of course, an infinite number of stronger output functions that one could consider, but most will have a greater computational cost, and the DXSM output function has now received many CPU cycles of testing via `PractRand` at this time.

Compatibility policy

numpy.random has a somewhat stricter compatibility policy than the rest of NumPy. Users of pseudorandomness often have use cases for being able to reproduce runs in fine detail given the same seed (so-called "stream compatibility"), and so we try to balance those needs with the flexibility to enhance our algorithms. NEP 19 describes the evolution of this policy.

The main kind of compatibility that we enforce is stream-compatibility from run to run under certain conditions. If you create a *Generator* with the same *BitGenerator*, with the same seed, perform the same sequence of method calls with the same arguments, on the same build of `numpy`, in the same environment, on the same machine, you should get the same stream of numbers. Note that these conditions are very strict. There are a number of factors outside of NumPy's control that limit our ability to guarantee much more than this. For example, different CPUs implement floating point arithmetic differently, and this can cause differences in certain edge cases that cascade to the rest of the stream. *Generator.multivariate_normal*, for another example, uses a matrix decomposition from *numpy.linalg*. Even on the same platform, a different build of `numpy` may use a different version of this matrix decomposition algorithm from the LAPACK that it links to, causing *Generator.multivariate_normal* to return completely different (but equally valid!) results. We strive to prefer algorithms that are more resistant to these effects, but this is always imperfect.

Note: Most of the *Generator* methods allow you to draw multiple values from a distribution as arrays. The requested size of this array is a parameter, for the purposes of the above policy. Calling `rng.random()` 5 times is not *guaranteed* to give the same numbers as `rng.random(5)`. We reserve the ability to decide to use different algorithms for different-sized blocks. In practice, this happens rarely.

Like the rest of NumPy, we generally maintain API source compatibility from version to version. If we *must* make an API-breaking change, then we will only do so with an appropriate deprecation period and warnings, according to general NumPy policy.

Breaking stream-compatibility in order to introduce new features or improve performance in *Generator* or *default_rng* will be *allowed* with *caution*. Such changes will be considered features, and as such will be no faster than the standard release cadence of features (i.e. on `X.Y` releases, never `X.Y.Z`). Slowness will not be considered a bug for this purpose. Correctness bug fixes that break stream-compatibility can happen on bugfix releases, per usual, but developers should consider if they can wait until the next feature release. We encourage developers to strongly weight user's pain from the break in stream-compatibility against the improvements. One example of a worthwhile improvement would be to change algorithms for a significant increase in performance, for example, moving from the Box-Muller transform method of Gaussian variate generation to the faster Ziggurat algorithm. An example of a discouraged improvement would be tweaking the Ziggurat tables just a little bit for a small performance improvement.

Note: In particular, *default_rng* is allowed to change the default *BitGenerator* that it uses (again, with *caution* and plenty of advance warning).

In general, *BitGenerator* classes have stronger guarantees of version-to-version stream compatibility. This allows

them to be a firmer building block for downstream users that need it. Their limited API surface makes it easier for them to maintain this compatibility from version to version. See the docstrings of each *BitGenerator* class for their individual compatibility guarantees.

The legacy *RandomState* and the *associated convenience functions* have a stricter version-to-version compatibility guarantee. For reasons outlined in NEP 19, we had made stronger promises about their version-to-version stability early in NumPy's development. There are still some limited use cases for this kind of compatibility (like generating data for tests), so we maintain as much compatibility as we can. There will be no more modifications to *RandomState*, not even to fix correctness bugs. There are a few gray areas where we can make minor fixes to keep *RandomState* working without segfaulting as NumPy's internals change, and some docstring fixes. However, the previously-mentioned caveats about the variability from machine to machine and build to build still apply to *RandomState* just as much as it does to *Generator*.

Features

Parallel random number generation

There are four main strategies implemented that can be used to produce repeatable pseudo-random numbers across multiple processes (local or distributed).

`SeedSequence` spawning

NumPy allows you to spawn new (with very high probability) independent *BitGenerator* and *Generator* instances via their `spawn()` method. This spawning is implemented by the *SeedSequence* used for initializing the bit generators random stream.

SeedSequence implements an algorithm to process a user-provided seed, typically as an integer of some size, and to convert it into an initial state for a *BitGenerator*. It uses hashing techniques to ensure that low-quality seeds are turned into high quality initial states (at least, with very high probability).

For example, *MT19937* has a state consisting of 624 `uint32` integers. A naive way to take a 32-bit integer seed would be to just set the last element of the state to the 32-bit seed and leave the rest 0s. This is a valid state for *MT19937*, but not a good one. The Mersenne Twister algorithm suffers if there are too many 0s. Similarly, two adjacent 32-bit integer seeds (i.e. `12345` and `12346`) would produce very similar streams.

SeedSequence avoids these problems by using successions of integer hashes with good avalanche properties to ensure that flipping any bit in the input has about a 50% chance of flipping any bit in the output. Two input seeds that are very close to each other will produce initial states that are very far from each other (with very high probability). It is also constructed in such a way that you can provide arbitrary-sized integers or lists of integers. *SeedSequence* will take all of the bits that you provide and mix them together to produce however many bits the consuming *BitGenerator* needs to initialize itself.

These properties together mean that we can safely mix together the usual user-provided seed with simple incrementing counters to get *BitGenerator* states that are (to very high probability) independent of each other. We can wrap this together into an API that is easy to use and difficult to misuse. Note that while *SeedSequence* attempts to solve many of the issues related to user-provided small seeds, we still *recommend* using `secrets.randbits` to generate seeds with 128 bits of entropy to avoid the remaining biases introduced by human-chosen seeds.

```
from numpy.random import SeedSequence, default_rng

ss = SeedSequence(12345)

# Spawn off 10 child SeedSequences to pass to child processes.
child_seeds = ss.spawn(10)
streams = [default_rng(s) for s in child_seeds]
```

For convenience the direct use of *SeedSequence* is not necessary. The above `streams` can be spawned directly from a parent generator via *spawn*:

```
parent_rng = default_rng(12345)
streams = parent_rng.spawn(10)
```

Child objects can also spawn to make grandchildren, and so on. Each child has a *SeedSequence* with its position in the tree of spawned child objects mixed in with the user-provided seed to generate independent (with very high probability) streams.

```
grandchildren = streams[0].spawn(4)
```

This feature lets you make local decisions about when and how to split up streams without coordination between processes. You do not have to preallocate space to avoid overlapping or request streams from a common global service. This general "tree-hashing" scheme is not unique to numpy but not yet widespread. Python has increasingly-flexible mechanisms for parallelization available, and this scheme fits in very well with that kind of use.

Using this scheme, an upper bound on the probability of a collision can be estimated if one knows the number of streams that you derive. *SeedSequence* hashes its inputs, both the seed and the spawn-tree-path, down to a 128-bit pool by default. The probability that there is a collision in that pool, pessimistically-estimated ([1]), will be about $n^2 * 2^{-128}$ where n is the number of streams spawned. If a program uses an aggressive million streams, about 2^{20}, then the probability that at least one pair of them are identical is about 2^{-88}, which is in solidly-ignorable territory ([2]).

Sequence of integer seeds

As discussed in the previous section, *SeedSequence* can not only take an integer seed, it can also take an arbitrary-length sequence of (non-negative) integers. If one exercises a little care, one can use this feature to design *ad hoc* schemes for getting safe parallel PRNG streams with similar safety guarantees as spawning.

For example, one common use case is that a worker process is passed one root seed integer for the whole calculation and also an integer worker ID (or something more granular like a job ID, batch ID, or something similar). If these IDs are created deterministically and uniquely, then one can derive reproducible parallel PRNG streams by combining the ID and the root seed integer in a list.

```
# default_rng() and each of the BitGenerators use SeedSequence underneath, so
# they all accept sequences of integers as seeds the same way.
from numpy.random import default_rng

def worker(root_seed, worker_id):
    rng = default_rng([worker_id, root_seed])
    # Do work ...

root_seed = 0x8c3c010cb4754c905776bdac5ee7501
results = [worker(root_seed, worker_id) for worker_id in range(10)]
```

This can be used to replace a number of unsafe strategies that have been used in the past which try to combine the root seed and the ID back into a single integer seed value. For example, it is common to see users add the worker ID to the root seed, especially with the legacy *RandomState* code.

[1] The algorithm is carefully designed to eliminate a number of possible ways to collide. For example, if one only does one level of spawning, it is guaranteed that all states will be unique. But it's easier to estimate the naive upper bound on a napkin and take comfort knowing that the probability is actually lower.

[2] In this calculation, we can mostly ignore the amount of numbers drawn from each stream. See *Upgrading PCG64 with PCG64DXSM* for the technical details about *PCG64*. The other PRNGs we provide have some extra protection built in that avoids overlaps if the *SeedSequence* pools differ in the slightest bit. *PCG64DXSM* has 2^{127} separate cycles determined by the seed in addition to the position in the 2^{128} long period for each cycle, so one has to both get on or near the same cycle *and* seed a nearby position in the cycle. *Philox* has completely independent cycles determined by the seed. *SFC64* incorporates a 64-bit counter so every unique seed is at least 2^{64} iterations away from any other seed. And finally, *MT19937* has just an unimaginably huge period. Getting a collision internal to *SeedSequence* is the way a failure would be observed.

```
# UNSAFE! Do not do this!
worker_seed = root_seed + worker_id
rng = np.random.RandomState(worker_seed)
```

It is true that for any one run of a parallel program constructed this way, each worker will have distinct streams. However, it is quite likely that multiple invocations of the program with different seeds will get overlapping sets of worker seeds. It is not uncommon (in the author's self-experience) to change the root seed merely by an increment or two when doing these repeat runs. If the worker seeds are also derived by small increments of the worker ID, then subsets of the workers will return identical results, causing a bias in the overall ensemble of results.

Combining the worker ID and the root seed as a list of integers eliminates this risk. Lazy seeding practices will still be fairly safe.

This scheme does require that the extra IDs be unique and deterministically created. This may require coordination between the worker processes. It is recommended to place the varying IDs *before* the unvarying root seed. `spawn` *appends* integers after the user-provided seed, so if you might be mixing both this *ad hoc* mechanism and spawning, or passing your objects down to library code that might be spawning, then it is a little bit safer to prepend your worker IDs rather than append them to avoid a collision.

```
# Good.
worker_seed = [worker_id, root_seed]

# Less good. It will *work*, but it's less flexible.
worker_seed = [root_seed, worker_id]
```

With those caveats in mind, the safety guarantees against collision are about the same as with spawning, discussed in the previous section. The algorithmic mechanisms are the same.

Independent streams

`Philox` is a counter-based RNG based which generates values by encrypting an incrementing counter using weak cryptographic primitives. The seed determines the key that is used for the encryption. Unique keys create unique, independent streams. `Philox` lets you bypass the seeding algorithm to directly set the 128-bit key. Similar, but different, keys will still create independent streams.

```
import secrets
from numpy.random import Philox

# 128-bit number as a seed
root_seed = secrets.getrandbits(128)
streams = [Philox(key=root_seed + stream_id) for stream_id in range(10)]
```

This scheme does require that you avoid reusing stream IDs. This may require coordination between the parallel processes.

Jumping the BitGenerator state

`jumped` advances the state of the BitGenerator *as-if* a large number of random numbers have been drawn, and returns a new instance with this state. The specific number of draws varies by BitGenerator, and ranges from 2^{64} to 2^{128}. Additionally, the *as-if* draws also depend on the size of the default random number produced by the specific BitGenerator. The BitGenerators that support `jumped`, along with the period of the BitGenerator, the size of the jump and the bits in the default unsigned random are listed below.

BitGenerator	Period	Jump Size	Bits per Draw
MT19937	$2^{19937} - 1$	2^{128}	32
PCG64	2^{128}	2^{127} ([3])	64
PCG64DXSM	2^{128}	2^{127} ([Page 357, 3])	64
Philox	2^{256}	2^{128}	64

`jumped` can be used to produce long blocks which should be long enough to not overlap.

```
import secrets
from numpy.random import PCG64

seed = secrets.getrandbits(128)
blocked_rng = []
rng = PCG64(seed)
for i in range(10):
    blocked_rng.append(rng.jumped(i))
```

When using `jumped`, one does have to take care not to jump to a stream that was already used. In the above example, one could not later use `blocked_rng[0].jumped()` as it would overlap with `blocked_rng[1]`. Like with the independent streams, if the main process here wants to split off 10 more streams by jumping, then it needs to start with `range(10, 20)`, otherwise it would recreate the same streams. On the other hand, if you carefully construct the streams, then you are guaranteed to have streams that do not overlap.

Multithreaded generation

The four core distributions (*random*, *standard_normal*, *standard_exponential*, and *standard_gamma*) all allow existing arrays to be filled using the `out` keyword argument. Existing arrays need to be contiguous and well-behaved (writable and aligned). Under normal circumstances, arrays created using the common constructors such as *numpy.empty* will satisfy these requirements.

This example makes use of Python 3 `concurrent.futures` to fill an array using multiple threads. Threads are long-lived so that repeated calls do not require any additional overheads from thread creation.

The random numbers generated are reproducible in the sense that the same seed will produce the same outputs, given that the number of threads does not change.

```
from numpy.random import default_rng, SeedSequence
import multiprocessing
import concurrent.futures
import numpy as np

class MultithreadedRNG:
    def __init__(self, n, seed=None, threads=None):
        if threads is None:
            threads = multiprocessing.cpu_count()
        self.threads = threads

        seq = SeedSequence(seed)
        self._random_generators = [default_rng(s)
```

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[3] The jump size is $(\phi - 1) * 2^{128}$ where ϕ is the golden ratio. As the jumps wrap around the period, the actual distances between neighboring streams will slowly grow smaller than the jump size, but using the golden ratio this way is a classic method of constructing a low-discrepancy sequence that spreads out the states around the period optimally. You will not be able to jump enough to make those distances small enough to overlap in your lifetime.

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```
                                    for s in seq.spawn(threads)]

        self.n = n
        self.executor = concurrent.futures.ThreadPoolExecutor(threads)
        self.values = np.empty(n)
        self.step = np.ceil(n / threads).astype(np.int_)

    def fill(self):
        def _fill(random_state, out, first, last):
            random_state.standard_normal(out=out[first:last])

        futures = {}
        for i in range(self.threads):
            args = (_fill,
                    self._random_generators[i],
                    self.values,
                    i * self.step,
                    (i + 1) * self.step)
            futures[self.executor.submit(*args)] = i
        concurrent.futures.wait(futures)

    def __del__(self):
        self.executor.shutdown(False)
```

The multithreaded random number generator can be used to fill an array. The `values` attributes shows the zero-value before the fill and the random value after.

```
In [2]: mrng = MultithreadedRNG(10000000, seed=12345)
   ...: print(mrng.values[-1])
Out[2]: 0.0

In [3]: mrng.fill()
   ...: print(mrng.values[-1])
Out[3]: 2.4545724517479104
```

The time required to produce using multiple threads can be compared to the time required to generate using a single thread.

```
In [4]: print(mrng.threads)
   ...: %timeit mrng.fill()

Out[4]: 4
   ...: 32.8 ms ± 2.71 ms per loop (mean ± std. dev. of 7 runs, 10 loops each)
```

The single threaded call directly uses the BitGenerator.

```
In [5]: values = np.empty(10000000)
   ...: rg = default_rng()
   ...: %timeit rg.standard_normal(out=values)

Out[5]: 99.6 ms ± 222 µs per loop (mean ± std. dev. of 7 runs, 10 loops each)
```

The gains are substantial and the scaling is reasonable even for arrays that are only moderately large. The gains are even larger when compared to a call that does not use an existing array due to array creation overhead.

```
In [6]: rg = default_rng()
   ...: %timeit rg.standard_normal(10000000)

Out[6]: 125 ms ± 309 µs per loop (mean ± std. dev. of 7 runs, 10 loops each)
```

Note that if `threads` is not set by the user, it will be determined by `multiprocessing.cpu_count()`.

```
In [7]: # simulate the behavior for `threads=None`, if the machine had only one thread
   ...: mrng = MultithreadedRNG(10000000, seed=12345, threads=1)
   ...: print(mrng.values[-1])
Out[7]: 1.1800150052158556
```

What's new or different

NumPy 1.17.0 introduced *Generator* as an improved replacement for the *legacy RandomState*. Here is a quick comparison of the two implementations.

Feature	Older Equivalent	Notes
Generator	*RandomState*	*Generator* requires a stream source, called a *BitGenerator* A number of these are provided. *RandomState* uses the Mersenne Twister *MT19937* by default, but can also be instantiated with any BitGenerator.
random	*random_sample*, *rand*	Access the values in a BitGenerator, convert them to `float64` in the interval `[0.0, 1.0)`. In addition to the `size` kwarg, now supports `dtype='d'` or `dtype='f'`, and an `out` kwarg to fill a user-supplied array. Many other distributions are also supported.
integers	*randint*, *random_integers*	Use the `endpoint` kwarg to adjust the inclusion or exclusion of the `high` interval endpoint.

- The normal, exponential and gamma generators use 256-step Ziggurat methods which are 2-10 times faster than NumPy's default implementation in *standard_normal*, *standard_exponential* or *standard_gamma*. Because of the change in algorithms, it is not possible to reproduce the exact random values using *Generator* for these distributions or any distribution method that relies on them.

```
In [1]: import numpy.random

In [2]: rng = np.random.default_rng()

In [3]: %timeit -n 1 rng.standard_normal(100000)
   ...: %timeit -n 1 numpy.random.standard_normal(100000)
   ...:
1.07 ms +- 55.2 us per loop (mean +- std. dev. of 7 runs, 1 loop each)
2.24 ms +- 51.1 us per loop (mean +- std. dev. of 7 runs, 1 loop each)
```

```
In [4]: %timeit -n 1 rng.standard_exponential(100000)
   ...: %timeit -n 1 numpy.random.standard_exponential(100000)
   ...:
582 us +- 14.3 us per loop (mean +- std. dev. of 7 runs, 1 loop each)
1.56 ms +- 48.8 us per loop (mean +- std. dev. of 7 runs, 1 loop each)
```

```
In [5]: %timeit -n 1 rng.standard_gamma(3.0, 100000)
   ...: %timeit -n 1 numpy.random.standard_gamma(3.0, 100000)
   ...:
2.22 ms +- 225 us per loop (mean +- std. dev. of 7 runs, 1 loop each)
4.7 ms +- 926 us per loop (mean +- std. dev. of 7 runs, 1 loop each)
```

- *integers* is now the canonical way to generate integer random numbers from a discrete uniform distribution. This replaces both *randint* and the deprecated *random_integers*.
- The *rand* and *randn* methods are only available through the legacy *RandomState*.
- *Generator.random* is now the canonical way to generate floating-point random numbers, which replaces *RandomState.random_sample*, *sample*, and *ranf*, all of which were aliases. This is consistent with Python's `random.random`.
- All bit generators can produce doubles, uint64s and uint32s via CTypes (*ctypes*) and CFFI (*cffi*). This allows these bit generators to be used in numba.
- The bit generators can be used in downstream projects via Cython.
- All bit generators use *SeedSequence* to *convert seed integers to initialized states*.
- Optional `dtype` argument that accepts `np.float32` or `np.float64` to produce either single or double precision uniform random variables for select distributions. *integers* accepts a `dtype` argument with any signed or unsigned integer dtype.
  - Uniforms (*random* and *integers*)
  - Normals (*standard_normal*)
  - Standard Gammas (*standard_gamma*)
  - Standard Exponentials (*standard_exponential*)

```
In [6]: rng = np.random.default_rng()

In [7]: rng.random(3, dtype=np.float64)
Out[7]: array([0.21714837, 0.68260615, 0.02907321])

In [8]: rng.random(3, dtype=np.float32)
Out[8]: array([0.8543214 , 0.9473313 , 0.30972785], dtype=float32)

In [9]: rng.integers(0, 256, size=3, dtype=np.uint8)
Out[9]: array([111,   5,  86], dtype=uint8)
```

- Optional `out` argument that allows existing arrays to be filled for select distributions
  - Uniforms (*random*)
  - Normals (*standard_normal*)
  - Standard Gammas (*standard_gamma*)
  - Standard Exponentials (*standard_exponential*)

  This allows multithreading to fill large arrays in chunks using suitable BitGenerators in parallel.

```
In [10]: rng = np.random.default_rng()

In [11]: existing = np.zeros(4)

In [12]: rng.random(out=existing[:2])
```

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```
Out[12]: array([0.00142669, 0.5702797 ])

In [13]: print(existing)
[0.00142669 0.5702797  0.         0.        ]
```

- Optional `axis` argument for methods like *`choice`*, *`permutation`* and *`shuffle`* that controls which axis an operation is performed over for multi-dimensional arrays.

```
In [14]: rng = np.random.default_rng()

In [15]: a = np.arange(12).reshape((3, 4))

In [16]: a
Out[16]:
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])

In [17]: rng.choice(a, axis=1, size=5)
Out[17]:
array([[ 3,  2,  1,  1,  3],
       [ 7,  6,  5,  5,  7],
       [11, 10,  9,  9, 11]])

In [18]: rng.shuffle(a, axis=1)        # Shuffle in-place

In [19]: a
Out[19]:
array([[ 1,  2,  3,  0],
       [ 5,  6,  7,  4],
       [ 9, 10, 11,  8]])
```

- Added a method to sample from the complex normal distribution (*complex_normal*)

Performance

Recommendation

The recommended generator for general use is *`PCG64`* or its upgraded variant *`PCG64DXSM`* for heavily-parallel use cases. They are statistically high quality, full-featured, and fast on most platforms, but somewhat slow when compiled for 32-bit processes. See *Upgrading PCG64 with PCG64DXSM* for details on when heavy parallelism would indicate using *`PCG64DXSM`*.

`Philox` is fairly slow, but its statistical properties have very high quality, and it is easy to get an assuredly-independent stream by using unique keys. If that is the style you wish to use for parallel streams, or you are porting from another system that uses that style, then *`Philox`* is your choice.

`SFC64` is statistically high quality and very fast. However, it lacks jumpability. If you are not using that capability and want lots of speed, even on 32-bit processes, this is your choice.

`MT19937` fails some statistical tests and is not especially fast compared to modern PRNGs. For these reasons, we mostly do not recommend using it on its own, only through the legacy *`RandomState`* for reproducing old results. That said, it has a very long history as a default in many systems.

Timings

The timings below are the time in ns to produce 1 random value from a specific distribution. The original *MT19937* generator is much slower since it requires 2 32-bit values to equal the output of the faster generators.

Integer performance has a similar ordering.

The pattern is similar for other, more complex generators. The normal performance of the legacy *RandomState* generator is much lower than the other since it uses the Box-Muller transform rather than the Ziggurat method. The performance gap for Exponentials is also large due to the cost of computing the log function to invert the CDF. The column labeled MT19973 uses the same 32-bit generator as *RandomState* but produces random variates using *Generator*.

	MT19937	PCG64	PCG64DXSM	Philox	SFC64	RandomState
32-bit Unsigned Ints	3.3	1.9	2.0	3.3	1.8	3.1
64-bit Unsigned Ints	5.6	3.2	2.9	4.9	2.5	5.5
Uniforms	5.9	3.1	2.9	5.0	2.6	6.0
Normals	13.9	10.8	10.5	12.0	8.3	56.8
Exponentials	9.1	6.0	5.8	8.1	5.4	63.9
Gammas	37.2	30.8	28.9	34.0	27.5	77.0
Binomials	21.3	17.4	17.6	19.3	15.6	21.4
Laplaces	73.2	72.3	76.1	73.0	72.3	82.5
Poissons	111.7	103.4	100.5	109.4	90.7	115.2

The next table presents the performance in percentage relative to values generated by the legacy generator, `RandomState(MT19937())`. The overall performance was computed using a geometric mean.

	MT19937	PCG64	PCG64DXSM	Philox	SFC64
32-bit Unsigned Ints	96	162	160	96	175
64-bit Unsigned Ints	97	171	188	113	218
Uniforms	102	192	206	121	233
Normals	409	526	541	471	684
Exponentials	701	1071	1101	784	1179
Gammas	207	250	266	227	281
Binomials	100	123	122	111	138
Laplaces	113	114	108	113	114
Poissons	103	111	115	105	127
Overall	159	219	225	174	251

Note: All timings were taken using Linux on an AMD Ryzen 9 3900X processor.

Performance on different operating systems

Performance differs across platforms due to compiler and hardware availability (e.g., register width) differences. The default bit generator has been chosen to perform well on 64-bit platforms. Performance on 32-bit operating systems is very different.

The values reported are normalized relative to the speed of MT19937 in each table. A value of 100 indicates that the performance matches the MT19937. Higher values indicate improved performance. These values cannot be compared across tables.

64-bit Linux

Distribution	MT19937	PCG64	PCG64DXSM	Philox	SFC64
32-bit Unsigned Ints	100	168	166	100	182
64-bit Unsigned Ints	100	176	193	116	224
Uniforms	100	188	202	118	228
Normals	100	128	132	115	167
Exponentials	100	152	157	111	168
Overall	100	161	168	112	192

64-bit Windows

The relative performance on 64-bit Linux and 64-bit Windows is broadly similar with the notable exception of the Philox generator.

Distribution	MT19937	PCG64	PCG64DXSM	Philox	SFC64
32-bit Unsigned Ints	100	155	131	29	150
64-bit Unsigned Ints	100	157	143	25	154
Uniforms	100	151	144	24	155
Normals	100	129	128	37	150
Exponentials	100	150	145	28	159
Overall	100	148	138	28	154

32-bit Windows

The performance of 64-bit generators on 32-bit Windows is much lower than on 64-bit operating systems due to register width. MT19937, the generator that has been in NumPy since 2005, operates on 32-bit integers.

Distribution	MT19937	PCG64	PCG64DXSM	Philox	SFC64
32-bit Unsigned Ints	100	24	34	14	57
64-bit Unsigned Ints	100	21	32	14	74
Uniforms	100	21	34	16	73
Normals	100	36	57	28	101
Exponentials	100	28	44	20	88
Overall	100	25	39	18	77

Note: Linux timings used Ubuntu 20.04 and GCC 9.3.0. Windows timings were made on Windows 10 using Microsoft C/C++ Optimizing Compiler Version 19 (Visual Studio 2019). All timings were produced on an AMD Ryzen 9 3900X processor.

C API for random

Access to various distributions below is available via Cython or C-wrapper libraries like CFFI. All the functions accept a *bitgen_t* as their first argument. To access these from Cython or C, you must link with the `npyrandom` static library which is part of the NumPy distribution, located in `numpy/random/lib`. Note that you must *also* link with `npymath`, see *Linking against the core math library in an extension*.

type **bitgen_t**

The *bitgen_t* holds the current state of the BitGenerator and pointers to functions that return standard C types while advancing the state.

```
struct bitgen:
    void *state
    npy_uint64 (*next_uint64)(void *st) nogil
    uint32_t (*next_uint32)(void *st) nogil
    double (*next_double)(void *st) nogil
    npy_uint64 (*next_raw)(void *st) nogil

ctypedef bitgen bitgen_t
```

See *Extending* for examples of using these functions.

The functions are named with the following conventions:

- "standard" refers to the reference values for any parameters. For instance "standard_uniform" means a uniform distribution on the interval `0.0` to `1.0`
- "fill" functions will fill the provided `out` with `cnt` values.
- The functions without "standard" in their name require additional parameters to describe the distributions.
- Functions with `inv` in their name are based on the slower inverse method instead of a ziggurat lookup algorithm, which is significantly faster. The non-ziggurat variants are used in corner cases and for legacy compatibility.

double **random_standard_uniform**(*bitgen_t* *bitgen_state)

void **random_standard_uniform_fill**(*bitgen_t* *bitgen_state, *npy_intp* cnt, double *out)

double **random_standard_exponential**(*bitgen_t* *bitgen_state)

void **random_standard_exponential_fill**(*bitgen_t* *bitgen_state, *npy_intp* cnt, double *out)

void **random_standard_exponential_inv_fill**(*bitgen_t* *bitgen_state, *npy_intp* cnt, double *out)

double **random_standard_normal**(*bitgen_t* *bitgen_state)

void **random_standard_normal_fill**(*bitgen_t* *bitgen_state, *npy_intp* count, double *out)

void **random_standard_normal_fill_f**(*bitgen_t* *bitgen_state, *npy_intp* count, float *out)

double **random_standard_gamma**(*bitgen_t* *bitgen_state, double shape)

float **random_standard_uniform_f**(*bitgen_t* *bitgen_state)

void **random_standard_uniform_fill_f**(*bitgen_t* *bitgen_state, *npy_intp* cnt, float *out)

float **random_standard_exponential_f**(*bitgen_t* *bitgen_state)

void **random_standard_exponential_fill_f**(*bitgen_t* *bitgen_state, *npy_intp* cnt, float *out)

void **random_standard_exponential_inv_fill_f**(*bitgen_t* *bitgen_state, *npy_intp* cnt, float *out)

float **random_standard_normal_f**(*bitgen_t* *bitgen_state)

float **random_standard_gamma_f**(*bitgen_t* *bitgen_state, float shape)

double **random_normal**(*bitgen_t* *bitgen_state, double loc, double scale)

double **random_gamma**(*bitgen_t* *bitgen_state, double shape, double scale)

float **random_gamma_f**(*bitgen_t* *bitgen_state, float shape, float scale)

double **random_exponential**(*bitgen_t* *bitgen_state, double scale)

double **random_uniform**(*bitgen_t* *bitgen_state, double lower, double range)

double **random_beta**(*bitgen_t* *bitgen_state, double a, double b)

double **random_chisquare**(*bitgen_t* *bitgen_state, double df)

double **random_f**(*bitgen_t* *bitgen_state, double dfnum, double dfden)

double **random_standard_cauchy**(*bitgen_t* *bitgen_state)

double **random_pareto**(*bitgen_t* *bitgen_state, double a)

double **random_weibull**(*bitgen_t* *bitgen_state, double a)

double **random_power**(*bitgen_t* *bitgen_state, double a)

double **random_laplace**(*bitgen_t* *bitgen_state, double loc, double scale)

double **random_gumbel**(*bitgen_t* *bitgen_state, double loc, double scale)

double **random_logistic**(*bitgen_t* *bitgen_state, double loc, double scale)

double **random_lognormal**(*bitgen_t* *bitgen_state, double mean, double sigma)

double **random_rayleigh**(*bitgen_t* *bitgen_state, double mode)

double **random_standard_t**(*bitgen_t* *bitgen_state, double df)

double **random_noncentral_chisquare**(*bitgen_t* *bitgen_state, double df, double nonc)

double **random_noncentral_f**(*bitgen_t* *bitgen_state, double dfnum, double dfden, double nonc)

double **random_wald**(*bitgen_t* *bitgen_state, double mean, double scale)

double **random_vonmises**(*bitgen_t* *bitgen_state, double mu, double kappa)

double **random_triangular**(*bitgen_t* *bitgen_state, double left, double mode, double right)

npy_int64 **random_poisson**(*bitgen_t* *bitgen_state, double lam)

npy_int64 **random_negative_binomial** (*bitgen_t* *bitgen_state, double n, double p)

type **binomial_t**

```
typedef struct s_binomial_t {
  int has_binomial; /* !=0: following parameters initialized for binomial */
  double psave;
  RAND_INT_TYPE nsave;
  double r;
  double q;
  double fm;
  RAND_INT_TYPE m;
  double p1;
  double xm;
  double xl;
  double xr;
  double c;
  double laml;
  double lamr;
  double p2;
  double p3;
  double p4;
} binomial_t;
```

npy_int64 **random_binomial** (*bitgen_t* *bitgen_state, double p, *npy_int64* n, *binomial_t* *binomial)

npy_int64 **random_logseries** (*bitgen_t* *bitgen_state, double p)

npy_int64 **random_geometric_search** (*bitgen_t* *bitgen_state, double p)

npy_int64 **random_geometric_inversion** (*bitgen_t* *bitgen_state, double p)

npy_int64 **random_geometric** (*bitgen_t* *bitgen_state, double p)

npy_int64 **random_zipf** (*bitgen_t* *bitgen_state, double a)

npy_int64 **random_hypergeometric** (*bitgen_t* *bitgen_state, *npy_int64* good, *npy_int64* bad, *npy_int64* sample)

npy_uint64 **random_interval** (*bitgen_t* *bitgen_state, *npy_uint64* max)

void **random_multinomial** (*bitgen_t* *bitgen_state, *npy_int64* n, *npy_int64* *mnix, double *pix, *npy_intp* d, *binomial_t* *binomial)

int **random_multivariate_hypergeometric_count** (*bitgen_t* *bitgen_state, *npy_int64* total, size_t num_colors, *npy_int64* *colors, *npy_int64* nsample, size_t num_variates, *npy_int64* *variates)

void **random_multivariate_hypergeometric_marginals** (*bitgen_t* *bitgen_state, *npy_int64* total, size_t num_colors, *npy_int64* *colors, *npy_int64* nsample, size_t num_variates, *npy_int64* *variates)

Generate a single integer

npy_int64 **random_positive_int64** (*bitgen_t* *bitgen_state)

npy_int32 **random_positive_int32** (*bitgen_t* *bitgen_state)

npy_int64 **random_positive_int** (*bitgen_t* *bitgen_state)

npy_uint64 **random_uint**(*bitgen_t* *bitgen_state)

Generate random uint64 numbers in closed interval [off, off + rng].

npy_uint64 **random_bounded_uint64**(*bitgen_t* *bitgen_state, *npy_uint64* off, *npy_uint64* rng, *npy_uint64* mask, bool use_masked)

Extending

The `BitGenerator`s have been designed to be extendable using standard tools for high-performance Python – numba and Cython. The `Generator` object can also be used with user-provided `BitGenerator`s as long as these export a small set of required functions.

Numba

Numba can be used with either CTypes or CFFI. The current iteration of the `BitGenerator`s all export a small set of functions through both interfaces.

This example shows how numba can be used to produce gaussian samples using a pure Python implementation which is then compiled. The random numbers are provided by `ctypes.next_double`.

```
import numpy as np
import numba as nb

from numpy.random import PCG64
from timeit import timeit

bit_gen = PCG64()
next_d = bit_gen.cffi.next_double
state_addr = bit_gen.cffi.state_address

def normals(n, state):
    out = np.empty(n)
    for i in range((n + 1) // 2):
        x1 = 2.0 * next_d(state) - 1.0
        x2 = 2.0 * next_d(state) - 1.0
        r2 = x1 * x1 + x2 * x2
        while r2 >= 1.0 or r2 == 0.0:
            x1 = 2.0 * next_d(state) - 1.0
            x2 = 2.0 * next_d(state) - 1.0
            r2 = x1 * x1 + x2 * x2
        f = np.sqrt(-2.0 * np.log(r2) / r2)
        out[2 * i] = f * x1
        if 2 * i + 1 < n:
            out[2 * i + 1] = f * x2
    return out

# Compile using Numba
normalsj = nb.jit(normals, nopython=True)
# Must use state address not state with numba
n = 10000

def numbacall():
    return normalsj(n, state_addr)
```

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```
rg = np.random.Generator(PCG64())

def numpycall():
    return rg.normal(size=n)

# Check that the functions work
r1 = numbacall()
r2 = numpycall()
assert r1.shape == (n,)
assert r1.shape == r2.shape

t1 = timeit(numbacall, number=1000)
print(f'{t1:.2f} secs for {n} PCG64 (Numba/PCG64) gaussian randoms')
t2 = timeit(numpycall, number=1000)
print(f'{t2:.2f} secs for {n} PCG64 (NumPy/PCG64) gaussian randoms')
```

Both CTypes and CFFI allow the more complicated distributions to be used directly in Numba after compiling the file distributions.c into a `DLL` or `so`. An example showing the use of a more complicated distribution is in the *Examples* section below.

Cython

Cython can be used to unpack the `PyCapsule` provided by a *`BitGenerator`*. This example uses *`PCG64`* and the example from above. The usual caveats for writing high-performance code using Cython – removing bounds checks and wrap around, providing array alignment information – still apply.

```
#cython: language_level=3
"""
This file shows how the to use a BitGenerator to create a distribution.
"""
import numpy as np
cimport numpy as np
cimport cython
from cpython.pycapsule cimport PyCapsule_IsValid, PyCapsule_GetPointer
from libc.stdint cimport uint16_t, uint64_t
from numpy.random cimport bitgen_t
from numpy.random import PCG64
from numpy.random.c_distributions cimport (
      random_standard_uniform_fill, random_standard_uniform_fill_f)


@cython.boundscheck(False)
@cython.wraparound(False)
def uniforms(Py_ssize_t n):
    """
    Create an array of `n` uniformly distributed doubles.
    A 'real' distribution would want to process the values into
    some non-uniform distribution
    """
    cdef Py_ssize_t i
    cdef bitgen_t *rng
    cdef const char *capsule_name = "BitGenerator"
    cdef double[::1] random_values
```

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```
    x = PCG64()
    capsule = x.capsule
    # Optional check that the capsule if from a BitGenerator
    if not PyCapsule_IsValid(capsule, capsule_name):
        raise ValueError("Invalid pointer to anon_func_state")
    # Cast the pointer
    rng = <bitgen_t *> PyCapsule_GetPointer(capsule, capsule_name)
    random_values = np.empty(n, dtype='float64')
    with x.lock, nogil:
        for i in range(n):
            # Call the function
            random_values[i] = rng.next_double(rng.state)
    randoms = np.asarray(random_values)

    return randoms
```

The *BitGenerator* can also be directly accessed using the members of the `bitgen_t` struct.

```
@cython.boundscheck(False)
@cython.wraparound(False)
def uint10_uniforms(Py_ssize_t n):
    """Uniform 10 bit integers stored as 16-bit unsigned integers"""
    cdef Py_ssize_t i
    cdef bitgen_t *rng
    cdef const char *capsule_name = "BitGenerator"
    cdef uint16_t[::1] random_values
    cdef int bits_remaining
    cdef int width = 10
    cdef uint64_t buff, mask = 0x3FF

    x = PCG64()
    capsule = x.capsule
    if not PyCapsule_IsValid(capsule, capsule_name):
        raise ValueError("Invalid pointer to anon_func_state")
    rng = <bitgen_t *> PyCapsule_GetPointer(capsule, capsule_name)
    random_values = np.empty(n, dtype='uint16')
    # Best practice is to release GIL and acquire the lock
    bits_remaining = 0
    with x.lock, nogil:
        for i in range(n):
            if bits_remaining < width:
                buff = rng.next_uint64(rng.state)
            random_values[i] = buff & mask
            buff >>= width

    randoms = np.asarray(random_values)
    return randoms
```

Cython can be used to directly access the functions in `numpy/random/c_distributions.pxd`. This requires linking with the `npyrandom` library located in `numpy/random/lib`.

```
def uniforms_ex(bit_generator, Py_ssize_t n, dtype=np.float64):
    """
    Create an array of `n` uniformly distributed doubles via a "fill" function.

    A 'real' distribution would want to process the values into
    some non-uniform distribution
```

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```
    Parameters
    ----------
    bit_generator: BitGenerator instance
    n: int
        Output vector length
    dtype: {str, dtype}, optional
        Desired dtype, either 'd' (or 'float64') or 'f' (or 'float32'). The
        default dtype value is 'd'
    """
    cdef Py_ssize_t i
    cdef bitgen_t *rng
    cdef const char *capsule_name = "BitGenerator"
    cdef np.ndarray randoms

    capsule = bit_generator.capsule
    # Optional check that the capsule if from a BitGenerator
    if not PyCapsule_IsValid(capsule, capsule_name):
        raise ValueError("Invalid pointer to anon_func_state")
    # Cast the pointer
    rng = <bitgen_t *> PyCapsule_GetPointer(capsule, capsule_name)

    _dtype = np.dtype(dtype)
    randoms = np.empty(n, dtype=_dtype)
    if _dtype == np.float32:
        with bit_generator.lock:
            random_standard_uniform_fill_f(rng, n, <float*>np.PyArray_DATA(randoms))
    elif _dtype == np.float64:
        with bit_generator.lock:
            random_standard_uniform_fill(rng, n, <double*>np.PyArray_DATA(randoms))
    else:
        raise TypeError('Unsupported dtype %r for random' % _dtype)
    return randoms
```

See *Extending numpy.random via Cython* for the complete listings of these examples and a minimal `setup.py` to build the c-extension modules.

CFFI

CFFI can be used to directly access the functions in `include/numpy/random/distributions.h`. Some "massaging" of the header file is required:

```
"""
Use cffi to access any of the underlying C functions from distributions.h
"""
import os
import numpy as np
import cffi
from .parse import parse_distributions_h
ffi = cffi.FFI()

inc_dir = os.path.join(np.get_include(), 'numpy')

# Basic numpy types
ffi.cdef('''
```

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```
    typedef intptr_t npy_intp;
    typedef unsigned char npy_bool;

''')

parse_distributions_h(ffi, inc_dir)
```

Once the header is parsed by `ffi.cdef`, the functions can be accessed directly from the `_generator` shared object, using the `BitGenerator.cffi` interface.

```
# Compare the distributions.h random_standard_normal_fill to
# Generator.standard_random
bit_gen = np.random.PCG64()
rng = np.random.Generator(bit_gen)
state = bit_gen.state

interface = rng.bit_generator.cffi
n = 100
vals_cffi = ffi.new('double[%d]' % n)
lib.random_standard_normal_fill(interface.bit_generator, n, vals_cffi)

# reset the state
bit_gen.state = state

vals = rng.standard_normal(n)

for i in range(n):
    assert vals[i] == vals_cffi[i]
```

New BitGenerators

Generator can be used with user-provided *BitGenerator*s. The simplest way to write a new *BitGenerator* is to examine the pyx file of one of the existing *BitGenerator*s. The key structure that must be provided is the `capsule` which contains a `PyCapsule` to a struct pointer of type `bitgen_t`,

```
typedef struct bitgen {
  void *state;
  uint64_t (*next_uint64)(void *st);
  uint32_t (*next_uint32)(void *st);
  double (*next_double)(void *st);
  uint64_t (*next_raw)(void *st);
} bitgen_t;
```

which provides 5 pointers. The first is an opaque pointer to the data structure used by the *BitGenerator*s. The next three are function pointers which return the next 64- and 32-bit unsigned integers, the next random double and the next raw value. This final function is used for testing and so can be set to the next 64-bit unsigned integer function if not needed. Functions inside *Generator* use this structure as in

```
bitgen_state->next_uint64(bitgen_state->state)
```

Examples

Extending via Numba

```
import numpy as np
import numba as nb

from numpy.random import PCG64
from timeit import timeit

bit_gen = PCG64()
next_d = bit_gen.cffi.next_double
state_addr = bit_gen.cffi.state_address

def normals(n, state):
    out = np.empty(n)
    for i in range((n + 1) // 2):
        x1 = 2.0 * next_d(state) - 1.0
        x2 = 2.0 * next_d(state) - 1.0
        r2 = x1 * x1 + x2 * x2
        while r2 >= 1.0 or r2 == 0.0:
            x1 = 2.0 * next_d(state) - 1.0
            x2 = 2.0 * next_d(state) - 1.0
            r2 = x1 * x1 + x2 * x2
        f = np.sqrt(-2.0 * np.log(r2) / r2)
        out[2 * i] = f * x1
        if 2 * i + 1 < n:
            out[2 * i + 1] = f * x2
    return out

# Compile using Numba
normalsj = nb.jit(normals, nopython=True)
# Must use state address not state with numba
n = 10000

def numbacall():
    return normalsj(n, state_addr)

rg = np.random.Generator(PCG64())

def numpycall():
    return rg.normal(size=n)

# Check that the functions work
r1 = numbacall()
r2 = numpycall()
assert r1.shape == (n,)
assert r1.shape == r2.shape

t1 = timeit(numbacall, number=1000)
print(f'{t1:.2f} secs for {n} PCG64 (Numba/PCG64) gaussian randoms')
t2 = timeit(numpycall, number=1000)
print(f'{t2:.2f} secs for {n} PCG64 (NumPy/PCG64) gaussian randoms')

# example 2

next_u32 = bit_gen.ctypes.next_uint32
```

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```
ctypes_state = bit_gen.ctypes.state

@nb.jit(nopython=True)
def bounded_uint(lb, ub, state):
    mask = delta = ub - lb
    mask |= mask >> 1
    mask |= mask >> 2
    mask |= mask >> 4
    mask |= mask >> 8
    mask |= mask >> 16

    val = next_u32(state) & mask
    while val > delta:
        val = next_u32(state) & mask

    return lb + val


print(bounded_uint(323, 2394691, ctypes_state.value))


@nb.jit(nopython=True)
def bounded_uints(lb, ub, n, state):
    out = np.empty(n, dtype=np.uint32)
    for i in range(n):
        out[i] = bounded_uint(lb, ub, state)


bounded_uints(323, 2394691, 10000000, ctypes_state.value)
```

Extending via Numba and CFFI

```
r"""
Building the required library in this example requires a source distribution
of NumPy or clone of the NumPy git repository since distributions.c is not
included in binary distributions.

On *nix, execute in numpy/random/src/distributions

export ${PYTHON_VERSION}=3.8 # Python version
export PYTHON_INCLUDE=#path to Python's include folder, usually \
    ${PYTHON_HOME}/include/python${PYTHON_VERSION}m
export NUMPY_INCLUDE=#path to numpy's include folder, usually \
    ${PYTHON_HOME}/lib/python${PYTHON_VERSION}/site-packages/numpy/_core/include
gcc -shared -o libdistributions.so -fPIC distributions.c \
    -I${NUMPY_INCLUDE} -I${PYTHON_INCLUDE}
mv libdistributions.so ../../_examples/numba/

On Windows

rem PYTHON_HOME and PYTHON_VERSION are setup dependent, this is an example
set PYTHON_HOME=c:\Anaconda
```

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```
set PYTHON_VERSION=38
cl.exe /LD .\distributions.c -DDLL_EXPORT \
    -I%PYTHON_HOME%\lib\site-packages\numpy\_core\include \
    -I%PYTHON_HOME%\include %PYTHON_HOME%\libs\python%PYTHON_VERSION%.lib
move distributions.dll ../../_examples/numba/
"""
import os

import numba as nb
import numpy as np
from cffi import FFI

from numpy.random import PCG64

ffi = FFI()
if os.path.exists('./distributions.dll'):
    lib = ffi.dlopen('./distributions.dll')
elif os.path.exists('./libdistributions.so'):
    lib = ffi.dlopen('./libdistributions.so')
else:
    raise RuntimeError('Required DLL/so file was not found.')

ffi.cdef("""
double random_standard_normal(void *bitgen_state);
""")
x = PCG64()
xffi = x.cffi
bit_generator = xffi.bit_generator

random_standard_normal = lib.random_standard_normal


def normals(n, bit_generator):
    out = np.empty(n)
    for i in range(n):
        out[i] = random_standard_normal(bit_generator)
    return out


normalsj = nb.jit(normals, nopython=True)

# Numba requires a memory address for void *
# Can also get address from x.ctypes.bit_generator.value
bit_generator_address = int(ffi.cast('uintptr_t', bit_generator))

norm = normalsj(1000, bit_generator_address)
print(norm[:12])
```

Extending `numpy.random` via Cython

Starting with NumPy 1.26.0, Meson is the default build system for NumPy. See *Status of numpy.distutils and migration advice*.

meson.build

```
project('random-build-examples', 'c', 'cpp', 'cython')

py_mod = import('python')
py3 = py_mod.find_installation(pure: false)

cc = meson.get_compiler('c')
cy = meson.get_compiler('cython')

# Keep synced with pyproject.toml
if not cy.version().version_compare('>=3.0.6')
  error('tests requires Cython >= 3.0.6')
endif

base_cython_args = []
if cy.version().version_compare('>=3.1.0')
  base_cython_args += ['-Xfreethreading_compatible=True']
endif

_numpy_abs = run_command(py3, ['-c',
              'import os; os.chdir(".."); import numpy; print(os.path.abspath(numpy.
↪get_include() + "../../.."))'],
                         check: true).stdout().strip()

npymath_path = _numpy_abs / '_core' / 'lib'
npy_include_path = _numpy_abs / '_core' / 'include'
npyrandom_path = _numpy_abs / 'random' / 'lib'
npymath_lib = cc.find_library('npymath', dirs: npymath_path)
npyrandom_lib = cc.find_library('npyrandom', dirs: npyrandom_path)

py3.extension_module(
    'extending_distributions',
    'extending_distributions.pyx',
    install: false,
    include_directories: [npy_include_path],
    dependencies: [npyrandom_lib, npymath_lib],
    cython_args: base_cython_args,
)
py3.extension_module(
    'extending',
    'extending.pyx',
    install: false,
    include_directories: [npy_include_path],
    dependencies: [npyrandom_lib, npymath_lib],
    cython_args: base_cython_args,
)
py3.extension_module(
    'extending_cpp',
    'extending_distributions.pyx',
    install: false,
```

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```
    override_options : ['cython_language=cpp'],
    cython_args: base_cython_args + ['--module-name', 'extending_cpp'],
    include_directories: [npy_include_path],
    dependencies: [npyrandom_lib, npymath_lib],
)
```

extending.pyx

```
#cython: language_level=3

from libc.stdint cimport uint32_t
from cpython.pycapsule cimport PyCapsule_IsValid, PyCapsule_GetPointer

import numpy as np
cimport numpy as np
cimport cython

from numpy.random cimport bitgen_t
from numpy.random import PCG64

np.import_array()


@cython.boundscheck(False)
@cython.wraparound(False)
def uniform_mean(Py_ssize_t n):
    cdef Py_ssize_t i
    cdef bitgen_t *rng
    cdef const char *capsule_name = "BitGenerator"
    cdef double[::1] random_values
    cdef np.ndarray randoms

    x = PCG64()
    capsule = x.capsule
    if not PyCapsule_IsValid(capsule, capsule_name):
        raise ValueError("Invalid pointer to anon_func_state")
    rng = <bitgen_t *> PyCapsule_GetPointer(capsule, capsule_name)
    random_values = np.empty(n)
    # Best practice is to acquire the lock whenever generating random values.
    # This prevents other threads from modifying the state. Acquiring the lock
    # is only necessary if the GIL is also released, as in this example.
    with x.lock, nogil:
        for i in range(n):
            random_values[i] = rng.next_double(rng.state)
    randoms = np.asarray(random_values)
    return randoms.mean()


# This function is declared nogil so it can be used without the GIL below
cdef uint32_t bounded_uint(uint32_t lb, uint32_t ub, bitgen_t *rng) nogil:
    cdef uint32_t mask, delta, val
    mask = delta = ub - lb
    mask |= mask >> 1
    mask |= mask >> 2
```

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```
    mask |= mask >> 4
    mask |= mask >> 8
    mask |= mask >> 16

    val = rng.next_uint32(rng.state) & mask
    while val > delta:
        val = rng.next_uint32(rng.state) & mask

    return lb + val


@cython.boundscheck(False)
@cython.wraparound(False)
def bounded_uints(uint32_t lb, uint32_t ub, Py_ssize_t n):
    cdef Py_ssize_t i
    cdef bitgen_t *rng
    cdef uint32_t[::1] out
    cdef const char *capsule_name = "BitGenerator"

    x = PCG64()
    out = np.empty(n, dtype=np.uint32)
    capsule = x.capsule

    if not PyCapsule_IsValid(capsule, capsule_name):
        raise ValueError("Invalid pointer to anon_func_state")
    rng = <bitgen_t *>PyCapsule_GetPointer(capsule, capsule_name)

    with x.lock, nogil:
        for i in range(n):
            out[i] = bounded_uint(lb, ub, rng)
    return np.asarray(out)
```

extending_distributions.pyx

```
#cython: language_level=3
"""
This file shows how the to use a BitGenerator to create a distribution.
"""
import numpy as np
cimport numpy as np
cimport cython
from cpython.pycapsule cimport PyCapsule_IsValid, PyCapsule_GetPointer
from libc.stdint cimport uint16_t, uint64_t
from numpy.random cimport bitgen_t
from numpy.random import PCG64
from numpy.random.c_distributions cimport (
      random_standard_uniform_fill, random_standard_uniform_fill_f)


@cython.boundscheck(False)
@cython.wraparound(False)
def uniforms(Py_ssize_t n):
    """
    Create an array of `n` uniformly distributed doubles.
```

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```
    A 'real' distribution would want to process the values into
    some non-uniform distribution
    """
    cdef Py_ssize_t i
    cdef bitgen_t *rng
    cdef const char *capsule_name = "BitGenerator"
    cdef double[::1] random_values

    x = PCG64()
    capsule = x.capsule
    # Optional check that the capsule if from a BitGenerator
    if not PyCapsule_IsValid(capsule, capsule_name):
        raise ValueError("Invalid pointer to anon_func_state")
    # Cast the pointer
    rng = <bitgen_t *> PyCapsule_GetPointer(capsule, capsule_name)
    random_values = np.empty(n, dtype='float64')
    with x.lock, nogil:
        for i in range(n):
            # Call the function
            random_values[i] = rng.next_double(rng.state)
    randoms = np.asarray(random_values)

    return randoms

# cython example 2
@cython.boundscheck(False)
@cython.wraparound(False)
def uint10_uniforms(Py_ssize_t n):
    """Uniform 10 bit integers stored as 16-bit unsigned integers"""
    cdef Py_ssize_t i
    cdef bitgen_t *rng
    cdef const char *capsule_name = "BitGenerator"
    cdef uint16_t[::1] random_values
    cdef int bits_remaining
    cdef int width = 10
    cdef uint64_t buff, mask = 0x3FF

    x = PCG64()
    capsule = x.capsule
    if not PyCapsule_IsValid(capsule, capsule_name):
        raise ValueError("Invalid pointer to anon_func_state")
    rng = <bitgen_t *> PyCapsule_GetPointer(capsule, capsule_name)
    random_values = np.empty(n, dtype='uint16')
    # Best practice is to release GIL and acquire the lock
    bits_remaining = 0
    with x.lock, nogil:
        for i in range(n):
            if bits_remaining < width:
                buff = rng.next_uint64(rng.state)
            random_values[i] = buff & mask
            buff >>= width

    randoms = np.asarray(random_values)
    return randoms

# cython example 3
def uniforms_ex(bit_generator, Py_ssize_t n, dtype=np.float64):
```

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```
    """
    Create an array of `n` uniformly distributed doubles via a "fill" function.

    A 'real' distribution would want to process the values into
    some non-uniform distribution

    Parameters
    ----------
    bit_generator: BitGenerator instance
    n: int
        Output vector length
    dtype: {str, dtype}, optional
        Desired dtype, either 'd' (or 'float64') or 'f' (or 'float32'). The
        default dtype value is 'd'
    """
    cdef Py_ssize_t i
    cdef bitgen_t *rng
    cdef const char *capsule_name = "BitGenerator"
    cdef np.ndarray randoms

    capsule = bit_generator.capsule
    # Optional check that the capsule if from a BitGenerator
    if not PyCapsule_IsValid(capsule, capsule_name):
        raise ValueError("Invalid pointer to anon_func_state")
    # Cast the pointer
    rng = <bitgen_t *> PyCapsule_GetPointer(capsule, capsule_name)

    _dtype = np.dtype(dtype)
    randoms = np.empty(n, dtype=_dtype)
    if _dtype == np.float32:
        with bit_generator.lock:
            random_standard_uniform_fill_f(rng, n, <float*>np.PyArray_DATA(randoms))
    elif _dtype == np.float64:
        with bit_generator.lock:
            random_standard_uniform_fill(rng, n, <double*>np.PyArray_DATA(randoms))
    else:
        raise TypeError('Unsupported dtype %r for random' % _dtype)
    return randoms
```

Extending via CFFI

```
"""
Use cffi to access any of the underlying C functions from distributions.h
"""
import os
import numpy as np
import cffi
from .parse import parse_distributions_h
ffi = cffi.FFI()

inc_dir = os.path.join(np.get_include(), 'numpy')

# Basic numpy types
ffi.cdef('''
```

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```
    typedef intptr_t npy_intp;
    typedef unsigned char npy_bool;

''')

parse_distributions_h(ffi, inc_dir)

lib = ffi.dlopen(np.random._generator.__file__)

# Compare the distributions.h random_standard_normal_fill to
# Generator.standard_random
bit_gen = np.random.PCG64()
rng = np.random.Generator(bit_gen)
state = bit_gen.state

interface = rng.bit_generator.cffi
n = 100
vals_cffi = ffi.new('double[%d]' % n)
lib.random_standard_normal_fill(interface.bit_generator, n, vals_cffi)

# reset the state
bit_gen.state = state

vals = rng.standard_normal(n)

for i in range(n):
    assert vals[i] == vals_cffi[i]
```

Original Source of the Generator and BitGenerators

This package was developed independently of NumPy and was integrated in version 1.17.0. The original repo is at https://github.com/bashtage/randomgen.

String functionality

The *numpy.strings* module provides a set of universal functions operating on arrays of type *numpy.str_* or *numpy.bytes_*. For example

```
>>> np.strings.add(["num", "doc"], ["py", "umentation"])
array(['numpy', 'documentation'], dtype='<U13')
```

These universal functions are also used in *numpy.char*, which provides the *numpy.char.chararray* array subclass, in order for those routines to get the performance benefits as well.

Note: Prior to NumPy 2.0, all string functionality was in *numpy.char*, which only operated on fixed-width strings. That module will not be getting updates and will be deprecated at some point in the future.

String operations

add(x1, x2, /[, out, where, casting, order, ...])	Add arguments element-wise.
center(a, width[, fillchar])	Return a copy of *a* with its elements centered in a string of length *width*.
capitalize(a)	Return a copy of `a` with only the first character of each element capitalized.
decode(a[, encoding, errors])	Calls `bytes.decode` element-wise.
encode(a[, encoding, errors])	Calls `str.encode` element-wise.
expandtabs(a[, tabsize])	Return a copy of each string element where all tab characters are replaced by one or more spaces.
ljust(a, width[, fillchar])	Return an array with the elements of *a* left-justified in a string of length *width*.
lower(a)	Return an array with the elements converted to lowercase.
lstrip(a[, chars])	For each element in *a*, return a copy with the leading characters removed.
mod(a, values)	Return (a % i), that is pre-Python 2.6 string formatting (interpolation), element-wise for a pair of array_likes of str or unicode.
multiply(a, i)	Return (a * i), that is string multiple concatenation, element-wise.
partition(a, sep)	Partition each element in `a` around `sep`.
replace(a, old, new[, count])	For each element in `a`, return a copy of the string with occurrences of substring `old` replaced by `new`.
rjust(a, width[, fillchar])	Return an array with the elements of *a* right-justified in a string of length *width*.
rpartition(a, sep)	Partition (split) each element around the right-most separator.
rstrip(a[, chars])	For each element in *a*, return a copy with the trailing characters removed.
strip(a[, chars])	For each element in *a*, return a copy with the leading and trailing characters removed.
swapcase(a)	Return element-wise a copy of the string with uppercase characters converted to lowercase and vice versa.
title(a)	Return element-wise title cased version of string or unicode.
translate(a, table[, deletechars])	For each element in *a*, return a copy of the string where all characters occurring in the optional argument *deletechars* are removed, and the remaining characters have been mapped through the given translation table.
upper(a)	Return an array with the elements converted to uppercase.
zfill(a, width)	Return the numeric string left-filled with zeros.

`strings.`**`add`**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **`= <ufunc 'add'>`**

Add arguments element-wise.

Parameters

x1, x2
[array_like] The arrays to be added. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out

[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

add
[ndarray or scalar] The sum of *x1* and *x2*, element-wise. This is a scalar if both *x1* and *x2* are scalars.

Notes

Equivalent to *x1* + *x2* in terms of array broadcasting.

Examples

```
>>> import numpy as np
>>> np.add(1.0, 4.0)
5.0
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> np.add(x1, x2)
array([[  0.,   2.,   4.],
       [  3.,   5.,   7.],
       [  6.,   8.,  10.]])
```

The + operator can be used as a shorthand for `np.add` on ndarrays.

```
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> x1 + x2
array([[ 0.,  2.,  4.],
       [ 3.,  5.,  7.],
       [ 6.,  8., 10.]])
```

`strings.`**`center`**(*a*, *width*, *fillchar=' '*)

Return a copy of *a* with its elements centered in a string of length *width*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

width
[array_like, with any integer dtype] The length of the resulting strings, unless `width < str_len(a)`.

fillchar
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Optional padding character to use (default is space).

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.center`

Notes

While it is possible for `a` and `fillchar` to have different dtypes, passing a non-ASCII character in `fillchar` when `a` is of dtype "S" is not allowed, and a `ValueError` is raised.

Examples

```
>>> import numpy as np
>>> c = np.array(['a1b2','1b2a','b2a1','2a1b']); c
array(['a1b2', '1b2a', 'b2a1', '2a1b'], dtype='<U4')
>>> np.strings.center(c, width=9)
array(['   a1b2  ', '   1b2a  ', '   b2a1  ', '   2a1b  '], dtype='<U9')
>>> np.strings.center(c, width=9, fillchar='*')
array(['***a1b2**', '***1b2a**', '***b2a1**', '***2a1b**'], dtype='<U9')
>>> np.strings.center(c, width=1)
array(['a1b2', '1b2a', 'b2a1', '2a1b'], dtype='<U4')
```

`strings.`**`capitalize`**(*a*)

Return a copy of `a` with only the first character of each element capitalized.

Calls `str.capitalize` element-wise.

For byte strings, this method is locale-dependent.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array of strings to capitalize.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.capitalize`

Examples

```
>>> import numpy as np
>>> c = np.array(['a1b2','1b2a','b2a1','2a1b'],'S4'); c
array(['a1b2', '1b2a', 'b2a1', '2a1b'],
    dtype='|S4')
>>> np.strings.capitalize(c)
array(['A1b2', '1b2a', 'B2a1', '2a1b'],
    dtype='|S4')
```

strings.**decode**(*a*, *encoding=None*, *errors=None*)

Calls bytes.decode element-wise.

The set of available codecs comes from the Python standard library, and may be extended at runtime. For more information, see the codecs module.

Parameters

a
[array_like, with bytes_ dtype]

encoding
[str, optional] The name of an encoding

errors
[str, optional] Specifies how to handle encoding errors

Returns

out
[ndarray]

See also:

bytes.decode

Notes

The type of the result will depend on the encoding specified.

Examples

```
>>> import numpy as np
>>> c = np.array([b'\x81\xc1\x81\xc1\x81\xc1', b'@@\x81\xc1@@',
...               b'\x81\x82\xc2\xc1\xc2\x82\x81'])
>>> c
array([b'\x81\xc1\x81\xc1\x81\xc1', b'@@\x81\xc1@@',
       b'\x81\x82\xc2\xc1\xc2\x82\x81'], dtype='|S7')
>>> np.strings.decode(c, encoding='cp037')
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
```

strings.**encode**(*a*, *encoding=None*, *errors=None*)

Calls str.encode element-wise.

The set of available codecs comes from the Python standard library, and may be extended at runtime. For more information, see the codecs module.

Parameters

a
[array_like, with `StringDType` or `str_` dtype]

encoding
[str, optional] The name of an encoding

errors
[str, optional] Specifies how to handle encoding errors

Returns

out
[ndarray]

See also:

`str.encode`

Notes

The type of the result will depend on the encoding specified.

Examples

```
>>> import numpy as np
>>> a = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> np.strings.encode(a, encoding='cp037')
array([b'\x81\xc1\x81\xc1\x81\xc1', b'@@\x81\xc1@@',
   b'\x81\x82\xc2\xc1\xc2\x82\x81'], dtype='|S7')
```

`strings.`**`expandtabs`**(*a*, *tabsize=8*)

Return a copy of each string element where all tab characters are replaced by one or more spaces.

Calls `str.expandtabs` element-wise.

Return a copy of each string element where all tab characters are replaced by one or more spaces, depending on the current column and the given *tabsize*. The column number is reset to zero after each newline occurring in the string. This doesn't understand other non-printing characters or escape sequences.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array

tabsize
[int, optional] Replace tabs with *tabsize* number of spaces. If not given defaults to 8 spaces.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input type

See also:

`str.expandtabs`

Examples

```
>>> import numpy as np
>>> a = np.array(['         Hello   world'])
>>> np.strings.expandtabs(a, tabsize=4)
array(['        Hello   world'], dtype='<U21')
```

strings.**ljust**(*a*, *width*, *fillchar=' '*)

Return an array with the elements of *a* left-justified in a string of length *width*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

width
[array_like, with any integer dtype] The length of the resulting strings, unless `width < str_len(a)`.

fillchar
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Optional character to use for padding (default is space).

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.ljust`

Notes

While it is possible for `a` and `fillchar` to have different dtypes, passing a non-ASCII character in `fillchar` when `a` is of dtype "S" is not allowed, and a `ValueError` is raised.

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> np.strings.ljust(c, width=3)
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> np.strings.ljust(c, width=9)
array(['aAaAaA   ', '  aA     ', 'abBABba  '], dtype='<U9')
```

strings.**lower**(*a*)

Return an array with the elements converted to lowercase.

Call `str.lower` element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.lower`

Examples

```
>>> import numpy as np
>>> c = np.array(['A1B C', '1BCA', 'BCA1']); c
array(['A1B C', '1BCA', 'BCA1'], dtype='<U5')
>>> np.strings.lower(c)
array(['a1b c', '1bca', 'bca1'], dtype='<U5')
```

`strings.`**`lstrip`**(*a*, *chars=None*)

For each element in *a*, return a copy with the leading characters removed.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

chars
[scalar with the same dtype as `a`, optional] The `chars` argument is a string specifying the set of characters to be removed. If `None`, the `chars` argument defaults to removing whitespace. The `chars` argument is not a prefix or suffix; rather, all combinations of its values are stripped.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.lstrip`

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> c
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
# The 'a' variable is unstripped from c[1] because of leading whitespace.
>>> np.strings.lstrip(c, 'a')
array(['AaAaA', '  aA  ', 'bBABba'], dtype='<U7')
>>> np.strings.lstrip(c, 'A') # leaves c unchanged
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> (np.strings.lstrip(c, ' ') == np.strings.lstrip(c, '')).all()
np.False_
>>> (np.strings.lstrip(c, ' ') == np.strings.lstrip(c)).all()
np.True_
```

strings.**mod**(*a*, *values*)

Return (a % i), that is pre-Python 2.6 string formatting (interpolation), element-wise for a pair of array_likes of str or unicode.

Parameters

a
[array_like, with *np.bytes_* or *np.str_* dtype]

values
[array_like of values] These values will be element-wise interpolated into the string.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

Examples

```
>>> import numpy as np
>>> a = np.array(["NumPy is a %s library"])
>>> np.strings.mod(a, values=["Python"])
array(['NumPy is a Python library'], dtype='<U25')
```

```
>>> a = np.array([b'%d bytes', b'%d bits'])
>>> values = np.array([8, 64])
>>> np.strings.mod(a, values)
array([b'8 bytes', b'64 bits'], dtype='|S7')
```

strings.**multiply**(*a*, *i*)

Return (a * i), that is string multiple concatenation, element-wise.

Values in `i` of less than 0 are treated as 0 (which yields an empty string).

Parameters

a
[array_like, with `StringDType`, `bytes_` or `str_` dtype]

i
[array_like, with any integer dtype]

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

Examples

```
>>> import numpy as np
>>> a = np.array(["a", "b", "c"])
>>> np.strings.multiply(a, 3)
array(['aaa', 'bbb', 'ccc'], dtype='<U3')
>>> i = np.array([1, 2, 3])
>>> np.strings.multiply(a, i)
array(['a', 'bb', 'ccc'], dtype='<U3')
>>> np.strings.multiply(np.array(['a']), i)
array(['a', 'aa', 'aaa'], dtype='<U3')
>>> a = np.array(['a', 'b', 'c', 'd', 'e', 'f']).reshape((2, 3))
>>> np.strings.multiply(a, 3)
array([['aaa', 'bbb', 'ccc'],
       ['ddd', 'eee', 'fff']], dtype='<U3')
>>> np.strings.multiply(a, i)
array([['a', 'bb', 'ccc'],
       ['d', 'ee', 'fff']], dtype='<U3')
```

strings.**partition**(*a*, *sep*)

Partition each element in a around sep.

For each element in a, split the element at the first occurrence of sep, and return a 3-tuple containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, the first item of the tuple will contain the whole string, and the second and third ones will be the empty string.

Parameters

a
[array-like, with StringDType, bytes_, or str_ dtype] Input array

sep
[array-like, with StringDType, bytes_, or str_ dtype] Separator to split each string element in a.

Returns

out
[3-tuple:]

- array with StringDType, bytes_ or str_ dtype with the part before the separator
- array with StringDType, bytes_ or str_ dtype with the separator
- array with StringDType, bytes_ or str_ dtype with the part after the separator

See also:

str.partition

Examples

```
>>> import numpy as np
>>> x = np.array(["Numpy is nice!"])
>>> np.strings.partition(x, " ")
(array(['Numpy'], dtype='<U5'),
 array([' '], dtype='<U1'),
 array(['is nice!'], dtype='<U8'))
```

strings.**replace**(*a*, *old*, *new*, *count=-1*)

For each element in `a`, return a copy of the string with occurrences of substring `old` replaced by `new`.

Parameters

a
[array_like, with `bytes_` or `str_` dtype]

old, new
[array_like, with `bytes_` or `str_` dtype]

count
[array_like, with `int_` dtype] If the optional argument `count` is given, only the first `count` occurrences are replaced.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.replace`

Examples

```
>>> import numpy as np
>>> a = np.array(["That is a mango", "Monkeys eat mangos"])
>>> np.strings.replace(a, 'mango', 'banana')
array(['That is a banana', 'Monkeys eat bananas'], dtype='<U19')
```

```
>>> a = np.array(["The dish is fresh", "This is it"])
>>> np.strings.replace(a, 'is', 'was')
array(['The dwash was fresh', 'Thwas was it'], dtype='<U19')
```

strings.**rjust**(*a*, *width*, *fillchar=' '*)

Return an array with the elements of *a* right-justified in a string of length *width*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

width
[array_like, with any integer dtype] The length of the resulting strings, unless `width < str_len(a)`.

fillchar
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Optional padding character to use (default is space).

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.rjust`

Notes

While it is possible for `a` and `fillchar` to have different dtypes, passing a non-ASCII character in `fillchar` when `a` is of dtype "S" is not allowed, and a `ValueError` is raised.

Examples

```
>>> import numpy as np
>>> a = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> np.strings.rjust(a, width=3)
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> np.strings.rjust(a, width=9)
array(['   aAaAaA', '     aA  ', '  abBABba'], dtype='<U9')
```

`strings.`**`rpartition`**(*a*, *sep*)

Partition (split) each element around the right-most separator.

For each element in `a`, split the element at the last occurrence of `sep`, and return a 3-tuple containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, the third item of the tuple will contain the whole string, and the first and second ones will be the empty string.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array

sep
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Separator to split each string element in `a`.

Returns

out
[3-tuple:]

- array with `StringDType`, `bytes_` or `str_` dtype with the part before the separator
- array with `StringDType`, `bytes_` or `str_` dtype with the separator
- array with `StringDType`, `bytes_` or `str_` dtype with the part after the separator

See also:

`str.rpartition`

Examples

```
>>> import numpy as np
>>> a = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> np.strings.rpartition(a, 'A')
(array(['aAaAa', '  a', 'abB'], dtype='<U5'),
 array(['A', 'A', 'A'], dtype='<U1'),
 array(['', '  ', 'Bba'], dtype='<U3'))
```

strings.**rstrip**(*a*, *chars=None*)

For each element in *a*, return a copy with the trailing characters removed.

Parameters

a
[array-like, with StringDType, bytes_, or str_ dtype]

chars
[scalar with the same dtype as a, optional] The chars argument is a string specifying the set of characters to be removed. If None, the chars argument defaults to removing whitespace. The chars argument is not a prefix or suffix; rather, all combinations of its values are stripped.

Returns

out
[ndarray] Output array of StringDType, bytes_ or str_ dtype, depending on input types

See also:

str.rstrip

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', 'abBABba'])
>>> c
array(['aAaAaA', 'abBABba'], dtype='<U7')
>>> np.strings.rstrip(c, 'a')
array(['aAaAaA', 'abBABb'], dtype='<U7')
>>> np.strings.rstrip(c, 'A')
array(['aAaAa', 'abBABba'], dtype='<U7')
```

strings.**strip**(*a*, *chars=None*)

For each element in *a*, return a copy with the leading and trailing characters removed.

Parameters

a
[array-like, with StringDType, bytes_, or str_ dtype]

chars
[scalar with the same dtype as a, optional] The chars argument is a string specifying the set of characters to be removed. If None, the chars argument defaults to removing whitespace. The chars argument is not a prefix or suffix; rather, all combinations of its values are stripped.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.strip`

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> c
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> np.strings.strip(c)
array(['aAaAaA', 'aA', 'abBABba'], dtype='<U7')
# 'a' unstripped from c[1] because of leading whitespace.
>>> np.strings.strip(c, 'a')
array(['AaAaA', '  aA  ', 'bBABb'], dtype='<U7')
# 'A' unstripped from c[1] because of trailing whitespace.
>>> np.strings.strip(c, 'A')
array(['aAaAa', '  aA  ', 'abBABba'], dtype='<U7')
```

`strings.`**`swapcase`**`(`*`a`*`)`

Return element-wise a copy of the string with uppercase characters converted to lowercase and vice versa.

Calls `str.swapcase` element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.swapcase`

Examples

```
>>> import numpy as np
>>> c=np.array(['a1B c','1b Ca','b Ca1','cA1b'],'S5'); c
array(['a1B c', '1b Ca', 'b Ca1', 'cA1b'],
    dtype='|S5')
>>> np.strings.swapcase(c)
array(['A1b C', '1B cA', 'B cA1', 'Ca1B'],
    dtype='|S5')
```

strings.**title**(*a*)

Return element-wise title cased version of string or unicode.

Title case words start with uppercase characters, all remaining cased characters are lowercase.

Calls `str.title` element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.title`

Examples

```
>>> import numpy as np
>>> c=np.array(['a1b c','1b ca','b ca1','ca1b'],'S5'); c
array(['a1b c', '1b ca', 'b ca1', 'ca1b'],
    dtype='|S5')
>>> np.strings.title(c)
array(['A1B C', '1B Ca', 'B Ca1', 'Ca1B'],
    dtype='|S5')
```

strings.**translate**(*a*, *table*, *deletechars=None*)

For each element in *a*, return a copy of the string where all characters occurring in the optional argument *deletechars* are removed, and the remaining characters have been mapped through the given translation table.

Calls `str.translate` element-wise.

Parameters

a
[array-like, with *np.bytes_* or *np.str_* dtype]

table
[str of length 256]

deletechars
[str]

Returns

out
[ndarray] Output array of str or unicode, depending on input type

See also:

`str.translate`

Examples

```
>>> import numpy as np
>>> a = np.array(['a1b c', '1bca', 'bca1'])
>>> table = a[0].maketrans('abc', '123')
>>> deletechars = ' '
>>> np.char.translate(a, table, deletechars)
array(['112 3', '1231', '2311'], dtype='<U5')
```

strings.**upper**(*a*)

Return an array with the elements converted to uppercase.

Calls `str.upper` element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

str.upper

Examples

```
>>> import numpy as np
>>> c = np.array(['a1b c', '1bca', 'bca1']); c
array(['a1b c', '1bca', 'bca1'], dtype='<U5')
>>> np.strings.upper(c)
array(['A1B C', '1BCA', 'BCA1'], dtype='<U5')
```

strings.**zfill**(*a*, *width*)

Return the numeric string left-filled with zeros. A leading sign prefix (+/−) is handled by inserting the padding after the sign character rather than before.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

width
[array_like, with any integer dtype] Width of string to left-fill elements in *a*.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input type

See also:

str.zfill

Examples

```
>>> import numpy as np
>>> np.strings.zfill(['1', '-1', '+1'], 3)
array(['001', '-01', '+01'], dtype='<U3')
```

Comparison

The *numpy.strings* module also exports the comparison universal functions that can now operate on string arrays as well.

equal(x1, x2, /[, out, where, casting, ...])	Return (x1 == x2) element-wise.
not_equal(x1, x2, /[, out, where, casting, ...])	Return (x1 != x2) element-wise.
greater_equal(x1, x2, /[, out, where, ...])	Return the truth value of (x1 >= x2) element-wise.
less_equal(x1, x2, /[, out, where, casting, ...])	Return the truth value of (x1 <= x2) element-wise.
greater(x1, x2, /[, out, where, casting, ...])	Return the truth value of (x1 > x2) element-wise.
less(x1, x2, /[, out, where, casting, ...])	Return the truth value of (x1 < x2) element-wise.

strings.**equal** (*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'equal'>**

Return (x1 == x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

not_equal, ***greater_equal***, ***less_equal***, ***greater***, ***less***

Examples

```
>>> import numpy as np
>>> np.equal([0, 1, 3], np.arange(3))
array([ True,  True, False])
```

What is compared are values, not types. So an int (1) and an array of length one can evaluate as True:

```
>>> np.equal(1, np.ones(1))
array([ True])
```

The == operator can be used as a shorthand for `np.equal` on ndarrays.

```
>>> a = np.array([2, 4, 6])
>>> b = np.array([2, 4, 2])
>>> a == b
array([ True,  True, False])
```

`strings.`**`not_equal`**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'not_equal'>**

Return (x1 != x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

equal, ***greater***, ***greater_equal***, ***less***, ***less_equal***

Examples

```
>>> import numpy as np
>>> np.not_equal([1.,2.], [1., 3.])
array([False,  True])
>>> np.not_equal([1, 2], [[1, 3],[1, 4]])
array([[False,  True],
       [False,  True]])
```

The != operator can be used as a shorthand for `np.not_equal` on ndarrays.

```
>>> a = np.array([1., 2.])
>>> b = np.array([1., 3.])
>>> a != b
array([False,  True])
```

strings.**greater_equal**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'greater_equal'>**

Return the truth value of (x1 >= x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [bool or ndarray of bool] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

greater, ***less***, ***less_equal***, ***equal***, ***not_equal***

Examples

```
>>> import numpy as np
>>> np.greater_equal([4, 2, 1], [2, 2, 2])
array([ True, True, False])
```

The >= operator can be used as a shorthand for `np.greater_equal` on ndarrays.

```
>>> a = np.array([4, 2, 1])
>>> b = np.array([2, 2, 2])
>>> a >= b
array([ True,  True, False])
```

`strings.`**`less_equal`**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'less_equal'>**

Return the truth value of (x1 <= x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

greater, ***less***, ***greater_equal***, ***equal***, ***not_equal***

Examples

```
>>> import numpy as np
>>> np.less_equal([4, 2, 1], [2, 2, 2])
array([False,  True,  True])
```

The <= operator can be used as a shorthand for `np.less_equal` on ndarrays.

```
>>> a = np.array([4, 2, 1])
>>> b = np.array([2, 2, 2])
>>> a <= b
array([False,  True,  True])
```

`strings.`**`greater`**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'greater'>**

Return the truth value of (x1 > x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

greater_equal, ***less***, ***less_equal***, ***equal***, ***not_equal***

Examples

```
>>> import numpy as np
>>> np.greater([4,2],[2,2])
array([ True, False])
```

The > operator can be used as a shorthand for `np.greater` on ndarrays.

```
>>> a = np.array([4, 2])
>>> b = np.array([2, 2])
>>> a > b
array([ True, False])
```

`strings.`**`less`**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'less'>**

Return the truth value of (x1 < x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

greater, ***less_equal***, ***greater_equal***, ***equal***, ***not_equal***

Examples

```
>>> import numpy as np
>>> np.less([1, 2], [2, 2])
array([ True, False])
```

The < operator can be used as a shorthand for `np.less` on ndarrays.

```
>>> a = np.array([1, 2])
>>> b = np.array([2, 2])
>>> a < b
array([ True, False])
```

String information

count(a, sub[, start, end])	Returns an array with the number of non-overlapping occurrences of substring `sub` in the range [`start`, `end`).
endswith(a, suffix[, start, end])	Returns a boolean array which is *True* where the string element in `a` ends with `suffix`, otherwise *False*.
find(a, sub[, start, end])	For each element, return the lowest index in the string where substring `sub` is found, such that `sub` is contained in the range [`start`, `end`).
index(a, sub[, start, end])	Like *find*, but raises `ValueError` when the substring is not found.
isalnum(x, /[, out, where, casting, order, ...])	Returns true for each element if all characters in the string are alphanumeric and there is at least one character, false otherwise.
isalpha(x, /[, out, where, casting, order, ...])	Returns true for each element if all characters in the data interpreted as a string are alphabetic and there is at least one character, false otherwise.
isdecimal(x, /[, out, where, casting, ...])	For each element, return True if there are only decimal characters in the element.
isdigit(x, /[, out, where, casting, order, ...])	Returns true for each element if all characters in the string are digits and there is at least one character, false otherwise.
islower(x, /[, out, where, casting, order, ...])	Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character, false otherwise.
isnumeric(x, /[, out, where, casting, ...])	For each element, return True if there are only numeric characters in the element.
isspace(x, /[, out, where, casting, order, ...])	Returns true for each element if there are only whitespace characters in the string and there is at least one character, false otherwise.
istitle(x, /[, out, where, casting, order, ...])	Returns true for each element if the element is a titlecased string and there is at least one character, false otherwise.
isupper(x, /[, out, where, casting, order, ...])	Return true for each element if all cased characters in the string are uppercase and there is at least one character, false otherwise.
rfind(a, sub[, start, end])	For each element, return the highest index in the string where substring `sub` is found, such that `sub` is contained in the range [`start`, `end`).
rindex(a, sub[, start, end])	Like *rfind*, but raises `ValueError` when the substring *sub* is not found.
startswith(a, prefix[, start, end])	Returns a boolean array which is *True* where the string element in `a` starts with `prefix`, otherwise *False*.
str_len(x, /[, out, where, casting, order, ...])	Returns the length of each element.

strings.**count**(*a*, *sub*, *start=0*, *end=None*)

Returns an array with the number of non-overlapping occurrences of substring `sub` in the range [`start`, `end`).

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

sub
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] The substring to search for.

start, end
[array_like, with any integer dtype] The range to look in, interpreted as in slice notation.

Returns

y
[ndarray] Output array of ints

See also:

`str.count`

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> c
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> np.strings.count(c, 'A')
array([3, 1, 1])
>>> np.strings.count(c, 'aA')
array([3, 1, 0])
>>> np.strings.count(c, 'A', start=1, end=4)
array([2, 1, 1])
>>> np.strings.count(c, 'A', start=1, end=3)
array([1, 0, 0])
```

`strings.`**`endswith`**(*a*, *suffix*, *start=0*, *end=None*)

Returns a boolean array which is *True* where the string element in `a` ends with `suffix`, otherwise *False*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

suffix
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

start, end
[array_like, with any integer dtype] With `start`, test beginning at that position. With `end`, stop comparing at that position.

Returns

out
[ndarray] Output array of bools

See also:

`str.endswith`

Examples

```
>>> import numpy as np
>>> s = np.array(['foo', 'bar'])
>>> s
array(['foo', 'bar'], dtype='<U3')
>>> np.strings.endswith(s, 'ar')
array([False,  True])
>>> np.strings.endswith(s, 'a', start=1, end=2)
array([False,  True])
```

strings.**find**(*a*, *sub*, *start=0*, *end=None*)

For each element, return the lowest index in the string where substring `sub` is found, such that `sub` is contained in the range [`start`, `end`).

Parameters

a
[array_like, with `StringDType`, `bytes_` or `str_` dtype]

sub
[array_like, with *np.bytes_* or *np.str_* dtype] The substring to search for.

start, end
[array_like, with any integer dtype] The range to look in, interpreted as in slice notation.

Returns

y
[ndarray] Output array of ints

See also:

`str.find`

Examples

```
>>> import numpy as np
>>> a = np.array(["NumPy is a Python library"])
>>> np.strings.find(a, "Python")
array([11])
```

strings.**index**(*a*, *sub*, *start=0*, *end=None*)

Like *find*, but raises `ValueError` when the substring is not found.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

sub
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

start, end
[array_like, with any integer dtype, optional]

Returns

out
[ndarray] Output array of ints.

See also:

find, str.index

Examples

```
>>> import numpy as np
>>> a = np.array(["Computer Science"])
>>> np.strings.index(a, "Science", start=0, end=None)
array([9])
```

strings.**isalnum**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isalnum'>**

Returns true for each element if all characters in the string are alphanumeric and there is at least one character, false otherwise.

Parameters

x
[array_like, with StringDType, bytes_ or str_ dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default out=None, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray] Output array of bool This is a scalar if *x* is a scalar.

See also:

str.isalnum

Examples

```
>>> import numpy as np
>>> a = np.array(['a', '1', 'a1', '(', ''])
>>> np.strings.isalnum(a)
array([ True,  True,  True, False, False])
```

strings.**isalpha**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isalpha'>**

Returns true for each element if all characters in the data interpreted as a string are alphabetic and there is at least one character, false otherwise.

For byte strings (i.e. `bytes`), alphabetic characters are those byte values in the sequence b'abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ'. For Unicode strings, alphabetic characters are those characters defined in the Unicode character database as "Letter".

Parameters

x
[array_like, with `StringDType`, `bytes_`, or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isalpha`

Examples

```
>>> import numpy as np
>>> a = np.array(['a', 'b', '0'])
>>> np.strings.isalpha(a)
array([ True,  True, False])
```

```
>>> a = np.array([['a', 'b', '0'], ['c', '1', '2']])
>>> np.strings.isalpha(a)
array([[ True,  True, False], [ True, False, False]])
```

`strings.`**`isdecimal`**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isdecimal'>**

For each element, return True if there are only decimal characters in the element.

Decimal characters include digit characters, and all characters that can be used to form decimal-radix numbers, e.g. `U+0660, ARABIC-INDIC DIGIT ZERO`.

Parameters

x
[array_like, with `StringDType` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None,

a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isdecimal`

Examples

```
>>> import numpy as np
>>> np.strings.isdecimal(['12345', '4.99', '123ABC', ''])
array([ True, False, False, False])
```

`strings.`**`isdigit`**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isdigit'>**

Returns true for each element if all characters in the string are digits and there is at least one character, false otherwise.

For byte strings, digits are the byte values in the sequence b'0123456789'. For Unicode strings, digits include decimal characters and digits that need special handling, such as the compatibility superscript digits. This also covers digits which cannot be used to form numbers in base 10, like the Kharosthi numbers.

Parameters

x
[array_like, with `StringDType`, `bytes_`, or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isdigit`

Examples

```
>>> import numpy as np
>>> a = np.array(['a', 'b', '0'])
>>> np.strings.isdigit(a)
array([False, False,  True])
>>> a = np.array([['a', 'b', '0'], ['c', '1', '2']])
>>> np.strings.isdigit(a)
array([[False, False,  True], [False,  True,  True]])
```

`strings.`**`islower`**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **`= <ufunc 'islower'>`**

Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character, false otherwise.

Parameters

x
[array_like, with `StringDType`, `bytes_` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.islower`

Examples

```
>>> import numpy as np
>>> np.strings.islower("GHC")
array(False)
>>> np.strings.islower("ghc")
array(True)
```

strings.**isnumeric**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isnumeric'>**

For each element, return True if there are only numeric characters in the element.

Numeric characters include digit characters, and all characters that have the Unicode numeric value property, e.g. `U+2155, VULGAR FRACTION ONE FIFTH`.

Parameters

x
[array_like, with `StringDType` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

str.isnumeric

Examples

```
>>> import numpy as np
>>> np.strings.isnumeric(['123', '123abc', '9.0', '1/4', 'VIII'])
array([ True, False, False, False, False])
```

strings.**isspace**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isspace'>**

Returns true for each element if there are only whitespace characters in the string and there is at least one character, false otherwise.

For byte strings, whitespace characters are the ones in the sequence b' tnrx0bf'. For Unicode strings, a character is whitespace, if, in the Unicode character database, its general category is Zs ("Separator, space"), or its bidirectional class is one of WS, B, or S.

Parameters

x
[array_like, with `StringDType`, `bytes_`, or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isspace`

Examples

```
>>> np.char.isspace(list("a b c"))
array([False,  True, False,  True, False])
>>> np.char.isspace(b'\x0a \x0b \x0c')
np.True_
>>> np.char.isspace(b'\x0a \x0b \x0c N')
np.False_
```

`strings.`**`istitle`**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **`= <ufunc 'istitle'>`**

Returns true for each element if the element is a titlecased string and there is at least one character, false otherwise.

Parameters

x
[array_like, with `StringDType`, `bytes_` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.istitle`

Examples

```
>>> import numpy as np
>>> np.strings.istitle("Numpy Is Great")
array(True)
```

```
>>> np.strings.istitle("Numpy is great")
array(False)
```

strings.**isupper**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isupper'>**

Return true for each element if all cased characters in the string are uppercase and there is at least one character, false otherwise.

Parameters

x
[array_like, with `StringDType`, `bytes_` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isupper`

Examples

```
>>> import numpy as np
>>> np.strings.isupper("GHC")
array(True)
>>> a = np.array(["hello", "HELLO", "Hello"])
>>> np.strings.isupper(a)
array([False,  True, False])
```

strings.**rfind**(*a*, *sub*, *start=0*, *end=None*)

For each element, return the highest index in the string where substring `sub` is found, such that `sub` is contained in the range [`start`, `end`).

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

sub
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] The substring to search for.

start, end
[array_like, with any integer dtype] The range to look in, interpreted as in slice notation.

Returns

y
[ndarray] Output array of ints

See also:

`str.rfind`

Examples

```
>>> import numpy as np
>>> a = np.array(["Computer Science"])
>>> np.strings.rfind(a, "Science", start=0, end=None)
array([9])
>>> np.strings.rfind(a, "Science", start=0, end=8)
array([-1])
>>> b = np.array(["Computer Science", "Science"])
>>> np.strings.rfind(b, "Science", start=0, end=None)
array([9, 0])
```

strings.**rindex**(*a*, *sub*, *start=0*, *end=None*)

Like *rfind*, but raises `ValueError` when the substring *sub* is not found.

Parameters

a
[array-like, with *np.bytes_* or *np.str_* dtype]

sub
[array-like, with *np.bytes_* or *np.str_* dtype]

start, end
[array-like, with any integer dtype, optional]

Returns

out
[ndarray] Output array of ints.

See also:

rfind, **str.rindex**

Examples

```
>>> a = np.array(["Computer Science"])
>>> np.strings.rindex(a, "Science", start=0, end=None)
array([9])
```

strings.**startswith**(*a*, *prefix*, *start=0*, *end=None*)

Returns a boolean array which is *True* where the string element in `a` starts with `prefix`, otherwise *False*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

prefix
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

start, end
[array_like, with any integer dtype] With `start`, test beginning at that position. With `end`, stop comparing at that position.

Returns

out
[ndarray] Output array of bools

See also:

str.startswith

Examples

```
>>> import numpy as np
>>> s = np.array(['foo', 'bar'])
>>> s
array(['foo', 'bar'], dtype='<U3')
>>> np.strings.startswith(s, 'fo')
array([True,  False])
>>> np.strings.startswith(s, 'o', start=1, end=2)
array([True,  False])
```

strings.**str_len**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'str_len'>**

Returns the length of each element. For byte strings, this is the number of bytes, while, for Unicode strings, it is the number of Unicode code points.

Parameters

x
[array_like, with `StringDType`, `bytes_`, or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of ints This is a scalar if *x* is a scalar.

See also:

`len`

Examples

```
>>> import numpy as np
>>> a = np.array(['Grace Hopper Conference', 'Open Source Day'])
>>> np.strings.str_len(a)
array([23, 15])
>>> a = np.array(['P', 'o'])
>>> np.strings.str_len(a)
array([1, 1])
>>> a = np.array([['hello', 'world'], ['P', 'o']])
>>> np.strings.str_len(a)
array([[5, 5], [1, 1]])
```

Test support (`numpy.testing`)

Common test support for all numpy test scripts.

This single module should provide all the common functionality for numpy tests in a single location, so that test scripts can just import it and work right away. For background, see the *Testing guidelines*

Asserts

assert_allclose(actual, desired[, rtol, ...])	Raises an AssertionError if two objects are not equal up to desired tolerance.
assert_array_almost_equal_nulp(x, y[, nulp])	Compare two arrays relatively to their spacing.
assert_array_max_ulp(a, b[, maxulp, dtype])	Check that all items of arrays differ in at most N Units in the Last Place.
assert_array_equal(actual, desired[, ...])	Raises an AssertionError if two array_like objects are not equal.
assert_array_less(x, y[, err_msg, verbose, ...])	Raises an AssertionError if two array_like objects are not ordered by less than.
assert_equal(actual, desired[, err_msg, ...])	Raises an AssertionError if two objects are not equal.
assert_raises(assert_raises)	Fail unless an exception of class exception_class is thrown by callable when invoked with arguments args and keyword arguments kwargs.
assert_raises_regex(exception_class, ...)	Fail unless an exception of class exception_class and with message that matches expected_regexp is thrown by callable when invoked with arguments args and keyword arguments kwargs.
assert_warns(warning_class, *args, **kwargs)	Fail unless the given callable throws the specified warning.
assert_no_warnings(*args, **kwargs)	Fail if the given callable produces any warnings.
assert_no_gc_cycles(*args, **kwargs)	Fail if the given callable produces any reference cycles.
assert_string_equal(actual, desired)	Test if two strings are equal.

testing.**assert_allclose**(*actual*, *desired*, *rtol=1e-07*, *atol=0*, *equal_nan=True*, *err_msg=''*, *verbose=True*, ***, *strict=False*)

Raises an AssertionError if two objects are not equal up to desired tolerance.

Given two array_like objects, check that their shapes and all elements are equal (but see the Notes for the special handling of a scalar). An exception is raised if the shapes mismatch or any values conflict. In contrast to the standard usage in numpy, NaNs are compared like numbers, no assertion is raised if both objects have NaNs in the same positions.

The test is equivalent to `allclose(actual, desired, rtol, atol)` (note that `allclose` has different default values). It compares the difference between *actual* and *desired* to `atol + rtol * abs(desired)`.

Parameters

actual
[array_like] Array obtained.

desired
[array_like] Array desired.

rtol
[float, optional] Relative tolerance.

atol
[float, optional] Absolute tolerance.

equal_nan
[bool, optional.] If True, NaNs will compare equal.

err_msg
[str, optional] The error message to be printed in case of failure.

verbose
: [bool, optional] If True, the conflicting values are appended to the error message.

strict
: [bool, optional] If True, raise an `AssertionError` when either the shape or the data type of the arguments does not match. The special handling of scalars mentioned in the Notes section is disabled.

  New in version 2.0.0.

Raises

AssertionError
: If actual and desired are not equal up to specified precision.

See also:

assert_array_almost_equal_nulp*, *assert_array_max_ulp

Notes

When one of *actual* and *desired* is a scalar and the other is array_like, the function performs the comparison as if the scalar were broadcasted to the shape of the array. This behaviour can be disabled with the *strict* parameter.

Examples

```
>>> x = [1e-5, 1e-3, 1e-1]
>>> y = np.arccos(np.cos(x))
>>> np.testing.assert_allclose(x, y, rtol=1e-5, atol=0)
```

As mentioned in the Notes section, *assert_allclose* has special handling for scalars. Here, the test checks that the value of *numpy.sin* is nearly zero at integer multiples of π.

```
>>> x = np.arange(3) * np.pi
>>> np.testing.assert_allclose(np.sin(x), 0, atol=1e-15)
```

Use *strict* to raise an `AssertionError` when comparing an array with one or more dimensions against a scalar.

```
>>> np.testing.assert_allclose(np.sin(x), 0, atol=1e-15, strict=True)
Traceback (most recent call last):
    ...
AssertionError:
Not equal to tolerance rtol=1e-07, atol=1e-15

(shapes (3,), () mismatch)
 ACTUAL: array([ 0.000000e+00,  1.224647e-16, -2.449294e-16])
 DESIRED: array(0)
```

The *strict* parameter also ensures that the array data types match:

```
>>> y = np.zeros(3, dtype=np.float32)
>>> np.testing.assert_allclose(np.sin(x), y, atol=1e-15, strict=True)
Traceback (most recent call last):
    ...
AssertionError:
Not equal to tolerance rtol=1e-07, atol=1e-15
```

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```
(dtypes float64, float32 mismatch)
 ACTUAL: array([ 0.000000e+00,  1.224647e-16, -2.449294e-16])
 DESIRED: array([0., 0., 0.], dtype=float32)
```

testing.**assert_array_almost_equal_nulp**(*x*, *y*, *nulp=1*)

Compare two arrays relatively to their spacing.

This is a relatively robust method to compare two arrays whose amplitude is variable.

Parameters

x, y
[array_like] Input arrays.

nulp
[int, optional] The maximum number of unit in the last place for tolerance (see Notes). Default is 1.

Returns

None

Raises

AssertionError
If the spacing between *x* and *y* for one or more elements is larger than *nulp*.

See also:

assert_array_max_ulp
Check that all items of arrays differ in at most N Units in the Last Place.

spacing
Return the distance between x and the nearest adjacent number.

Notes

An assertion is raised if the following condition is not met:

```
abs(x - y) <= nulp * spacing(maximum(abs(x), abs(y)))
```

Examples

```
>>> x = np.array([1., 1e-10, 1e-20])
>>> eps = np.finfo(x.dtype).eps
>>> np.testing.assert_array_almost_equal_nulp(x, x*eps/2 + x)
```

```
>>> np.testing.assert_array_almost_equal_nulp(x, x*eps + x)
Traceback (most recent call last):
  ...
AssertionError: Arrays are not equal to 1 ULP (max is 2)
```

testing.**assert_array_max_ulp**(*a*, *b*, *maxulp=1*, *dtype=None*)

Check that all items of arrays differ in at most N Units in the Last Place.

Parameters

a, b
[array_like] Input arrays to be compared.

maxulp
[int, optional] The maximum number of units in the last place that elements of *a* and *b* can differ. Default is 1.

dtype
[dtype, optional] Data-type to convert *a* and *b* to if given. Default is None.

Returns

ret
[ndarray] Array containing number of representable floating point numbers between items in *a* and *b*.

Raises

AssertionError
If one or more elements differ by more than *maxulp*.

See also:

assert_array_almost_equal_nulp
Compare two arrays relatively to their spacing.

Notes

For computing the ULP difference, this API does not differentiate between various representations of NAN (ULP difference between 0x7fc00000 and 0xffc00000 is zero).

Examples

```
>>> a = np.linspace(0., 1., 100)
>>> res = np.testing.assert_array_max_ulp(a, np.arcsin(np.sin(a)))
```

testing.**assert_array_equal**(*actual*, *desired*, *err_msg=''*, *verbose=True*, ***, *strict=False*)

Raises an AssertionError if two array_like objects are not equal.

Given two array_like objects, check that the shape is equal and all elements of these objects are equal (but see the Notes for the special handling of a scalar). An exception is raised at shape mismatch or conflicting values. In contrast to the standard usage in numpy, NaNs are compared like numbers, no assertion is raised if both objects have NaNs in the same positions.

The usual caution for verifying equality with floating point numbers is advised.

Note: When either *actual* or *desired* is already an instance of *numpy.ndarray* and *desired* is not a `dict`, the behavior of `assert_equal(actual, desired)` is identical to the behavior of this function. Otherwise, this function performs *np.asanyarray* on the inputs before comparison, whereas *assert_equal* defines special comparison rules for common Python types. For example, only *assert_equal* can be used to compare nested Python lists. In new code, consider using only *assert_equal*, explicitly converting either *actual* or *desired* to arrays if the behavior of *assert_array_equal* is desired.

Parameters

actual
[array_like] The actual object to check.

desired
[array_like] The desired, expected object.

err_msg
[str, optional] The error message to be printed in case of failure.

verbose
[bool, optional] If True, the conflicting values are appended to the error message.

strict
[bool, optional] If True, raise an AssertionError when either the shape or the data type of the array_like objects does not match. The special handling for scalars mentioned in the Notes section is disabled.

New in version 1.24.0.

Raises

AssertionError
If actual and desired objects are not equal.

See also:

assert_allclose
Compare two array_like objects for equality with desired relative and/or absolute precision.

assert_array_almost_equal_nulp, ***assert_array_max_ulp***, ***assert_equal***

Notes

When one of *actual* and *desired* is a scalar and the other is array_like, the function checks that each element of the array_like object is equal to the scalar. This behaviour can be disabled with the *strict* parameter.

Examples

The first assert does not raise an exception:

```
>>> np.testing.assert_array_equal([1.0,2.33333,np.nan],
...                               [np.exp(0),2.33333, np.nan])
```

Assert fails with numerical imprecision with floats:

```
>>> np.testing.assert_array_equal([1.0,np.pi,np.nan],
...                               [1, np.sqrt(np.pi)**2, np.nan])
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not equal

Mismatched elements: 1 / 3 (33.3%)
Max absolute difference among violations: 4.4408921e-16
Max relative difference among violations: 1.41357986e-16
 ACTUAL: array([1.      , 3.141593,      nan])
 DESIRED: array([1.      , 3.141593,      nan])
```

Use *assert_allclose* or one of the nulp (number of floating point values) functions for these cases instead:

```
>>> np.testing.assert_allclose([1.0,np.pi,np.nan],
...                            [1, np.sqrt(np.pi)**2, np.nan],
...                            rtol=1e-10, atol=0)
```

As mentioned in the Notes section, *assert_array_equal* has special handling for scalars. Here the test checks that each value in *x* is 3:

```
>>> x = np.full((2, 5), fill_value=3)
>>> np.testing.assert_array_equal(x, 3)
```

Use *strict* to raise an AssertionError when comparing a scalar with an array:

```
>>> np.testing.assert_array_equal(x, 3, strict=True)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not equal

(shapes (2, 5), () mismatch)
 ACTUAL: array([[3, 3, 3, 3, 3],
       [3, 3, 3, 3, 3]])
 DESIRED: array(3)
```

The *strict* parameter also ensures that the array data types match:

```
>>> x = np.array([2, 2, 2])
>>> y = np.array([2., 2., 2.], dtype=np.float32)
>>> np.testing.assert_array_equal(x, y, strict=True)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not equal

(dtypes int64, float32 mismatch)
 ACTUAL: array([2, 2, 2])
 DESIRED: array([2., 2., 2.], dtype=float32)
```

testing.**assert_array_less**(*x*, *y*, *err_msg=''*, *verbose=True*, ***, *strict=False*)

Raises an AssertionError if two array_like objects are not ordered by less than.

Given two array_like objects *x* and *y*, check that the shape is equal and all elements of *x* are strictly less than the corresponding elements of *y* (but see the Notes for the special handling of a scalar). An exception is raised at shape mismatch or values that are not correctly ordered. In contrast to the standard usage in NumPy, no assertion is raised if both objects have NaNs in the same positions.

Parameters

x
: [array_like] The smaller object to check.

y
: [array_like] The larger object to compare.

err_msg
: [string] The error message to be printed in case of failure.

verbose
: [bool] If True, the conflicting values are appended to the error message.

strict
: [bool, optional] If True, raise an AssertionError when either the shape or the data type of the array_like objects does not match. The special handling for scalars mentioned in the Notes section is disabled.

  New in version 2.0.0.

Raises

AssertionError
: If x is not strictly smaller than y, element-wise.

See also:

assert_array_equal
: tests objects for equality

assert_array_almost_equal
: test objects for equality up to precision

Notes

When one of *x* and *y* is a scalar and the other is array_like, the function performs the comparison as though the scalar were broadcasted to the shape of the array. This behaviour can be disabled with the *strict* parameter.

Examples

The following assertion passes because each finite element of *x* is strictly less than the corresponding element of *y*, and the NaNs are in corresponding locations.

```
>>> x = [1.0, 1.0, np.nan]
>>> y = [1.1, 2.0, np.nan]
>>> np.testing.assert_array_less(x, y)
```

The following assertion fails because the zeroth element of *x* is no longer strictly less than the zeroth element of *y*.

```
>>> y[0] = 1
>>> np.testing.assert_array_less(x, y)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not strictly ordered `x < y`

Mismatched elements: 1 / 3 (33.3%)
Max absolute difference among violations: 0.
Max relative difference among violations: 0.
 x: array([ 1.,  1., nan])
 y: array([ 1.,  2., nan])
```

Here, *y* is a scalar, so each element of *x* is compared to *y*, and the assertion passes.

```
>>> x = [1.0, 4.0]
>>> y = 5.0
>>> np.testing.assert_array_less(x, y)
```

However, with `strict=True`, the assertion will fail because the shapes do not match.

```
>>> np.testing.assert_array_less(x, y, strict=True)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not strictly ordered `x < y`

(shapes (2,), () mismatch)
 x: array([1., 4.])
 y: array(5.)
```

With `strict=True`, the assertion also fails if the dtypes of the two arrays do not match.

```
>>> y = [5, 5]
>>> np.testing.assert_array_less(x, y, strict=True)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not strictly ordered `x < y`

(dtypes float64, int64 mismatch)
 x: array([1., 4.])
 y: array([5, 5])
```

testing.**assert_equal**(*actual*, *desired*, *err_msg=''*, *verbose=True*, ***, *strict=False*)

Raises an AssertionError if two objects are not equal.

Given two objects (scalars, lists, tuples, dictionaries or numpy arrays), check that all elements of these objects are equal. An exception is raised at the first conflicting values.

This function handles NaN comparisons as if NaN was a "normal" number. That is, AssertionError is not raised if both objects have NaNs in the same positions. This is in contrast to the IEEE standard on NaNs, which says that NaN compared to anything must return False.

Parameters

actual
[array_like] The object to check.

desired
[array_like] The expected object.

err_msg
[str, optional] The error message to be printed in case of failure.

verbose
[bool, optional] If True, the conflicting values are appended to the error message.

strict
[bool, optional] If True and either of the *actual* and *desired* arguments is an array, raise an `AssertionError` when either the shape or the data type of the arguments does not match. If neither argument is an array, this parameter has no effect.

New in version 2.0.0.

Raises

AssertionError
If actual and desired are not equal.

See also:

assert_allclose
assert_array_almost_equal_nulp
assert_array_max_ulp

Notes

By default, when one of *actual* and *desired* is a scalar and the other is an array, the function checks that each element of the array is equal to the scalar. This behaviour can be disabled by setting `strict==True`.

Examples

```
>>> np.testing.assert_equal([4, 5], [4, 6])
Traceback (most recent call last):
    ...
AssertionError:
Items are not equal:
item=1
 ACTUAL: 5
 DESIRED: 6
```

The following comparison does not raise an exception. There are NaNs in the inputs, but they are in the same positions.

```
>>> np.testing.assert_equal(np.array([1.0, 2.0, np.nan]), [1, 2, np.nan])
```

As mentioned in the Notes section, *assert_equal* has special handling for scalars when one of the arguments is an array. Here, the test checks that each value in *x* is 3:

```
>>> x = np.full((2, 5), fill_value=3)
>>> np.testing.assert_equal(x, 3)
```

Use *strict* to raise an AssertionError when comparing a scalar with an array of a different shape:

```
>>> np.testing.assert_equal(x, 3, strict=True)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not equal

(shapes (2, 5), () mismatch)
 ACTUAL: array([[3, 3, 3, 3, 3],
       [3, 3, 3, 3, 3]])
 DESIRED: array(3)
```

The *strict* parameter also ensures that the array data types match:

```
>>> x = np.array([2, 2, 2])
>>> y = np.array([2., 2., 2.], dtype=np.float32)
>>> np.testing.assert_equal(x, y, strict=True)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not equal
```

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```
(dtypes int64, float32 mismatch)
 ACTUAL: array([2, 2, 2])
 DESIRED: array([2., 2., 2.], dtype=float32)
```

testing.**assert_raises**(*exception_class*, *callable*, **args*, ***kwargs) *assert_raises(exception_class*)

testing.**assert_raises**(*exception_class*) → None

Fail unless an exception of class exception_class is thrown by callable when invoked with arguments args and keyword arguments kwargs. If a different type of exception is thrown, it will not be caught, and the test case will be deemed to have suffered an error, exactly as for an unexpected exception.

Alternatively, *assert_raises* can be used as a context manager:

```
>>> from numpy.testing import assert_raises
>>> with assert_raises(ZeroDivisionError):
...     1 / 0
```

is equivalent to

```
>>> def div(x, y):
...     return x / y
>>> assert_raises(ZeroDivisionError, div, 1, 0)
```

testing.**assert_raises_regex**(*exception_class*, *expected_regexp*, *callable*, **args*, ***kwargs)*
assert_raises_regex(exception_class, *expected_regexp*)

Fail unless an exception of class exception_class and with message that matches expected_regexp is thrown by callable when invoked with arguments args and keyword arguments kwargs.

Alternatively, can be used as a context manager like *assert_raises*.

testing.**assert_warns**(*warning_class*, **args*, ***kwargs*)

Fail unless the given callable throws the specified warning.

A warning of class warning_class should be thrown by the callable when invoked with arguments args and keyword arguments kwargs. If a different type of warning is thrown, it will not be caught.

If called with all arguments other than the warning class omitted, may be used as a context manager:

```
with assert_warns(SomeWarning):
    do_something()
```

The ability to be used as a context manager is new in NumPy v1.11.0.

Parameters

warning_class
[class] The class defining the warning that *func* is expected to throw.

func
[callable, optional] Callable to test

***args**
[Arguments] Arguments for *func*.

****kwargs**
[Kwargs] Keyword arguments for *func*.

Returns

The value returned by *func*.

Examples

```
>>> import warnings
>>> def deprecated_func(num):
...     warnings.warn("Please upgrade", DeprecationWarning)
...     return num*num
>>> with np.testing.assert_warns(DeprecationWarning):
...     assert deprecated_func(4) == 16
>>> # or passing a func
>>> ret = np.testing.assert_warns(DeprecationWarning, deprecated_func, 4)
>>> assert ret == 16
```

testing.**assert_no_warnings**(**args*, ***kwargs*)

Fail if the given callable produces any warnings.

If called with all arguments omitted, may be used as a context manager:

```
with assert_no_warnings():
    do_something()
```

The ability to be used as a context manager is new in NumPy v1.11.0.

Parameters

func
[callable] The callable to test.

***args**
[Arguments] Arguments passed to *func*.

****kwargs**
[Kwargs] Keyword arguments passed to *func*.

Returns

The value returned by *func*.

testing.**assert_no_gc_cycles**(**args*, ***kwargs*)

Fail if the given callable produces any reference cycles.

If called with all arguments omitted, may be used as a context manager:

```
with assert_no_gc_cycles():
    do_something()
```

Parameters

func
[callable] The callable to test.

***args**
[Arguments] Arguments passed to *func*.

****kwargs**
[Kwargs] Keyword arguments passed to *func*.

Returns

Nothing. The result is deliberately discarded to ensure that all cycles are found.

testing.**assert_string_equal**(*actual*, *desired*)

Test if two strings are equal.

If the given strings are equal, *assert_string_equal* does nothing. If they are not equal, an AssertionError is raised, and the diff between the strings is shown.

Parameters

actual
[str] The string to test for equality against the expected string.

desired
[str] The expected string.

Examples

```
>>> np.testing.assert_string_equal('abc', 'abc')
>>> np.testing.assert_string_equal('abc', 'abcd')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
...
AssertionError: Differences in strings:
- abc+ abcd?    +
```

Asserts (not recommended)

It is recommended to use one of *assert_allclose*, *assert_array_almost_equal_nulp* or *assert_array_max_ulp* instead of these functions for more consistent floating point comparisons.

*assert_*(val[, msg])	Assert that works in release mode.
assert_almost_equal(actual, desired[, ...])	Raises an AssertionError if two items are not equal up to desired precision.
assert_approx_equal(actual, desired[, ...])	Raises an AssertionError if two items are not equal up to significant digits.
assert_array_almost_equal(actual, desired[, ...])	Raises an AssertionError if two objects are not equal up to desired precision.
print_assert_equal(test_string, actual, desired)	Test if two objects are equal, and print an error message if test fails.

testing.**assert_**(*val*, *msg=''*)

Assert that works in release mode. Accepts callable msg to allow deferring evaluation until failure.

The Python built-in `assert` does not work when executing code in optimized mode (the `-O` flag) - no byte-code is generated for it.

For documentation on usage, refer to the Python documentation.

testing.**assert_almost_equal**(*actual*, *desired*, *decimal=7*, *err_msg=''*, *verbose=True*)

Raises an AssertionError if two items are not equal up to desired precision.

Note: It is recommended to use one of *assert_allclose*, *assert_array_almost_equal_nulp* or *assert_array_max_ulp* instead of this function for more consistent floating point comparisons.

The test verifies that the elements of *actual* and *desired* satisfy:

```
abs(desired-actual) < float64(1.5 * 10**(-decimal))
```

That is a looser test than originally documented, but agrees with what the actual implementation in *assert_array_almost_equal* did up to rounding vagaries. An exception is raised at conflicting values. For ndarrays this delegates to assert_array_almost_equal

Parameters

actual
[array_like] The object to check.

desired
[array_like] The expected object.

decimal
[int, optional] Desired precision, default is 7.

err_msg
[str, optional] The error message to be printed in case of failure.

verbose
[bool, optional] If True, the conflicting values are appended to the error message.

Raises

AssertionError
If actual and desired are not equal up to specified precision.

See also:

assert_allclose
Compare two array_like objects for equality with desired relative and/or absolute precision.

assert_array_almost_equal_nulp, ***assert_array_max_ulp***, ***assert_equal***

Examples

```
>>> from numpy.testing import assert_almost_equal
>>> assert_almost_equal(2.3333333333333, 2.33333334)
>>> assert_almost_equal(2.3333333333333, 2.33333334, decimal=10)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not almost equal to 10 decimals
 ACTUAL: 2.3333333333333
 DESIRED: 2.33333334
```

```
>>> assert_almost_equal(np.array([1.0,2.3333333333333]),
...                     np.array([1.0,2.33333334]), decimal=9)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not almost equal to 9 decimals

Mismatched elements: 1 / 2 (50%)
Max absolute difference among violations: 6.66669964e-09
Max relative difference among violations: 2.85715698e-09
```

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```
 ACTUAL: array([1.         , 2.333333333])
 DESIRED: array([1.        , 2.33333334])
```

testing.**assert_approx_equal**(*actual*, *desired*, *significant=7*, *err_msg=''*, *verbose=True*)

Raises an AssertionError if two items are not equal up to significant digits.

Note: It is recommended to use one of *assert_allclose*, *assert_array_almost_equal_nulp* or *assert_array_max_ulp* instead of this function for more consistent floating point comparisons.

Given two numbers, check that they are approximately equal. Approximately equal is defined as the number of significant digits that agree.

Parameters

actual
[scalar] The object to check.

desired
[scalar] The expected object.

significant
[int, optional] Desired precision, default is 7.

err_msg
[str, optional] The error message to be printed in case of failure.

verbose
[bool, optional] If True, the conflicting values are appended to the error message.

Raises

AssertionError
If actual and desired are not equal up to specified precision.

See also:

assert_allclose
Compare two array_like objects for equality with desired relative and/or absolute precision.

assert_array_almost_equal_nulp, ***assert_array_max_ulp***, ***assert_equal***

Examples

```
>>> np.testing.assert_approx_equal(0.12345677777777e-20, 0.1234567e-20)
>>> np.testing.assert_approx_equal(0.12345670e-20, 0.12345671e-20,
...                                significant=8)
>>> np.testing.assert_approx_equal(0.12345670e-20, 0.12345672e-20,
...                                significant=8)
Traceback (most recent call last):
    ...
AssertionError:
Items are not equal to 8 significant digits:
 ACTUAL: 1.234567e-21
 DESIRED: 1.2345672e-21
```

the evaluated condition that raises the exception is

```
>>> abs(0.12345670e-20/1e-21 - 0.12345672e-20/1e-21) >= 10**-(8-1)
True
```

testing.**assert_array_almost_equal**(*actual*, *desired*, *decimal=6*, *err_msg=''*, *verbose=True*)

Raises an AssertionError if two objects are not equal up to desired precision.

Note: It is recommended to use one of *assert_allclose*, *assert_array_almost_equal_nulp* or *assert_array_max_ulp* instead of this function for more consistent floating point comparisons.

The test verifies identical shapes and that the elements of `actual` and `desired` satisfy:

```
abs(desired-actual) < 1.5 * 10**(-decimal)
```

That is a looser test than originally documented, but agrees with what the actual implementation did up to rounding vagaries. An exception is raised at shape mismatch or conflicting values. In contrast to the standard usage in numpy, NaNs are compared like numbers, no assertion is raised if both objects have NaNs in the same positions.

Parameters

actual
[array_like] The actual object to check.

desired
[array_like] The desired, expected object.

decimal
[int, optional] Desired precision, default is 6.

err_msg
[str, optional] The error message to be printed in case of failure.

verbose
[bool, optional] If True, the conflicting values are appended to the error message.

Raises

AssertionError
If actual and desired are not equal up to specified precision.

See also:

assert_allclose
Compare two array_like objects for equality with desired relative and/or absolute precision.

assert_array_almost_equal_nulp, *assert_array_max_ulp*, *assert_equal*

Examples

the first assert does not raise an exception

```
>>> np.testing.assert_array_almost_equal([1.0,2.333,np.nan],
...                                      [1.0,2.333,np.nan])
```

```
>>> np.testing.assert_array_almost_equal([1.0,2.33333,np.nan],
...                                      [1.0,2.33339,np.nan], decimal=5)
Traceback (most recent call last):
```

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```
    ...
AssertionError:
Arrays are not almost equal to 5 decimals

Mismatched elements: 1 / 3 (33.3%)
Max absolute difference among violations: 6.e-05
Max relative difference among violations: 2.57136612e-05
 ACTUAL: array([1.     , 2.33333,     nan])
 DESIRED: array([1.     , 2.33339,     nan])
```

```
>>> np.testing.assert_array_almost_equal([1.0,2.33333,np.nan],
...                                      [1.0,2.33333, 5], decimal=5)
Traceback (most recent call last):
    ...
AssertionError:
Arrays are not almost equal to 5 decimals

nan location mismatch:
 ACTUAL: array([1.     , 2.33333,     nan])
 DESIRED: array([1.     , 2.33333, 5.     ])
```

testing.**print_assert_equal**(*test_string*, *actual*, *desired*)

Test if two objects are equal, and print an error message if test fails.

The test is performed with `actual == desired`.

Parameters

test_string
[str] The message supplied to AssertionError.

actual
[object] The object to test for equality against *desired*.

desired
[object] The expected result.

Examples

```
>>> np.testing.print_assert_equal('Test XYZ of func xyz', [0, 1], [0, 1])
>>> np.testing.print_assert_equal('Test XYZ of func xyz', [0, 1], [0, 2])
Traceback (most recent call last):
...
AssertionError: Test XYZ of func xyz failed
ACTUAL:
[0, 1]
DESIRED:
[0, 2]
```

Decorators

decorate_methods(cls, decorator[, testmatch])	Apply a decorator to all methods in a class matching a regular expression.

testing.**decorate_methods**(*cls*, *decorator*, *testmatch=None*)

Apply a decorator to all methods in a class matching a regular expression.

The given decorator is applied to all public methods of *cls* that are matched by the regular expression *testmatch* (`testmatch.search(methodname)`). Methods that are private, i.e. start with an underscore, are ignored.

Parameters

cls
[class] Class whose methods to decorate.

decorator
[function] Decorator to apply to methods

testmatch
[compiled regexp or str, optional] The regular expression. Default value is None, in which case the nose default (`re.compile(r'(?:^|[\b_\.%s-])[Tt]est' % os.sep)`) is used. If *testmatch* is a string, it is compiled to a regular expression first.

Test running

clear_and_catch_warnings([record, modules])	Context manager that resets warning registry for catching warnings
measure(code_str[, times, label])	Return elapsed time for executing code in the namespace of the caller.
rundocs([filename, raise_on_error])	Run doctests found in the given file.
suppress_warnings([forwarding_rule])	Context manager and decorator doing much the same as `warnings.catch_warnings`.

class numpy.testing.**clear_and_catch_warnings**(*record=False*, *modules=()*)

Context manager that resets warning registry for catching warnings

Warnings can be slippery, because, whenever a warning is triggered, Python adds a `__warningregistry__` member to the *calling* module. This makes it impossible to retrigger the warning in this module, whatever you put in the warnings filters. This context manager accepts a sequence of *modules* as a keyword argument to its constructor and:

- stores and removes any `__warningregistry__` entries in given *modules* on entry;
- resets `__warningregistry__` to its previous state on exit.

This makes it possible to trigger any warning afresh inside the context manager without disturbing the state of warnings outside.

For compatibility with Python 3.0, please consider all arguments to be keyword-only.

Parameters

record
[bool, optional] Specifies whether warnings should be captured by a custom implementation of `warnings.showwarning()` and be appended to a list returned by the context manager. Otherwise None is returned by the context manager. The objects appended to the list are arguments whose attributes mirror the arguments to `showwarning()`.

modules
[sequence, optional] Sequence of modules for which to reset warnings registry on entry and restore on exit. To work correctly, all 'ignore' filters should filter by one of these modules.

Examples

```
>>> import warnings
>>> with np.testing.clear_and_catch_warnings(
...         modules=[np._core.fromnumeric]):
...     warnings.simplefilter('always')
...     warnings.filterwarnings('ignore', module='np._core.fromnumeric')
...     # do something that raises a warning but ignore those in
...     # np._core.fromnumeric
```

testing.**measure**(*code_str*, *times=1*, *label=None*)

Return elapsed time for executing code in the namespace of the caller.

The supplied code string is compiled with the Python builtin `compile`. The precision of the timing is 10 milliseconds. If the code will execute fast on this timescale, it can be executed many times to get reasonable timing accuracy.

Parameters

code_str
[str] The code to be timed.

times
[int, optional] The number of times the code is executed. Default is 1. The code is only compiled once.

label
[str, optional] A label to identify *code_str* with. This is passed into `compile` as the second argument (for run-time error messages).

Returns

elapsed
[float] Total elapsed time in seconds for executing *code_str times* times.

Examples

```
>>> times = 10
>>> etime = np.testing.measure('for i in range(1000): np.sqrt(i**2)', times=times)
>>> print("Time for a single execution : ", etime / times, "s")
Time for a single execution :  0.005 s
```

testing.**rundocs**(*filename=None*, *raise_on_error=True*)

Run doctests found in the given file.

By default *rundocs* raises an AssertionError on failure.

Parameters

filename
[str] The path to the file for which the doctests are run.

raise_on_error
[bool] Whether to raise an AssertionError when a doctest fails. Default is True.

Notes

The doctests can be run by the user/developer by adding the `doctests` argument to the `test()` call. For example, to run all tests (including doctests) for `numpy.lib`:

```
>>> np.lib.test(doctests=True)
```

class numpy.testing.**suppress_warnings**(*forwarding_rule='always'*)

Context manager and decorator doing much the same as `warnings.catch_warnings`.

However, it also provides a filter mechanism to work around https://bugs.python.org/issue4180.

This bug causes Python before 3.4 to not reliably show warnings again after they have been ignored once (even within catch_warnings). It means that no "ignore" filter can be used easily, since following tests might need to see the warning. Additionally it allows easier specificity for testing warnings and can be nested.

Parameters

forwarding_rule
: [str, optional] One of "always", "once", "module", or "location". Analogous to the usual warnings module filter mode, it is useful to reduce noise mostly on the outmost level. Unsuppressed and unrecorded warnings will be forwarded based on this rule. Defaults to "always". "location" is equivalent to the warnings "default", match by exact location the warning warning originated from.

Notes

Filters added inside the context manager will be discarded again when leaving it. Upon entering all filters defined outside a context will be applied automatically.

When a recording filter is added, matching warnings are stored in the `log` attribute as well as in the list returned by `record`.

If filters are added and the `module` keyword is given, the warning registry of this module will additionally be cleared when applying it, entering the context, or exiting it. This could cause warnings to appear a second time after leaving the context if they were configured to be printed once (default) and were already printed before the context was entered.

Nesting this context manager will work as expected when the forwarding rule is "always" (default). Unfiltered and unrecorded warnings will be passed out and be matched by the outer level. On the outmost level they will be printed (or caught by another warnings context). The forwarding rule argument can modify this behaviour.

Like `catch_warnings` this context manager is not threadsafe.

Examples

With a context manager:

```
with np.testing.suppress_warnings() as sup:
    sup.filter(DeprecationWarning, "Some text")
    sup.filter(module=np.ma.core)
    log = sup.record(FutureWarning, "Does this occur?")
    command_giving_warnings()
    # The FutureWarning was given once, the filtered warnings were
    # ignored. All other warnings abide outside settings (may be
    # printed/error)
```

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```
    assert_(len(log) == 1)
    assert_(len(sup.log) == 1)  # also stored in log attribute
```

Or as a decorator:

```
sup = np.testing.suppress_warnings()
sup.filter(module=np.ma.core)  # module must match exactly
@sup
def some_function():
    # do something which causes a warning in np.ma.core
    pass
```

Methods

__call__(func)	Function decorator to apply certain suppressions to a whole function.
filter([category, message, module])	Add a new suppressing filter or apply it if the state is entered.
record([category, message, module])	Append a new recording filter or apply it if the state is entered.

method

testing.suppress_warnings.**__call__**(*func*)

Function decorator to apply certain suppressions to a whole function.

method

testing.suppress_warnings.**filter**(*category=<class 'Warning'>*, *message=''*, *module=None*)

Add a new suppressing filter or apply it if the state is entered.

Parameters

category
[class, optional] Warning class to filter

message
[string, optional] Regular expression matching the warning message.

module
[module, optional] Module to filter for. Note that the module (and its file) must match exactly and cannot be a submodule. This may make it unreliable for external modules.

Notes

When added within a context, filters are only added inside the context and will be forgotten when the context is exited.

method

testing.suppress_warnings.**record**(*category=<class 'Warning'>*, *message=''*, *module=None*)

Append a new recording filter or apply it if the state is entered.

All warnings matching will be appended to the `log` attribute.

Parameters

category
[class, optional] Warning class to filter

message
[string, optional] Regular expression matching the warning message.

module
[module, optional] Module to filter for. Note that the module (and its file) must match exactly and cannot be a submodule. This may make it unreliable for external modules.

Returns

log
[list] A list which will be filled with all matched warnings.

Notes

When added within a context, filters are only added inside the context and will be forgotten when the context is exited.

Testing custom array containers (`numpy.testing.overrides`)

These functions can be useful when testing custom array container implementations which make use of `__array_ufunc__`/`__array_function__`.

allows_array_function_override(func)	Determine if a Numpy function can be overridden via *__array_function__*
allows_array_ufunc_override(func)	Determine if a function can be overridden via *__array_ufunc__*
get_overridable_numpy_ufuncs()	List all numpy ufuncs overridable via *__array_ufunc__*
get_overridable_numpy_array_functions()	List all numpy functions overridable via *__array_function__*

testing.overrides.**allows_array_function_override**(*func*)

Determine if a Numpy function can be overridden via *__array_function__*

Parameters

func
[callable] Function that may be overridable via *__array_function__*

Returns

bool
True if *func* is a function in the Numpy API that is overridable via *__array_function__* and *False* otherwise.

testing.overrides.**allows_array_ufunc_override**(*func*)

Determine if a function can be overridden via *__array_ufunc__*

Parameters

func
[callable] Function that may be overridable via *__array_ufunc__*

Returns

bool
True if *func* is overridable via *__array_ufunc__* and *False* otherwise.

Notes

This function is equivalent to `isinstance(func, np.ufunc)` and will work correctly for ufuncs defined outside of Numpy.

`testing.overrides.`**`get_overridable_numpy_ufuncs`**`()`
List all numpy ufuncs overridable via *__array_ufunc__*

Parameters

None

Returns

set
A set containing all overridable ufuncs in the public numpy API.

`testing.overrides.`**`get_overridable_numpy_array_functions`**`()`
List all numpy functions overridable via *__array_function__*

Parameters

None

Returns

set
A set containing all functions in the public numpy API that are overridable via *__array_function__*.

Guidelines

Testing guidelines

Introduction

Until the 1.15 release, NumPy used the nose testing framework, it now uses the pytest framework. The older framework is still maintained in order to support downstream projects that use the old numpy framework, but all tests for NumPy should use pytest.

Our goal is that every module and package in NumPy should have a thorough set of unit tests. These tests should exercise the full functionality of a given routine as well as its robustness to erroneous or unexpected input arguments. Well-designed tests with good coverage make an enormous difference to the ease of refactoring. Whenever a new bug is found in a routine, you should write a new test for that specific case and add it to the test suite to prevent that bug from creeping back in unnoticed.

Note: SciPy uses the testing framework from *`numpy.testing`*, so all of the NumPy examples shown below are also applicable to SciPy

---

Testing NumPy

NumPy can be tested in a number of ways, choose any way you feel comfortable.

Running tests from inside Python

You can test an installed NumPy by *numpy.test*, for example, To run NumPy's full test suite, use the following:

```
>>> import numpy
>>> numpy.test(label='slow')
```

The test method may take two or more arguments; the first `label` is a string specifying what should be tested and the second `verbose` is an integer giving the level of output verbosity. See the docstring *numpy.test* for details. The default value for `label` is 'fast' - which will run the standard tests. The string 'full' will run the full battery of tests, including those identified as being slow to run. If `verbose` is 1 or less, the tests will just show information messages about the tests that are run; but if it is greater than 1, then the tests will also provide warnings on missing tests. So if you want to run every test and get messages about which modules don't have tests:

```
>>> numpy.test(label='full', verbose=2)  # or numpy.test('full', 2)
```

Finally, if you are only interested in testing a subset of NumPy, for example, the `_core` module, use the following:

```
>>> numpy._core.test()
```

Running tests from the command line

If you want to build NumPy in order to work on NumPy itself, use the `spin` utility. To run NumPy's full test suite:

```
$ spin test -m full
```

Testing a subset of NumPy:

```
$ spin test -t numpy/_core/tests
```

For detailed info on testing, see testing-builds

Running doctests

NumPy documentation contains code examples, "doctests". To check that the examples are correct, install the `scipy-doctest` package:

```
$ pip install scipy-doctest
```

and run one of:

```
$ spin check-docs -v
$ spin check-docs numpy/linalg
$ spin check-docs -- -k 'det and not slogdet'
```

Note that the doctests are not run when you use `spin test`.

Other methods of running tests

Run tests using your favourite IDE such as vscode or pycharm

Writing your own tests

If you are writing code that you'd like to become part of NumPy, please write the tests as you develop your code. Every Python module, extension module, or subpackage in the NumPy package directory should have a corresponding `test_<name>.py` file. Pytest examines these files for test methods (named `test*`) and test classes (named `Test*`).

Suppose you have a NumPy module `numpy/xxx/yyy.py` containing a function `zzz()`. To test this function you would create a test module called `test_yyy.py`. If you only need to test one aspect of `zzz`, you can simply add a test function:

```
def test_zzz():
    assert zzz() == 'Hello from zzz'
```

More often, we need to group a number of tests together, so we create a test class:

```
import pytest

# import xxx symbols
from numpy.xxx.yyy import zzz
import pytest

class TestZzz:
    def test_simple(self):
        assert zzz() == 'Hello from zzz'

    def test_invalid_parameter(self):
        with pytest.raises(ValueError, match='.*some matching regex.*'):
            ...
```

Within these test methods, the `assert` statement or a specialized assertion function is used to test whether a certain assumption is valid. If the assertion fails, the test fails. Common assertion functions include:

- *`numpy.testing.assert_equal`* for testing exact elementwise equality between a result array and a reference,
- *`numpy.testing.assert_allclose`* for testing near elementwise equality between a result array and a reference (i.e. with specified relative and absolute tolerances), and
- *`numpy.testing.assert_array_less`* for testing (strict) elementwise ordering between a result array and a reference.

By default, these assertion functions only compare the numerical values in the arrays. Consider using the `strict=True` option to check the array dtype and shape, too.

When you need custom assertions, use the Python `assert` statement. Note that `pytest` internally rewrites `assert` statements to give informative output when it fails, so it should be preferred over the legacy variant `numpy.testing.assert_`. Whereas plain `assert` statements are ignored when running Python in optimized mode with `-O`, this is not an issue when running tests with pytest.

Similarly, the pytest functions `pytest.raises` and `pytest.warns` should be preferred over their legacy counterparts *`numpy.testing.assert_raises`* and *`numpy.testing.assert_warns`*, which are more broadly used. These versions also accept a `match` parameter, which should always be used to precisely target the intended warning or error.

Note that `test_` functions or methods should not have a docstring, because that makes it hard to identify the test from the output of running the test suite with `verbose=2` (or similar verbosity setting). Use plain comments (`#`) to describe the intent of the test and help the unfamiliar reader to interpret the code.

Also, since much of NumPy is legacy code that was originally written without unit tests, there are still several modules that don't have tests yet. Please feel free to choose one of these modules and develop tests for it.

Using C code in tests

NumPy exposes a rich *C-API* . These are tested using c-extension modules written "as-if" they know nothing about the internals of NumPy, rather using the official C-API interfaces only. Examples of such modules are tests for a user-defined `rational` dtype in `_rational_tests` or the ufunc machinery tests in `_umath_tests` which are part of the binary distribution. Starting from version 1.21, you can also write snippets of C code in tests that will be compiled locally into c-extension modules and loaded into python.

`numpy.testing.extbuild.`**`build_and_import_extension`**(*modname*, *functions*, *, *prologue=''*, *build_dir=None*, *include_dirs=[]*, *more_init=''*)

Build and imports a c-extension module *modname* from a list of function fragments *functions*.

Parameters

functions
[list of fragments] Each fragment is a sequence of func_name, calling convention, snippet.

prologue
[string] Code to precede the rest, usually extra `#include` or `#define` macros.

build_dir
[pathlib.Path] Where to build the module, usually a temporary directory

include_dirs
[list] Extra directories to find include files when compiling

more_init
[string] Code to appear in the module PyMODINIT_FUNC

Returns

out: module
The module will have been loaded and is ready for use

Examples

```
>>> functions = [("test_bytes", "METH_O", """
    if ( !PyBytesCheck(args)) {
        Py_RETURN_FALSE;
    }
    Py_RETURN_TRUE;
""")]
>>> mod = build_and_import_extension("testme", functions)
>>> assert not mod.test_bytes('abc')
>>> assert mod.test_bytes(b'abc')
```

Labeling tests

Unlabeled tests like the ones above are run in the default `numpy.test()` run. If you want to label your test as slow - and therefore reserved for a full `numpy.test(label='full')` run, you can label it with `pytest.mark.slow`:

```
import pytest

@pytest.mark.slow
def test_big(self):
    print('Big, slow test')
```

Similarly for methods:

```
class test_zzz:
    @pytest.mark.slow
    def test_simple(self):
        assert_(zzz() == 'Hello from zzz')
```

Easier setup and teardown functions / methods

Testing looks for module-level or class method-level setup and teardown functions by name; thus:

```
def setup_module():
    """Module-level setup"""
    print('doing setup')

def teardown_module():
    """Module-level teardown"""
    print('doing teardown')


class TestMe:
    def setup_method(self):
        """Class-level setup"""
        print('doing setup')

    def teardown_method():
        """Class-level teardown"""
        print('doing teardown')
```

Setup and teardown functions to functions and methods are known as "fixtures", and they should be used sparingly. `pytest` supports more general fixture at various scopes which may be used automatically via special arguments. For example, the special argument name `tmpdir` is used in test to create a temporary directory.

Parametric tests

One very nice feature of `pytest` is the ease of testing across a range of parameter values using the `pytest.mark.parametrize` decorator. For example, suppose you wish to test `linalg.solve` for all combinations of three array sizes and two data types:

```
@pytest.mark.parametrize('dimensionality', [3, 10, 25])
@pytest.mark.parametrize('dtype', [np.float32, np.float64])
def test_solve(dimensionality, dtype):
    np.random.seed(842523)
```

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```
    A = np.random.random(size=(dimensionality, dimensionality)).astype(dtype)
    b = np.random.random(size=dimensionality).astype(dtype)
    x = np.linalg.solve(A, b)
    eps = np.finfo(dtype).eps
    assert_allclose(A @ x, b, rtol=eps*1e2, atol=0)
    assert x.dtype == np.dtype(dtype)
```

Doctests

Doctests are a convenient way of documenting the behavior of a function and allowing that behavior to be tested at the same time. The output of an interactive Python session can be included in the docstring of a function, and the test framework can run the example and compare the actual output to the expected output.

The doctests can be run by adding the `doctests` argument to the `test()` call; for example, to run all tests (including doctests) for numpy.lib:

```
>>> import numpy as np
>>> np.lib.test(doctests=True)
```

The doctests are run as if they are in a fresh Python instance which has executed `import numpy as np`. Tests that are part of a NumPy subpackage will have that subpackage already imported. E.g. for a test in `numpy/linalg/tests/`, the namespace will be created such that `from numpy import linalg` has already executed.

`tests/`

Rather than keeping the code and the tests in the same directory, we put all the tests for a given subpackage in a `tests/` subdirectory. For our example, if it doesn't already exist you will need to create a `tests/` directory in `numpy/xxx/`. So the path for `test_yyy.py` is `numpy/xxx/tests/test_yyy.py`.

Once the `numpy/xxx/tests/test_yyy.py` is written, its possible to run the tests by going to the `tests/` directory and typing:

```
python test_yyy.py
```

Or if you add `numpy/xxx/tests/` to the Python path, you could run the tests interactively in the interpreter like this:

```
>>> import test_yyy
>>> test_yyy.test()
```

`__init__.py` and `setup.py`

Usually, however, adding the `tests/` directory to the python path isn't desirable. Instead it would better to invoke the test straight from the module `xxx`. To this end, simply place the following lines at the end of your package's `__init__.py` file:

```
...
def test(level=1, verbosity=1):
    from numpy.testing import Tester
    return Tester().test(level, verbosity)
```

You will also need to add the tests directory in the configuration section of your setup.py:

```
...
def configuration(parent_package='', top_path=None):
    ...
    config.add_subpackage('tests')
    return config
...
```

Now you can do the following to test your module:

```
>>> import numpy
>>> numpy.xxx.test()
```

Also, when invoking the entire NumPy test suite, your tests will be found and run:

```
>>> import numpy
>>> numpy.test()
# your tests are included and run automatically!
```

Tips & Tricks

Known failures & skipping tests

Sometimes you might want to skip a test or mark it as a known failure, such as when the test suite is being written before the code it's meant to test, or if a test only fails on a particular architecture.

To skip a test, simply use `skipif`:

```
import pytest

@pytest.mark.skipif(SkipMyTest, reason="Skipping this test because...")
def test_something(foo):
    ...
```

The test is marked as skipped if `SkipMyTest` evaluates to nonzero, and the message in verbose test output is the second argument given to `skipif`. Similarly, a test can be marked as a known failure by using `xfail`:

```
import pytest

@pytest.mark.xfail(MyTestFails, reason="This test is known to fail because...")
def test_something_else(foo):
    ...
```

Of course, a test can be unconditionally skipped or marked as a known failure by using `skip` or `xfail` without argument, respectively.

A total of the number of skipped and known failing tests is displayed at the end of the test run. Skipped tests are marked as `'S'` in the test results (or `'SKIPPED'` for `verbose > 1`), and known failing tests are marked as `'x'` (or `'XFAIL'` if `verbose > 1`).

Tests on random data

Tests on random data are good, but since test failures are meant to expose new bugs or regressions, a test that passes most of the time but fails occasionally with no code changes is not helpful. Make the random data deterministic by setting the random number seed before generating it. Use either Python's `random.seed(some_number)` or NumPy's `numpy.random.seed(some_number)`, depending on the source of random numbers.

Alternatively, you can use Hypothesis to generate arbitrary data. Hypothesis manages both Python's and Numpy's random seeds for you, and provides a very concise and powerful way to describe data (including `hypothesis.extra.numpy`, e.g. for a set of mutually-broadcastable shapes).

The advantages over random generation include tools to replay and share failures without requiring a fixed seed, reporting *minimal* examples for each failure, and better-than-naive-random techniques for triggering bugs.

Documentation for `numpy.test`

`numpy.test`(*label='fast'*, *verbose=1*, *extra_argv=None*, *doctests=False*, *coverage=False*, *durations=-1*, *tests=None*)

Pytest test runner.

A test function is typically added to a package's __init__.py like so:

```
from numpy._pytesttester import PytestTester
test = PytestTester(__name__).test
del PytestTester
```

Calling this test function finds and runs all tests associated with the module and all its sub-modules.

Parameters

module_name
[module name] The name of the module to test.

Notes

Unlike the previous `nose`-based implementation, this class is not publicly exposed as it performs some `numpy`-specific warning suppression.

Attributes

module_name
[str] Full path to the package to test.

Typing (`numpy.typing`)

New in version 1.20.

Large parts of the NumPy API have **PEP 484**-style type annotations. In addition a number of type aliases are available to users, most prominently the two below:

- *`ArrayLike`*: objects that can be converted to arrays
- *`DTypeLike`*: objects that can be converted to dtypes

Mypy plugin

New in version 1.21. A mypy plugin for managing a number of platform-specific annotations. Its functionality can be split into three distinct parts:

- Assigning the (platform-dependent) precisions of certain *number* subclasses, including the likes of *int_*, *intp* and *longlong*. See the documentation on *scalar types* for a comprehensive overview of the affected classes. Without the plugin the precision of all relevant classes will be inferred as Any.
- Removing all extended-precision *number* subclasses that are unavailable for the platform in question. Most notably this includes the likes of *float128* and *complex256*. Without the plugin *all* extended-precision types will, as far as mypy is concerned, be available to all platforms.
- Assigning the (platform-dependent) precision of *c_intp*. Without the plugin the type will default to ctypes.c_int64.

  New in version 1.22.

Examples

To enable the plugin, one must add it to their mypy configuration file:

```
[mypy]
plugins = numpy.typing.mypy_plugin
```

Differences from the runtime NumPy API

NumPy is very flexible. Trying to describe the full range of possibilities statically would result in types that are not very helpful. For that reason, the typed NumPy API is often stricter than the runtime NumPy API. This section describes some notable differences.

ArrayLike

The *ArrayLike* type tries to avoid creating object arrays. For example,

```
>>> np.array(x**2 for x in range(10))
array(<generator object <genexpr> at ...>, dtype=object)
```

is valid NumPy code which will create a 0-dimensional object array. Type checkers will complain about the above example when using the NumPy types however. If you really intended to do the above, then you can either use a `# type: ignore` comment:

```
>>> np.array(x**2 for x in range(10))  # type: ignore
```

or explicitly type the array like object as Any:

```
>>> from typing import Any
>>> array_like: Any = (x**2 for x in range(10))
>>> np.array(array_like)
array(<generator object <genexpr> at ...>, dtype=object)
```

ndarray

It's possible to mutate the dtype of an array at runtime. For example, the following code is valid:

```
>>> x = np.array([1, 2])
>>> x.dtype = np.bool
```

This sort of mutation is not allowed by the types. Users who want to write statically typed code should instead use the *numpy.ndarray.view* method to create a view of the array with a different dtype.

DTypeLike

The *DTypeLike* type tries to avoid creation of dtype objects using dictionary of fields like below:

```
>>> x = np.dtype({"field1": (float, 1), "field2": (int, 3)})
```

Although this is valid NumPy code, the type checker will complain about it, since its usage is discouraged. Please see : *Data type objects*

Number precision

The precision of *numpy.number* subclasses is treated as a invariant generic parameter (see *NBitBase*), simplifying the annotating of processes involving precision-based casting.

```
>>> from typing import TypeVar
>>> import numpy as np
>>> import numpy.typing as npt

>>> T = TypeVar("T", bound=npt.NBitBase)
>>> def func(a: "np.floating[T]", b: "np.floating[T]") -> "np.floating[T]":
...     ...
```

Consequently, the likes of *float16*, *float32* and *float64* are still sub-types of *floating*, but, contrary to runtime, they're not necessarily considered as sub-classes.

Timedelta64

The *timedelta64* class is not considered a subclass of *signedinteger*, the former only inheriting from *generic* while static type checking.

0D arrays

During runtime numpy aggressively casts any passed 0D arrays into their corresponding *generic* instance. Until the introduction of shape typing (see **PEP 646**) it is unfortunately not possible to make the necessary distinction between 0D and >0D arrays. While thus not strictly correct, all operations are that can potentially perform a 0D-array -> scalar cast are currently annotated as exclusively returning an *ndarray*.

If it is known in advance that an operation *will* perform a 0D-array -> scalar cast, then one can consider manually remedying the situation with either `typing.cast` or a `# type: ignore` comment.

Record array dtypes

The dtype of *numpy.recarray*, and the *Creating record arrays* functions in general, can be specified in one of two ways:

- Directly via the `dtype` argument.
- With up to five helper arguments that operate via *numpy.rec.format_parser*: `formats`, `names`, `titles`, `aligned` and `byteorder`.

These two approaches are currently typed as being mutually exclusive, *i.e.* if `dtype` is specified than one may not specify `formats`. While this mutual exclusivity is not (strictly) enforced during runtime, combining both dtype specifiers can lead to unexpected or even downright buggy behavior.

API

numpy.typing.**ArrayLike = typing.Union[...]**

A `Union` representing objects that can be coerced into an *ndarray*.

Among others this includes the likes of:

- Scalars.
- (Nested) sequences.
- Objects implementing the *__array__* protocol.

New in version 1.20.

See Also

array_like:
Any scalar or sequence that can be interpreted as an ndarray.

Examples

```
>>> import numpy as np
>>> import numpy.typing as npt

>>> def as_array(a: npt.ArrayLike) -> np.ndarray:
...     return np.array(a)
```

numpy.typing.**DTypeLike = typing.Union[...]**

A `Union` representing objects that can be coerced into a *dtype*.

Among others this includes the likes of:

- `type` objects.
- Character codes or the names of `type` objects.
- Objects with the `.dtype` attribute.

New in version 1.20.

See Also

Specifying and constructing data types
A comprehensive overview of all objects that can be coerced into data types.

Examples

```
>>> import numpy as np
>>> import numpy.typing as npt

>>> def as_dtype(d: npt.DTypeLike) -> np.dtype:
...     return np.dtype(d)
```

numpy.typing.**NDArray = numpy.ndarray[tuple[int, ...], numpy.dtype[+_ScalarType_co]]**

A *np.ndarray[tuple[int, ...], np.dtype[+ScalarType]]* type alias generic w.r.t. its *dtype.type*.

Can be used during runtime for typing arrays with a given dtype and unspecified shape.

New in version 1.21.

Examples

```
>>> import numpy as np
>>> import numpy.typing as npt

>>> print(npt.NDArray)
numpy.ndarray[tuple[int, ...], numpy.dtype[+_ScalarType_co]]

>>> print(npt.NDArray[np.float64])
numpy.ndarray[tuple[int, ...], numpy.dtype[numpy.float64]]

>>> NDArrayInt = npt.NDArray[np.int_]
>>> a: NDArrayInt = np.arange(10)

>>> def func(a: npt.ArrayLike) -> npt.NDArray[Any]:
...     return np.array(a)
```

class numpy.typing.**NBitBase**

A type representing *numpy.number* precision during static type checking.

Used exclusively for the purpose static type checking, *NBitBase* represents the base of a hierarchical set of subclasses. Each subsequent subclass is herein used for representing a lower level of precision, *e.g.* `64Bit > 32Bit > 16Bit`.

New in version 1.20.

Examples

Below is a typical usage example: *NBitBase* is herein used for annotating a function that takes a float and integer of arbitrary precision as arguments and returns a new float of whichever precision is largest (*e.g.* `np.float16 + np.int64 -> np.float64`).

```
>>> from __future__ import annotations
>>> from typing import TypeVar, TYPE_CHECKING
>>> import numpy as np
>>> import numpy.typing as npt

>>> S = TypeVar("S", bound=npt.NBitBase)
>>> T = TypeVar("T", bound=npt.NBitBase)

>>> def add(a: np.floating[S], b: np.integer[T]) -> np.floating[S | T]:
...     return a + b

>>> a = np.float16()
>>> b = np.int64()
>>> out = add(a, b)

>>> if TYPE_CHECKING:
...     reveal_locals()
...     # note: Revealed local types are:
...     # note:     a: numpy.floating[numpy.typing._16Bit*]
...     # note:     b: numpy.signedinteger[numpy.typing._64Bit*]
...     # note:     out: numpy.floating[numpy.typing._64Bit*]
```

ctypes foreign function interface (`numpy.ctypeslib`)

numpy.ctypeslib.**as_array**(*obj*, *shape=None*)

Create a numpy array from a ctypes array or POINTER.

The numpy array shares the memory with the ctypes object.

The shape parameter must be given if converting from a ctypes POINTER. The shape parameter is ignored if converting from a ctypes array

Examples

Converting a ctypes integer array:

```
>>> import ctypes
>>> ctypes_array = (ctypes.c_int * 5)(0, 1, 2, 3, 4)
>>> np_array = np.ctypeslib.as_array(ctypes_array)
>>> np_array
array([0, 1, 2, 3, 4], dtype=int32)
```

Converting a ctypes POINTER:

```
>>> import ctypes
>>> buffer = (ctypes.c_int * 5)(0, 1, 2, 3, 4)
>>> pointer = ctypes.cast(buffer, ctypes.POINTER(ctypes.c_int))
>>> np_array = np.ctypeslib.as_array(pointer, (5,))
>>> np_array
array([0, 1, 2, 3, 4], dtype=int32)
```

numpy.ctypeslib.**as_ctypes**(*obj*)

Create and return a ctypes object from a numpy array. Actually anything that exposes the __array_interface__ is accepted.

Examples

Create ctypes object from inferred int `np.array`:

```
>>> inferred_int_array = np.array([1, 2, 3])
>>> c_int_array = np.ctypeslib.as_ctypes(inferred_int_array)
>>> type(c_int_array)
<class 'c_long_Array_3'>
>>> c_int_array[:]
[1, 2, 3]
```

Create ctypes object from explicit 8 bit unsigned int `np.array` :

```
>>> exp_int_array = np.array([1, 2, 3], dtype=np.uint8)
>>> c_int_array = np.ctypeslib.as_ctypes(exp_int_array)
>>> type(c_int_array)
<class 'c_ubyte_Array_3'>
>>> c_int_array[:]
[1, 2, 3]
```

numpy.ctypeslib.**as_ctypes_type**(*dtype*)

Convert a dtype into a ctypes type.

Parameters

dtype
[dtype] The dtype to convert

Returns

ctype
A ctype scalar, union, array, or struct

Raises

NotImplementedError
If the conversion is not possible

Notes

This function does not losslessly round-trip in either direction.

`np.dtype(as_ctypes_type(dt))` will:

- insert padding fields
- reorder fields to be sorted by offset
- discard field titles

`as_ctypes_type(np.dtype(ctype))` will:

- discard the class names of `ctypes.Structure`s and `ctypes.Union`s
- convert single-element `ctypes.Union`s into single-element `ctypes.Structure`s

- insert padding fields

Examples

Converting a simple dtype:

```
>>> dt = np.dtype('int8')
>>> ctype = np.ctypeslib.as_ctypes_type(dt)
>>> ctype
<class 'ctypes.c_byte'>
```

Converting a structured dtype:

```
>>> dt = np.dtype([('x', 'i4'), ('y', 'f4')])
>>> ctype = np.ctypeslib.as_ctypes_type(dt)
>>> ctype
<class 'struct'>
```

numpy.ctypeslib.**load_library**(*libname*, *loader_path*)

It is possible to load a library using

```
>>> lib = ctypes.cdll[<full_path_name>]
```

But there are cross-platform considerations, such as library file extensions, plus the fact Windows will just load the first library it finds with that name. NumPy supplies the load_library function as a convenience.

Changed in version 1.20.0: Allow libname and loader_path to take any path-like object.

Parameters

libname
[path-like] Name of the library, which can have 'lib' as a prefix, but without an extension.

loader_path
[path-like] Where the library can be found.

Returns

ctypes.cdll[libpath]
[library object] A ctypes library object

Raises

OSError
If there is no library with the expected extension, or the library is defective and cannot be loaded.

numpy.ctypeslib.**ndpointer**(*dtype=None*, *ndim=None*, *shape=None*, *flags=None*)

Array-checking restype/argtypes.

An ndpointer instance is used to describe an ndarray in restypes and argtypes specifications. This approach is more flexible than using, for example, `POINTER(c_double)`, since several restrictions can be specified, which are verified upon calling the ctypes function. These include data type, number of dimensions, shape and flags. If a given array does not satisfy the specified restrictions, a `TypeError` is raised.

Parameters

dtype
[data-type, optional] Array data-type.

ndim
[int, optional] Number of array dimensions.

shape
[tuple of ints, optional] Array shape.

flags
[str or tuple of str] Array flags; may be one or more of:

- C_CONTIGUOUS / C / CONTIGUOUS
- F_CONTIGUOUS / F / FORTRAN
- OWNDATA / O
- WRITEABLE / W
- ALIGNED / A
- WRITEBACKIFCOPY / X

Returns

klass
[ndpointer type object] A type object, which is an `_ndtpr` instance containing dtype, ndim, shape and flags information.

Raises

TypeError
If a given array does not satisfy the specified restrictions.

Examples

```
>>> clib.somefunc.argtypes = [np.ctypeslib.ndpointer(dtype=np.float64,
...                                                  ndim=1,
...                                                  flags='C_CONTIGUOUS')]
...
>>> clib.somefunc(np.array([1, 2, 3], dtype=np.float64))
...
```

class numpy.ctypeslib.**c_intp**

A `ctypes` signed integer type of the same size as *`numpy.intp`*.

Depending on the platform, it can be an alias for either `c_int`, `c_long` or `c_longlong`.

Data type classes (`numpy.dtypes`)

This module is home to specific dtypes related functionality and their classes. For more general information about dtypes, also see *`numpy.dtype`* and *Data type objects (dtype)*.

Similar to the builtin `types` module, this submodule defines types (classes) that are not widely used directly.

New in version NumPy: 1.25

The dtypes module is new in NumPy 1.25. Previously DType classes were only accessible indirectly.

DType classes

The following are the classes of the corresponding NumPy dtype instances and NumPy scalar types. The classes can be used in `isinstance` checks and can also be instantiated or used directly. Direct use of these classes is not typical, since their scalar counterparts (e.g. `np.float64`) or strings like `"float64"` can be used.

Boolean

numpy.dtypes.**BoolDType**

Bit-sized integers

numpy.dtypes.**Int8DType**
numpy.dtypes.**UInt8DType**
numpy.dtypes.**Int16DType**
numpy.dtypes.**UInt16DType**
numpy.dtypes.**Int32DType**
numpy.dtypes.**UInt32DType**
numpy.dtypes.**Int64DType**
numpy.dtypes.**UInt64DType**

C-named integers (may be aliases)

numpy.dtypes.**ByteDType**
numpy.dtypes.**UByteDType**
numpy.dtypes.**ShortDType**
numpy.dtypes.**UShortDType**
numpy.dtypes.**IntDType**
numpy.dtypes.**UIntDType**
numpy.dtypes.**LongDType**
numpy.dtypes.**ULongDType**
numpy.dtypes.**LongLongDType**
numpy.dtypes.**ULongLongDType**

Floating point

numpy.dtypes.**Float16DType**
numpy.dtypes.**Float32DType**
numpy.dtypes.**Float64DType**
numpy.dtypes.**LongDoubleDType**

Complex

numpy.dtypes.**Complex64DType**
numpy.dtypes.**Complex128DType**
numpy.dtypes.**CLongDoubleDType**

Strings and Bytestrings

numpy.dtypes.**StrDType**

numpy.dtypes.**BytesDType**

numpy.dtypes.**StringDType**

Times

numpy.dtypes.**DateTime64DType**

numpy.dtypes.**TimeDelta64DType**

Others

numpy.dtypes.**ObjectDType**

numpy.dtypes.**VoidDType**

Mathematical functions with automatic domain

Note: `numpy.emath` is a preferred alias for `numpy.lib.scimath`, available after *numpy* is imported.

Wrapper functions to more user-friendly calling of certain math functions whose output data-type is different than the input data-type in certain domains of the input.

For example, for functions like *log* with branch cuts, the versions in this module provide the mathematically valid answers in the complex plane:

```
>>> import math
>>> np.emath.log(-math.exp(1)) == (1+1j*math.pi)
True
```

Similarly, *sqrt*, other base logarithms, *power* and trig functions are correctly handled. See their respective docstrings for specific examples.

Functions

arccos(x)	Compute the inverse cosine of x.
arcsin(x)	Compute the inverse sine of x.
arctanh(x)	Compute the inverse hyperbolic tangent of *x*.
log(x)	Compute the natural logarithm of *x*.
log2(x)	Compute the logarithm base 2 of *x*.
logn(n, x)	Take log base n of x.
log10(x)	Compute the logarithm base 10 of *x*.
power(x, p)	Return x to the power p, (x**p).
sqrt(x)	Compute the square root of x.

emath.**arccos**(*x*)

Compute the inverse cosine of x.

Return the "principal value" (for a description of this, see *numpy.arccos*) of the inverse cosine of *x*. For real *x* such that *abs(x)* <= *1*, this is a real number in the closed interval $[0, \pi]$. Otherwise, the complex principle value is returned.

Parameters

x
[array_like or scalar] The value(s) whose arccos is (are) required.

Returns

out
[ndarray or scalar] The inverse cosine(s) of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array object is returned.

See also:

numpy.arccos

Notes

For an arccos() that returns NAN when real *x* is not in the interval `[-1,1]`, use *numpy.arccos*.

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.arccos(1) # a scalar is returned
0.0
```

```
>>> np.emath.arccos([1,2])
array([0.-0.j   , 0.-1.317j])
```

emath.**arcsin**(*x*)

Compute the inverse sine of x.

Return the "principal value" (for a description of this, see *numpy.arcsin*) of the inverse sine of *x*. For real *x* such that *abs(x)* <= *1*, this is a real number in the closed interval $[-\pi/2, \pi/2]$. Otherwise, the complex principle value is returned.

Parameters

x
[array_like or scalar] The value(s) whose arcsin is (are) required.

Returns

out
[ndarray or scalar] The inverse sine(s) of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array object is returned.

See also:

numpy.arcsin

Notes

For an arcsin() that returns NAN when real *x* is not in the interval `[-1,1]`, use *numpy.arcsin*.

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.arcsin(0)
0.0
```

```
>>> np.emath.arcsin([0,1])
array([0.    , 1.5708])
```

emath.**arctanh**(*x*)

Compute the inverse hyperbolic tangent of *x*.

Return the "principal value" (for a description of this, see *numpy.arctanh*) of `arctanh(x)`. For real *x* such that `abs(x) < 1`, this is a real number. If *abs(x) > 1*, or if *x* is complex, the result is complex. Finally, *x = 1* returns``inf`` and `x=-1` returns `-inf`.

Parameters

x
: [array_like] The value(s) whose arctanh is (are) required.

Returns

out
: [ndarray or scalar] The inverse hyperbolic tangent(s) of the *x* value(s). If *x* was a scalar so is *out*, otherwise an array is returned.

See also:

numpy.arctanh

Notes

For an arctanh() that returns NAN when real *x* is not in the interval `(-1,1)`, use *numpy.arctanh* (this latter, however, does return +/-inf for `x = +/-1`).

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.arctanh(0.5)
0.5493061443340549
```

```
>>> from numpy.testing import suppress_warnings
>>> with suppress_warnings() as sup:
...     sup.filter(RuntimeWarning)
...     np.emath.arctanh(np.eye(2))
array([[inf,  0.],
       [ 0., inf]])
>>> np.emath.arctanh([1j])
array([0.+0.7854j])
```

emath.**log**(*x*)

Compute the natural logarithm of *x*.

Return the "principal value" (for a description of this, see *numpy.log*) of $log_e(x)$. For real $x > 0$, this is a real number (`log(0)` returns `-inf` and `log(np.inf)` returns `inf`). Otherwise, the complex principle value is returned.

Parameters

x
[array_like] The value(s) whose log is (are) required.

Returns

out
[ndarray or scalar] The log of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array is returned.

See also:

numpy.log

Notes

For a log() that returns `NAN` when real $x < 0$, use *numpy.log* (note, however, that otherwise *numpy.log* and this *log* are identical, i.e., both return `-inf` for $x = 0$, `inf` for $x = inf$, and, notably, the complex principle value if `x.imag != 0`).

Examples

```
>>> import numpy as np
>>> np.emath.log(np.exp(1))
1.0
```

Negative arguments are handled "correctly" (recall that `exp(log(x)) == x` does *not* hold for real `x < 0`):

```
>>> np.emath.log(-np.exp(1)) == (1 + np.pi * 1j)
True
```

emath.**log2**(*x*)

Compute the logarithm base 2 of *x*.

Return the "principal value" (for a description of this, see *numpy.log2*) of $log_2(x)$. For real $x > 0$, this is a real number (`log2(0)` returns `-inf` and `log2(np.inf)` returns `inf`). Otherwise, the complex principle value is returned.

Parameters

x
[array_like] The value(s) whose log base 2 is (are) required.

Returns

out
[ndarray or scalar] The log base 2 of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array is returned.

See also:

numpy.log2

Notes

For a log2() that returns `NAN` when real $x < 0$, use *numpy.log2* (note, however, that otherwise *numpy.log2* and this *log2* are identical, i.e., both return `-inf` for $x = 0$, `inf` for $x = inf$, and, notably, the complex principle value if `x.imag != 0`).

Examples

We set the printing precision so the example can be auto-tested:

```
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.log2(8)
3.0
>>> np.emath.log2([-4, -8, 8])
array([2.+4.5324j, 3.+4.5324j, 3.+0.j    ])
```

emath.**logn**(*n*, *x*)

Take log base n of x.

If *x* contains negative inputs, the answer is computed and returned in the complex domain.

Parameters

n
[array_like] The integer base(s) in which the log is taken.

x
[array_like] The value(s) whose log base *n* is (are) required.

Returns

out
[ndarray or scalar] The log base *n* of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array is returned.

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.logn(2, [4, 8])
array([2., 3.])
>>> np.emath.logn(2, [-4, -8, 8])
array([2.+4.5324j, 3.+4.5324j, 3.+0.j    ])
```

emath.**log10**(*x*)

Compute the logarithm base 10 of *x*.

Return the "principal value" (for a description of this, see *numpy.log10*) of $log_{10}(x)$. For real $x > 0$, this is a real number (`log10(0)` returns `-inf` and `log10(np.inf)` returns `inf`). Otherwise, the complex principle value is returned.

Parameters

x
[array_like or scalar] The value(s) whose log base 10 is (are) required.

Returns

out
[ndarray or scalar] The log base 10 of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array object is returned.

See also:

numpy.log10

Notes

For a log10() that returns `NAN` when real $x < 0$, use *numpy.log10* (note, however, that otherwise *numpy.log10* and this *log10* are identical, i.e., both return `-inf` for $x = 0$, `inf` for $x = inf$, and, notably, the complex principle value if `x.imag != 0`).

Examples

```
>>> import numpy as np
```

(We set the printing precision so the example can be auto-tested)

```
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.log10(10**1)
1.0
```

```
>>> np.emath.log10([-10**1, -10**2, 10**2])
array([1.+1.3644j, 2.+1.3644j, 2.+0.j    ])
```

emath.**power**(*x*, *p*)

Return x to the power p, (x**p).

If *x* contains negative values, the output is converted to the complex domain.

Parameters

x
[array_like] The input value(s).

p
[array_like of ints] The power(s) to which *x* is raised. If *x* contains multiple values, *p* has to either be a scalar, or contain the same number of values as *x*. In the latter case, the result is `x[0]**p[0], x[1]**p[1], ...`.

Returns

out
[ndarray or scalar] The result of `x**p`. If *x* and *p* are scalars, so is *out*, otherwise an array is returned.

See also:

numpy.power

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.power(2, 2)
4
```

```
>>> np.emath.power([2, 4], 2)
array([ 4, 16])
```

```
>>> np.emath.power([2, 4], -2)
array([0.25  ,  0.0625])
```

```
>>> np.emath.power([-2, 4], 2)
array([ 4.-0.j, 16.+0.j])
```

```
>>> np.emath.power([2, 4], [2, 4])
array([  4, 256])
```

emath.**sqrt**(*x*)

Compute the square root of x.

For negative input elements, a complex value is returned (unlike *numpy.sqrt* which returns NaN).

Parameters

x
[array_like] The input value(s).

Returns

out
: [ndarray or scalar] The square root of *x*. If *x* was a scalar, so is *out*, otherwise an array is returned.

See also:

numpy.sqrt

Examples

For real, non-negative inputs this works just like *numpy.sqrt*:

```
>>> import numpy as np
```

```
>>> np.emath.sqrt(1)
1.0
>>> np.emath.sqrt([1, 4])
array([1.,  2.])
```

But it automatically handles negative inputs:

```
>>> np.emath.sqrt(-1)
1j
>>> np.emath.sqrt([-1,4])
array([0.+1.j, 2.+0.j])
```

Different results are expected because: floating point 0.0 and -0.0 are distinct.

For more control, explicitly use complex() as follows:

```
>>> np.emath.sqrt(complex(-4.0, 0.0))
2j
>>> np.emath.sqrt(complex(-4.0, -0.0))
-2j
```

Lib module (`numpy.lib`)

Functions & other objects

add_docstring(obj, docstring)	Add a docstring to a built-in obj if possible.
add_newdoc(place, obj, doc[, warn_on_python])	Add documentation to an existing object, typically one defined in C
Arrayterator(var[, buf_size])	Buffered iterator for big arrays.
NumpyVersion(vstring)	Parse and compare numpy version strings.

lib.**add_docstring**(*obj*, *docstring*)

Add a docstring to a built-in obj if possible. If the obj already has a docstring raise a RuntimeError If this routine does not know how to add a docstring to the object raise a TypeError

lib.**add_newdoc**(*place*, *obj*, *doc*, *warn_on_python=True*)

Add documentation to an existing object, typically one defined in C

The purpose is to allow easier editing of the docstrings without requiring a re-compile. This exists primarily for internal use within numpy itself.

Parameters

place
[str] The absolute name of the module to import from

obj
[str or None] The name of the object to add documentation to, typically a class or function name.

doc
[{str, Tuple[str, str], List[Tuple[str, str]]}] If a string, the documentation to apply to *obj*

If a tuple, then the first element is interpreted as an attribute of *obj* and the second as the docstring to apply - `(method, docstring)`

If a list, then each element of the list should be a tuple of length two - `[(method1, docstring1), (method2, docstring2), ...]`

warn_on_python
[bool] If True, the default, emit *UserWarning* if this is used to attach documentation to a pure-python object.

Notes

This routine never raises an error if the docstring can't be written, but will raise an error if the object being documented does not exist.

This routine cannot modify read-only docstrings, as appear in new-style classes or built-in functions. Because this routine never raises an error the caller must check manually that the docstrings were changed.

Since this function grabs the `char *` from a c-level str object and puts it into the `tp_doc` slot of the type of *obj*, it violates a number of C-API best-practices, by:

- modifying a *PyTypeObject* after calling *PyType_Ready*
- calling *Py_INCREF* on the str and losing the reference, so the str will never be released

If possible it should be avoided.

class numpy.lib.**Arrayterator**(*var*, *buf_size=None*)

Buffered iterator for big arrays.

Arrayterator creates a buffered iterator for reading big arrays in small contiguous blocks. The class is useful for objects stored in the file system. It allows iteration over the object *without* reading everything in memory; instead, small blocks are read and iterated over.

Arrayterator can be used with any object that supports multidimensional slices. This includes NumPy arrays, but also variables from Scientific.IO.NetCDF or pynetcdf for example.

Parameters

var
[array_like] The object to iterate over.

buf_size
[int, optional] The buffer size. If *buf_size* is supplied, the maximum amount of data that will be read into memory is *buf_size* elements. Default is None, which will read as many element as possible into memory.

See also:

numpy.ndenumerate
Multidimensional array iterator.

numpy.flatiter
Flat array iterator.

numpy.memmap
Create a memory-map to an array stored in a binary file on disk.

Notes

The algorithm works by first finding a "running dimension", along which the blocks will be extracted. Given an array of dimensions `(d1, d2, ..., dn)`, e.g. if *buf_size* is smaller than `d1`, the first dimension will be used. If, on the other hand, `d1 < buf_size < d1*d2` the second dimension will be used, and so on. Blocks are extracted along this dimension, and when the last block is returned the process continues from the next dimension, until all elements have been read.

Examples

```
>>> import numpy as np
>>> a = np.arange(3 * 4 * 5 * 6).reshape(3, 4, 5, 6)
>>> a_itor = np.lib.Arrayterator(a, 2)
>>> a_itor.shape
(3, 4, 5, 6)
```

Now we can iterate over `a_itor`, and it will return arrays of size two. Since *buf_size* was smaller than any dimension, the first dimension will be iterated over first:

```
>>> for subarr in a_itor:
...     if not subarr.all():
...         print(subarr, subarr.shape)
>>> # [[[[0 1]]]] (1, 1, 1, 2)
```

Attributes

var
buf_size
start
stop
step
shape
The shape of the array to be iterated over.

flat
A 1-D flat iterator for Arrayterator objects.

class numpy.lib.**NumpyVersion**(*vstring*)
Parse and compare numpy version strings.

NumPy has the following versioning scheme (numbers given are examples; they can be > 9 in principle):

- Released version: '1.8.0', '1.8.1', etc.
- Alpha: '1.8.0a1', '1.8.0a2', etc.
- Beta: '1.8.0b1', '1.8.0b2', etc.

- Release candidates: '1.8.0rc1', '1.8.0rc2', etc.
- Development versions: '1.8.0.dev-f1234afa' (git commit hash appended)
- **Development versions after a1: '1.8.0a1.dev-f1234afa',**
  '1.8.0b2.dev-f1234afa', '1.8.1rc1.dev-f1234afa', etc.
- Development versions (no git hash available): '1.8.0.dev-Unknown'

Comparing needs to be done against a valid version string or other *NumpyVersion* instance. Note that all development versions of the same (pre-)release compare equal.

Parameters

vstring
[str] NumPy version string (`np.__version__`).

Examples

```
>>> from numpy.lib import NumpyVersion
>>> if NumpyVersion(np.__version__) < '1.7.0':
...     print('skip')
>>> # skip
```

```
>>> NumpyVersion('1.7')  # raises ValueError, add ".0"
Traceback (most recent call last):
    ...
ValueError: Not a valid numpy version string
```

Submodules

array_utils	Miscellaneous utils.
format	Binary serialization
introspect	Introspection helper functions.
mixins	Mixin classes for custom array types that don't inherit from ndarray.
npyio	IO related functions.
scimath	Wrapper functions to more user-friendly calling of certain math functions whose output data-type is different than the input data-type in certain domains of the input.
stride_tricks	Utilities that manipulate strides to achieve desirable effects.

Miscellaneous utils.

Functions

byte_bounds(a)	Returns pointers to the end-points of an array.
normalize_axis_index(axis, ndim[, msg_prefix])	Normalizes an axis index, *axis*, such that is a valid positive index into the shape of array with *ndim* dimensions.
normalize_axis_tuple(axis, ndim[, argname, ...])	Normalizes an axis argument into a tuple of non-negative integer axes.

lib.array_utils.**byte_bounds**(*a*)

Returns pointers to the end-points of an array.

Parameters

a
[ndarray] Input array. It must conform to the Python-side of the array interface.

Returns

(low, high)
[tuple of 2 integers] The first integer is the first byte of the array, the second integer is just past the last byte of the array. If *a* is not contiguous it will not use every byte between the (*low*, *high*) values.

Examples

```
>>> import numpy as np
>>> I = np.eye(2, dtype='f'); I.dtype
dtype('float32')
>>> low, high = np.lib.array_utils.byte_bounds(I)
>>> high - low == I.size*I.itemsize
True
>>> I = np.eye(2); I.dtype
dtype('float64')
>>> low, high = np.lib.array_utils.byte_bounds(I)
>>> high - low == I.size*I.itemsize
True
```

lib.array_utils.**normalize_axis_index**(*axis*, *ndim*, *msg_prefix=None*)

Normalizes an axis index, *axis*, such that is a valid positive index into the shape of array with *ndim* dimensions. Raises an AxisError with an appropriate message if this is not possible.

Used internally by all axis-checking logic.

Parameters

axis
[int] The un-normalized index of the axis. Can be negative

ndim
[int] The number of dimensions of the array that *axis* should be normalized against

msg_prefix
[str] A prefix to put before the message, typically the name of the argument

Returns

normalized_axis
[int] The normalized axis index, such that *0* <= *normalized_axis* < *ndim*

Raises

AxisError
If the axis index is invalid, when *-ndim* <= *axis* < *ndim* is false.

Examples

```
>>> import numpy as np
>>> from numpy.lib.array_utils import normalize_axis_index
>>> normalize_axis_index(0, ndim=3)
0
>>> normalize_axis_index(1, ndim=3)
1
>>> normalize_axis_index(-1, ndim=3)
2
```

```
>>> normalize_axis_index(3, ndim=3)
Traceback (most recent call last):
...
numpy.exceptions.AxisError: axis 3 is out of bounds for array ...
>>> normalize_axis_index(-4, ndim=3, msg_prefix='axes_arg')
Traceback (most recent call last):
...
numpy.exceptions.AxisError: axes_arg: axis -4 is out of bounds ...
```

lib.array_utils.**normalize_axis_tuple**(*axis*, *ndim*, *argname=None*, *allow_duplicate=False*)

Normalizes an axis argument into a tuple of non-negative integer axes.

This handles shorthands such as `1` and converts them to `(1,)`, as well as performing the handling of negative indices covered by *normalize_axis_index*.

By default, this forbids axes from being specified multiple times.

Used internally by multi-axis-checking logic.

Parameters

axis
[int, iterable of int] The un-normalized index or indices of the axis.

ndim
[int] The number of dimensions of the array that *axis* should be normalized against.

argname
[str, optional] A prefix to put before the error message, typically the name of the argument.

allow_duplicate
[bool, optional] If False, the default, disallow an axis from being specified twice.

Returns

normalized_axes
[tuple of int] The normalized axis index, such that *0* <= *normalized_axis* < *ndim*

Raises

AxisError
If any axis provided is out of range

ValueError
If an axis is repeated

See also:

normalize_axis_index
normalizing a single scalar axis

Binary serialization

NPY format

A simple format for saving numpy arrays to disk with the full information about them.

The `.npy` format is the standard binary file format in NumPy for persisting a *single* arbitrary NumPy array on disk. The format stores all of the shape and dtype information necessary to reconstruct the array correctly even on another machine with a different architecture. The format is designed to be as simple as possible while achieving its limited goals.

The `.npz` format is the standard format for persisting *multiple* NumPy arrays on disk. A `.npz` file is a zip file containing multiple `.npy` files, one for each array.

Capabilities

- Can represent all NumPy arrays including nested record arrays and object arrays.
- Represents the data in its native binary form.
- Supports Fortran-contiguous arrays directly.
- Stores all of the necessary information to reconstruct the array including shape and dtype on a machine of a different architecture. Both little-endian and big-endian arrays are supported, and a file with little-endian numbers will yield a little-endian array on any machine reading the file. The types are described in terms of their actual sizes. For example, if a machine with a 64-bit C "long int" writes out an array with "long ints", a reading machine with 32-bit C "long ints" will yield an array with 64-bit integers.
- Is straightforward to reverse engineer. Datasets often live longer than the programs that created them. A competent developer should be able to create a solution in their preferred programming language to read most `.npy` files that they have been given without much documentation.
- Allows memory-mapping of the data. See *open_memmap*.
- Can be read from a filelike stream object instead of an actual file.
- Stores object arrays, i.e. arrays containing elements that are arbitrary Python objects. Files with object arrays are not to be mmapable, but can be read and written to disk.

Limitations

- Arbitrary subclasses of numpy.ndarray are not completely preserved. Subclasses will be accepted for writing, but only the array data will be written out. A regular numpy.ndarray object will be created upon reading the file.

Warning: Due to limitations in the interpretation of structured dtypes, dtypes with fields with empty names will have the names replaced by 'f0', 'f1', etc. Such arrays will not round-trip through the format entirely accurately. The data is intact; only the field names will differ. We are working on a fix for this. This fix will not require a change in

the file format. The arrays with such structures can still be saved and restored, and the correct dtype may be restored by using the `loadedarray.view(correct_dtype)` method.

File extensions

We recommend using the `.npy` and `.npz` extensions for files saved in this format. This is by no means a requirement; applications may wish to use these file formats but use an extension specific to the application. In the absence of an obvious alternative, however, we suggest using `.npy` and `.npz`.

Version numbering

The version numbering of these formats is independent of NumPy version numbering. If the format is upgraded, the code in *numpy.io* will still be able to read and write Version 1.0 files.

Format Version 1.0

The first 6 bytes are a magic string: exactly `\x93NUMPY`.

The next 1 byte is an unsigned byte: the major version number of the file format, e.g. `\x01`.

The next 1 byte is an unsigned byte: the minor version number of the file format, e.g. `\x00`. Note: the version of the file format is not tied to the version of the numpy package.

The next 2 bytes form a little-endian unsigned short int: the length of the header data HEADER_LEN.

The next HEADER_LEN bytes form the header data describing the array's format. It is an ASCII string which contains a Python literal expression of a dictionary. It is terminated by a newline (`\n`) and padded with spaces (`\x20`) to make the total of `len(magic string) + 2 + len(length) + HEADER_LEN` be evenly divisible by 64 for alignment purposes.

The dictionary contains three keys:

"descr"
: [dtype.descr] An object that can be passed as an argument to the *numpy.dtype* constructor to create the array's dtype.

"fortran_order"
: [bool] Whether the array data is Fortran-contiguous or not. Since Fortran-contiguous arrays are a common form of non-C-contiguity, we allow them to be written directly to disk for efficiency.

"shape"
: [tuple of int] The shape of the array.

For repeatability and readability, the dictionary keys are sorted in alphabetic order. This is for convenience only. A writer SHOULD implement this if possible. A reader MUST NOT depend on this.

Following the header comes the array data. If the dtype contains Python objects (i.e. `dtype.hasobject is True`), then the data is a Python pickle of the array. Otherwise the data is the contiguous (either C- or Fortran-, depending on `fortran_order`) bytes of the array. Consumers can figure out the number of bytes by multiplying the number of elements given by the shape (noting that `shape=()` means there is 1 element) by `dtype.itemsize`.

Format Version 2.0

The version 1.0 format only allowed the array header to have a total size of 65535 bytes. This can be exceeded by structured arrays with a large number of columns. The version 2.0 format extends the header size to 4 GiB. *numpy.save* will automatically save in 2.0 format if the data requires it, else it will always use the more compatible 1.0 format.

The description of the fourth element of the header therefore has become: "The next 4 bytes form a little-endian unsigned int: the length of the header data HEADER_LEN."

Format Version 3.0

This version replaces the ASCII string (which in practice was latin1) with a utf8-encoded string, so supports structured types with any unicode field names.

Notes

The `.npy` format, including motivation for creating it and a comparison of alternatives, is described in the "npy-format" NEP, however details have evolved with time and this document is more current.

Functions

descr_to_dtype(descr)	Returns a dtype based off the given description.
drop_metadata(dtype, /)	Returns the dtype unchanged if it contained no metadata or a copy of the dtype if it (or any of its structure dtypes) contained metadata.
dtype_to_descr(dtype)	Get a serializable descriptor from the dtype.
header_data_from_array_1_0(array)	Get the dictionary of header metadata from a numpy.ndarray.
isfileobj(f)	
magic(major, minor)	Return the magic string for the given file format version.
open_memmap(filename[, mode, dtype, shape, ...])	Open a .npy file as a memory-mapped array.
read_array(fp[, allow_pickle, ...])	Read an array from an NPY file.
read_array_header_1_0(fp[, max_header_size])	Read an array header from a filelike object using the 1.0 file format version.
read_array_header_2_0(fp[, max_header_size])	Read an array header from a filelike object using the 2.0 file format version.
read_magic(fp)	Read the magic string to get the version of the file format.
write_array(fp, array[, version, ...])	Write an array to an NPY file, including a header.
write_array_header_1_0(fp, d)	Write the header for an array using the 1.0 format.
write_array_header_2_0(fp, d)	Write the header for an array using the 2.0 format.

lib.format.**descr_to_dtype**(*descr*)

Returns a dtype based off the given description.

This is essentially the reverse of *dtype_to_descr*. It will remove the valueless padding fields created by, i.e. simple fields like dtype('float32'), and then convert the description to its corresponding dtype.

Parameters

descr
[object] The object retrieved by dtype.descr. Can be passed to *numpy.dtype* in order to replicate the input dtype.

Returns

dtype
[dtype] The dtype constructed by the description.

lib.format.**drop_metadata**(*dtype*, */*)

Returns the dtype unchanged if it contained no metadata or a copy of the dtype if it (or any of its structure dtypes) contained metadata.

This utility is used by *np.save* and *np.savez* to drop metadata before saving.

Note: Due to its limitation this function may move to a more appropriate home or change in the future and is considered semi-public API only.

Warning: This function does not preserve more strange things like record dtypes and user dtypes may simply return the wrong thing. If you need to be sure about the latter, check the result with: `np.can_cast(new_dtype, dtype, casting="no")`.

lib.format.**dtype_to_descr**(*dtype*)

Get a serializable descriptor from the dtype.

The .descr attribute of a dtype object cannot be round-tripped through the dtype() constructor. Simple types, like dtype('float32'), have a descr which looks like a record array with one field with '' as a name. The dtype() constructor interprets this as a request to give a default name. Instead, we construct descriptor that can be passed to dtype().

Parameters

dtype
[dtype] The dtype of the array that will be written to disk.

Returns

descr
[object] An object that can be passed to *numpy.dtype()* in order to replicate the input dtype.

lib.format.**header_data_from_array_1_0**(*array*)

Get the dictionary of header metadata from a numpy.ndarray.

Parameters

array
[numpy.ndarray]

Returns

d
[dict] This has the appropriate entries for writing its string representation to the header of the file.

lib.format.**isfileobj**(*f*)

lib.format.**magic**(*major*, *minor*)

Return the magic string for the given file format version.

Parameters

major
[int in [0, 255]]

minor
[int in [0, 255]]

Returns

magic
[str]

Raises

ValueError if the version cannot be formatted.

lib.format.**open_memmap**(*filename*, *mode='r+'*, *dtype=None*, *shape=None*, *fortran_order=False*, *version=None*, ***, *max_header_size=10000*)

Open a .npy file as a memory-mapped array.

This may be used to read an existing file or create a new one.

Parameters

filename
[str or path-like] The name of the file on disk. This may *not* be a file-like object.

mode
[str, optional] The mode in which to open the file; the default is 'r+'. In addition to the standard file modes, 'c' is also accepted to mean "copy on write." See *memmap* for the available mode strings.

dtype
[data-type, optional] The data type of the array if we are creating a new file in "write" mode, if not, *dtype* is ignored. The default value is None, which results in a data-type of *float64*.

shape
[tuple of int] The shape of the array if we are creating a new file in "write" mode, in which case this parameter is required. Otherwise, this parameter is ignored and is thus optional.

fortran_order
[bool, optional] Whether the array should be Fortran-contiguous (True) or C-contiguous (False, the default) if we are creating a new file in "write" mode.

version
[tuple of int (major, minor) or None] If the mode is a "write" mode, then this is the version of the file format used to create the file. None means use the oldest supported version that is able to store the data. Default: None

max_header_size
[int, optional] Maximum allowed size of the header. Large headers may not be safe to load securely and thus require explicitly passing a larger value. See ast.literal_eval for details.

Returns

marray
[memmap] The memory-mapped array.

Raises

ValueError
If the data or the mode is invalid.

OSError
If the file is not found or cannot be opened correctly.

See also:

numpy.memmap

lib.format.**read_array**(*fp*, *allow_pickle=False*, *pickle_kwargs=None*, ***, *max_header_size=10000*)

Read an array from an NPY file.

Parameters

fp
[file_like object] If this is not a real file object, then this may take extra memory and time.

allow_pickle
[bool, optional] Whether to allow writing pickled data. Default: False

pickle_kwargs
[dict] Additional keyword arguments to pass to pickle.load. These are only useful when loading object arrays saved on Python 2 when using Python 3.

max_header_size
[int, optional] Maximum allowed size of the header. Large headers may not be safe to load securely and thus require explicitly passing a larger value. See ast.literal_eval for details. This option is ignored when *allow_pickle* is passed. In that case the file is by definition trusted and the limit is unnecessary.

Returns

array
[ndarray] The array from the data on disk.

Raises

ValueError
If the data is invalid, or allow_pickle=False and the file contains an object array.

lib.format.**read_array_header_1_0**(*fp*, *max_header_size=10000*)

Read an array header from a filelike object using the 1.0 file format version.

This will leave the file object located just after the header.

Parameters

fp
[filelike object] A file object or something with a *read()* method like a file.

Returns

shape
[tuple of int] The shape of the array.

fortran_order
[bool] The array data will be written out directly if it is either C-contiguous or Fortran-contiguous. Otherwise, it will be made contiguous before writing it out.

dtype
[dtype] The dtype of the file's data.

max_header_size
[int, optional] Maximum allowed size of the header. Large headers may not be safe to load

securely and thus require explicitly passing a larger value. See `ast.literal_eval` for details.

Raises

ValueError
If the data is invalid.

`lib.format.`**`read_array_header_2_0`**(*fp*, *max_header_size=10000*)

Read an array header from a filelike object using the 2.0 file format version.

This will leave the file object located just after the header.

Parameters

fp
[filelike object] A file object or something with a *read()* method like a file.

max_header_size
[int, optional] Maximum allowed size of the header. Large headers may not be safe to load securely and thus require explicitly passing a larger value. See `ast.literal_eval` for details.

Returns

shape
[tuple of int] The shape of the array.

fortran_order
[bool] The array data will be written out directly if it is either C-contiguous or Fortran-contiguous. Otherwise, it will be made contiguous before writing it out.

dtype
[dtype] The dtype of the file's data.

Raises

ValueError
If the data is invalid.

`lib.format.`**`read_magic`**(*fp*)

Read the magic string to get the version of the file format.

Parameters

fp
[filelike object]

Returns

major
[int]

minor
[int]

`lib.format.`**`write_array`**(*fp*, *array*, *version=None*, *allow_pickle=True*, *pickle_kwargs=None*)

Write an array to an NPY file, including a header.

If the array is neither C-contiguous nor Fortran-contiguous AND the file_like object is not a real file object, this function will have to copy data in memory.

Parameters

fp
[file_like object] An open, writable file object, or similar object with a `.write()` method.

array
[ndarray] The array to write to disk.

version
[(int, int) or None, optional] The version number of the format. None means use the oldest supported version that is able to store the data. Default: None

allow_pickle
[bool, optional] Whether to allow writing pickled data. Default: True

pickle_kwargs
[dict, optional] Additional keyword arguments to pass to pickle.dump, excluding 'protocol'. These are only useful when pickling objects in object arrays on Python 3 to Python 2 compatible format.

Raises

ValueError
If the array cannot be persisted. This includes the case of allow_pickle=False and array being an object array.

Various other errors
If the array contains Python objects as part of its dtype, the process of pickling them may raise various errors if the objects are not picklable.

`lib.format.`**`write_array_header_1_0`**(*fp*, *d*)

Write the header for an array using the 1.0 format.

Parameters

fp
[filelike object]

d
[dict] This has the appropriate entries for writing its string representation to the header of the file.

`lib.format.`**`write_array_header_2_0`**(*fp*, *d*)

Write the header for an array using the 2.0 format.
The 2.0 format allows storing very large structured arrays.

Parameters

fp
[filelike object]

d
[dict] This has the appropriate entries for writing its string representation to the header of the file.

Introspection helper functions.

Functions

opt_func_info([func_name, signature])	Returns a dictionary containing the currently supported CPU dispatched features for all optimized functions.

lib.introspect.**opt_func_info**(*func_name=None*, *signature=None*)

Returns a dictionary containing the currently supported CPU dispatched features for all optimized functions.

Parameters

func_name
[str (optional)] Regular expression to filter by function name.

signature
[str (optional)] Regular expression to filter by data type.

Returns

dict
A dictionary where keys are optimized function names and values are nested dictionaries indicating supported targets based on data types.

Examples

Retrieve dispatch information for functions named 'add' or 'sub' and data types 'float64' or 'float32':

```
>>> import numpy as np
>>> dict = np.lib.introspect.opt_func_info(
...     func_name="add|abs", signature="float64|complex64"
... )
>>> import json
>>> print(json.dumps(dict, indent=2))
{
  "absolute": {
    "dd": {
      "current": "SSE41",
      "available": "SSE41 baseline(SSE SSE2 SSE3)"
    },
    "Ff": {
      "current": "FMA3__AVX2",
      "available": "AVX512F FMA3__AVX2 baseline(SSE SSE2 SSE3)"
    },
    "Dd": {
      "current": "FMA3__AVX2",
      "available": "AVX512F FMA3__AVX2 baseline(SSE SSE2 SSE3)"
    }
  },
  "add": {
    "ddd": {
      "current": "FMA3__AVX2",
      "available": "FMA3__AVX2 baseline(SSE SSE2 SSE3)"
    },
    "FFF": {
      "current": "FMA3__AVX2",
      "available": "FMA3__AVX2 baseline(SSE SSE2 SSE3)"
    }
```

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```
    }
}
```

Mixin classes for custom array types that don't inherit from ndarray.

Classes

NDArrayOperatorsMixin()	Mixin defining all operator special methods using __array_ufunc__.

class numpy.lib.mixins.**NDArrayOperatorsMixin**

Mixin defining all operator special methods using __array_ufunc__.

This class implements the special methods for almost all of Python's builtin operators defined in the `operator` module, including comparisons (==, >, etc.) and arithmetic (+, *, -, etc.), by deferring to the `__array_ufunc__` method, which subclasses must implement.

It is useful for writing classes that do not inherit from *numpy.ndarray*, but that should support arithmetic and numpy universal functions like arrays as described in A Mechanism for Overriding Ufuncs.

As an trivial example, consider this implementation of an `ArrayLike` class that simply wraps a NumPy array and ensures that the result of any arithmetic operation is also an `ArrayLike` object:

```
>>> import numbers
>>> class ArrayLike(np.lib.mixins.NDArrayOperatorsMixin):
...     def __init__(self, value):
...         self.value = np.asarray(value)
...
...     # One might also consider adding the built-in list type to this
...     # list, to support operations like np.add(array_like, list)
...     _HANDLED_TYPES = (np.ndarray, numbers.Number)
...
...     def __array_ufunc__(self, ufunc, method, *inputs, **kwargs):
...         out = kwargs.get('out', ())
...         for x in inputs + out:
...             # Only support operations with instances of
...             # _HANDLED_TYPES. Use ArrayLike instead of type(self)
...             # for isinstance to allow subclasses that don't
...             # override __array_ufunc__ to handle ArrayLike objects.
...             if not isinstance(
...                 x, self._HANDLED_TYPES + (ArrayLike,)
...             ):
...                 return NotImplemented
...
...         # Defer to the implementation of the ufunc
...         # on unwrapped values.
...         inputs = tuple(x.value if isinstance(x, ArrayLike) else x
...                        for x in inputs)
...         if out:
...             kwargs['out'] = tuple(
...                 x.value if isinstance(x, ArrayLike) else x
...                 for x in out)
...         result = getattr(ufunc, method)(*inputs, **kwargs)
...
```

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```
...         if type(result) is tuple:
...             # multiple return values
...             return tuple(type(self)(x) for x in result)
...         elif method == 'at':
...             # no return value
...             return None
...         else:
...             # one return value
...             return type(self)(result)
...
...     def __repr__(self):
...         return '%s(%r)' % (type(self).__name__, self.value)
```

In interactions between `ArrayLike` objects and numbers or numpy arrays, the result is always another `ArrayLike`:

```
>>> x = ArrayLike([1, 2, 3])
>>> x - 1
ArrayLike(array([0, 1, 2]))
>>> 1 - x
ArrayLike(array([ 0, -1, -2]))
>>> np.arange(3) - x
ArrayLike(array([-1, -1, -1]))
>>> x - np.arange(3)
ArrayLike(array([1, 1, 1]))
```

Note that unlike `numpy.ndarray`, `ArrayLike` does not allow operations with arbitrary, unrecognized types. This ensures that interactions with ArrayLike preserve a well-defined casting hierarchy.

IO related functions.

Classes

DataSource([destpath])	A generic data source file (file, http, ftp, ...).
NpzFile(fid)	A dictionary-like object with lazy-loading of files in the zipped archive provided on construction.

class numpy.lib.npyio.**DataSource**(*destpath='.'*)

A generic data source file (file, http, ftp, …).

DataSources can be local files or remote files/URLs. The files may also be compressed or uncompressed. DataSource hides some of the low-level details of downloading the file, allowing you to simply pass in a valid file path (or URL) and obtain a file object.

Parameters

destpath

[str or None, optional] Path to the directory where the source file gets downloaded to for use. If *destpath* is None, a temporary directory will be created. The default path is the current directory.

Notes

URLs require a scheme string (`http://`) to be used, without it they will fail:

```
>>> repos = np.lib.npyio.DataSource()
>>> repos.exists('www.google.com/index.html')
False
>>> repos.exists('http://www.google.com/index.html')
True
```

Temporary directories are deleted when the DataSource is deleted.

Examples

```
>>> ds = np.lib.npyio.DataSource('/home/guido')
>>> urlname = 'http://www.google.com/'
>>> gfile = ds.open('http://www.google.com/')
>>> ds.abspath(urlname)
'/home/guido/www.google.com/index.html'

>>> ds = np.lib.npyio.DataSource(None)  # use with temporary file
>>> ds.open('/home/guido/foobar.txt')
<open file '/home/guido.foobar.txt', mode 'r' at 0x91d4430>
>>> ds.abspath('/home/guido/foobar.txt')
'/tmp/.../home/guido/foobar.txt'
```

Methods

abspath(path)	Return absolute path of file in the DataSource directory.
exists(path)	Test if path exists.
open(path[, mode, encoding, newline])	Open and return file-like object.

method

`lib.npyio.DataSource.`**`abspath`**(*path*)

Return absolute path of file in the DataSource directory.

If *path* is an URL, then *abspath* will return either the location the file exists locally or the location it would exist when opened using the *open* method.

Parameters

path
[str or pathlib.Path] Can be a local file or a remote URL.

Returns

out
[str] Complete path, including the *DataSource* destination directory.

Notes

The functionality is based on `os.path.abspath`.

method

`lib.npyio.DataSource.`**`exists`**(*path*)

Test if path exists.

Test if *path* exists as (and in this order):

- a local file.
- a remote URL that has been downloaded and stored locally in the *DataSource* directory.
- a remote URL that has not been downloaded, but is valid and accessible.

Parameters

path
[str or pathlib.Path] Can be a local file or a remote URL.

Returns

out
[bool] True if *path* exists.

Notes

When *path* is an URL, *exists* will return True if it's either stored locally in the *DataSource* directory, or is a valid remote URL. *DataSource* does not discriminate between the two, the file is accessible if it exists in either location.

method

`lib.npyio.DataSource.`**`open`**(*path*, *mode='r'*, *encoding=None*, *newline=None*)

Open and return file-like object.

If *path* is an URL, it will be downloaded, stored in the *DataSource* directory and opened from there.

Parameters

path
[str or pathlib.Path] Local file path or URL to open.

mode
[{'r', 'w', 'a'}, optional] Mode to open *path*. Mode 'r' for reading, 'w' for writing, 'a' to append. Available modes depend on the type of object specified by *path*. Default is 'r'.

encoding
[{None, str}, optional] Open text file with given encoding. The default encoding will be what *open* uses.

newline
[{None, str}, optional] Newline to use when reading text file.

Returns

out
[file object] File object.

class numpy.lib.npyio.**NpzFile**(*fid*)

A dictionary-like object with lazy-loading of files in the zipped archive provided on construction.

NpzFile is used to load files in the NumPy `.npz` data archive format. It assumes that files in the archive have a `.npy` extension, other files are ignored.

The arrays and file strings are lazily loaded on either getitem access using `obj['key']` or attribute lookup using `obj.f.key`. A list of all files (without `.npy` extensions) can be obtained with `obj.files` and the ZipFile object itself using `obj.zip`.

Parameters

fid
[file, str, or pathlib.Path] The zipped archive to open. This is either a file-like object or a string containing the path to the archive.

own_fid
[bool, optional] Whether NpzFile should close the file handle. Requires that `fid` is a file-like object.

Examples

```
>>> import numpy as np
>>> from tempfile import TemporaryFile
>>> outfile = TemporaryFile()
>>> x = np.arange(10)
>>> y = np.sin(x)
>>> np.savez(outfile, x=x, y=y)
>>> _ = outfile.seek(0)
```

```
>>> npz = np.load(outfile)
>>> isinstance(npz, np.lib.npyio.NpzFile)
True
>>> npz
NpzFile 'object' with keys: x, y
>>> sorted(npz.files)
['x', 'y']
>>> npz['x']  # getitem access
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> npz.f.x  # attribute lookup
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

Attributes

files
[list of str] List of all files in the archive with a `.npy` extension.

zip
[ZipFile instance] The ZipFile object initialized with the zipped archive.

f
[BagObj instance] An object on which attribute can be performed as an alternative to getitem access on the *NpzFile* instance itself.

allow_pickle
[bool, optional] Allow loading pickled data. Default: False

pickle_kwargs
: [dict, optional] Additional keyword arguments to pass on to pickle.load. These are only useful when loading object arrays saved on Python 2 when using Python 3.

max_header_size
: [int, optional] Maximum allowed size of the header. Large headers may not be safe to load securely and thus require explicitly passing a larger value. See `ast.literal_eval` for details. This option is ignored when *allow_pickle* is passed. In that case the file is by definition trusted and the limit is unnecessary.

Methods

close()	Close the file.
get(key[, default])	D.get(k,[,d]) returns D[k] if k in D, else d.
items()	D.items() returns a set-like object providing a view on the items
keys()	D.keys() returns a set-like object providing a view on the keys
values()	D.values() returns a set-like object providing a view on the values

method

lib.npyio.NpzFile.**close**()
: Close the file.

method

lib.npyio.NpzFile.**get**(*key*, *default=None*, */*)
: D.get(k,[,d]) returns D[k] if k in D, else d. d defaults to None.

method

lib.npyio.NpzFile.**items**()
: D.items() returns a set-like object providing a view on the items

method

lib.npyio.NpzFile.**keys**()
: D.keys() returns a set-like object providing a view on the keys

method

lib.npyio.NpzFile.**values**()
: D.values() returns a set-like object providing a view on the values

Wrapper functions to more user-friendly calling of certain math functions whose output data-type is different than the input data-type in certain domains of the input.

For example, for functions like *log* with branch cuts, the versions in this module provide the mathematically valid answers in the complex plane:

```
>>> import math
>>> np.emath.log(-math.exp(1)) == (1+1j*math.pi)
True
```

Similarly, *sqrt*, other base logarithms, *power* and trig functions are correctly handled. See their respective docstrings for specific examples.

Functions

arccos(x)	Compute the inverse cosine of x.
arcsin(x)	Compute the inverse sine of x.
arctanh(x)	Compute the inverse hyperbolic tangent of *x*.
log(x)	Compute the natural logarithm of *x*.
log10(x)	Compute the logarithm base 10 of *x*.
log2(x)	Compute the logarithm base 2 of *x*.
logn(n, x)	Take log base n of x.
power(x, p)	Return x to the power p, (x**p).
sqrt(x)	Compute the square root of x.

lib.scimath.**arccos**(*x*)

Compute the inverse cosine of x.

Return the "principal value" (for a description of this, see *numpy.arccos*) of the inverse cosine of *x*. For real *x* such that *abs(x)* <= *1*, this is a real number in the closed interval $[0, \pi]$. Otherwise, the complex principle value is returned.

Parameters

x
[array_like or scalar] The value(s) whose arccos is (are) required.

Returns

out
[ndarray or scalar] The inverse cosine(s) of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array object is returned.

See also:

numpy.arccos

Notes

For an arccos() that returns NAN when real *x* is not in the interval `[-1,1]`, use *numpy.arccos*.

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.arccos(1) # a scalar is returned
0.0
```

```
>>> np.emath.arccos([1,2])
array([0.-0.j   , 0.-1.317j])
```

lib.scimath.**arcsin**(*x*)

Compute the inverse sine of x.

Return the "principal value" (for a description of this, see *numpy.arcsin*) of the inverse sine of *x*. For real *x* such that *abs(x)* <= *1*, this is a real number in the closed interval $[-\pi/2, \pi/2]$. Otherwise, the complex principle value is returned.

Parameters

x
[array_like or scalar] The value(s) whose arcsin is (are) required.

Returns

out
[ndarray or scalar] The inverse sine(s) of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array object is returned.

See also:

numpy.arcsin

Notes

For an arcsin() that returns NAN when real *x* is not in the interval `[-1,1]`, use *numpy.arcsin*.

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.arcsin(0)
0.0
```

```
>>> np.emath.arcsin([0,1])
array([0.    , 1.5708])
```

lib.scimath.**arctanh**(*x*)

Compute the inverse hyperbolic tangent of *x*.

Return the "principal value" (for a description of this, see *numpy.arctanh*) of `arctanh(x)`. For real *x* such that `abs(x) < 1`, this is a real number. If *abs(x)* > *1*, or if *x* is complex, the result is complex. Finally, *x* = *1* returns``inf`` and `x=-1` returns `-inf`.

Parameters

x
[array_like] The value(s) whose arctanh is (are) required.

Returns

out
[ndarray or scalar] The inverse hyperbolic tangent(s) of the *x* value(s). If *x* was a scalar so is *out*, otherwise an array is returned.

See also:

numpy.arctanh

Notes

For an arctanh() that returns NAN when real *x* is not in the interval `(-1,1)`, use *numpy.arctanh* (this latter, however, does return +/-inf for `x = +/-1`).

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.arctanh(0.5)
0.5493061443340549
```

```
>>> from numpy.testing import suppress_warnings
>>> with suppress_warnings() as sup:
...     sup.filter(RuntimeWarning)
...     np.emath.arctanh(np.eye(2))
array([[inf,  0.],
       [ 0., inf]])
>>> np.emath.arctanh([1j])
array([0.+0.7854j])
```

`lib.scimath.`**`log`**`(x)`

Compute the natural logarithm of *x*.

Return the "principal value" (for a description of this, see *numpy.log*) of $log_e(x)$. For real $x > 0$, this is a real number (`log(0)` returns `-inf` and `log(np.inf)` returns `inf`). Otherwise, the complex principle value is returned.

Parameters

x
: [array_like] The value(s) whose log is (are) required.

Returns

out
: [ndarray or scalar] The log of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array is returned.

See also:

numpy.log

Notes

For a log() that returns NAN when real $x < 0$, use *numpy.log* (note, however, that otherwise *numpy.log* and this *log* are identical, i.e., both return `-inf` for $x = 0$, `inf` for $x = inf$, and, notably, the complex principle value if `x.imag != 0`).

Examples

```
>>> import numpy as np
>>> np.emath.log(np.exp(1))
1.0
```

Negative arguments are handled "correctly" (recall that `exp(log(x)) == x` does *not* hold for real `x < 0`):

```
>>> np.emath.log(-np.exp(1)) == (1 + np.pi * 1j)
True
```

lib.scimath.**log10**(*x*)

Compute the logarithm base 10 of *x*.

Return the "principal value" (for a description of this, see *numpy.log10*) of $log_{10}(x)$. For real $x > 0$, this is a real number (`log10(0)` returns `-inf` and `log10(np.inf)` returns `inf`). Otherwise, the complex principle value is returned.

Parameters

x
[array_like or scalar] The value(s) whose log base 10 is (are) required.

Returns

out
[ndarray or scalar] The log base 10 of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array object is returned.

See also:

numpy.log10

Notes

For a log10() that returns `NAN` when real $x < 0$, use *numpy.log10* (note, however, that otherwise *numpy.log10* and this *log10* are identical, i.e., both return `-inf` for $x = 0$, `inf` for $x = inf$, and, notably, the complex principle value if `x.imag != 0`).

Examples

```
>>> import numpy as np
```

(We set the printing precision so the example can be auto-tested)

```
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.log10(10**1)
1.0
```

```
>>> np.emath.log10([-10**1, -10**2, 10**2])
array([1.+1.3644j, 2.+1.3644j, 2.+0.j    ])
```

lib.scimath.**log2**(*x*)

Compute the logarithm base 2 of *x*.

Return the "principal value" (for a description of this, see *numpy.log2*) of $log_2(x)$. For real $x > 0$, this is a real number (`log2(0)` returns `-inf` and `log2(np.inf)` returns `inf`). Otherwise, the complex principle value is returned.

Parameters

x
[array_like] The value(s) whose log base 2 is (are) required.

Returns

out
[ndarray or scalar] The log base 2 of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array is returned.

See also:

numpy.log2

Notes

For a log2() that returns `NAN` when real $x < 0$, use *numpy.log2* (note, however, that otherwise *numpy.log2* and this *log2* are identical, i.e., both return `-inf` for $x = 0$, `inf` for $x = inf$, and, notably, the complex principle value if `x.imag != 0`).

Examples

We set the printing precision so the example can be auto-tested:

```
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.log2(8)
3.0
>>> np.emath.log2([-4, -8, 8])
array([2.+4.5324j, 3.+4.5324j, 3.+0.j    ])
```

lib.scimath.**logn**(*n*, *x*)

Take log base n of x.

If *x* contains negative inputs, the answer is computed and returned in the complex domain.

Parameters

n
[array_like] The integer base(s) in which the log is taken.

x
[array_like] The value(s) whose log base *n* is (are) required.

Returns

out
[ndarray or scalar] The log base *n* of the *x* value(s). If *x* was a scalar, so is *out*, otherwise an array is returned.

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.logn(2, [4, 8])
array([2., 3.])
>>> np.emath.logn(2, [-4, -8, 8])
array([2.+4.5324j, 3.+4.5324j, 3.+0.j    ])
```

lib.scimath.**power**(*x*, *p*)

Return x to the power p, (x**p).

If *x* contains negative values, the output is converted to the complex domain.

Parameters

x

[array_like] The input value(s).

p

[array_like of ints] The power(s) to which *x* is raised. If *x* contains multiple values, *p* has to either be a scalar, or contain the same number of values as *x*. In the latter case, the result is `x[0]**p[0], x[1]**p[1], ...`.

Returns

out

[ndarray or scalar] The result of `x**p`. If *x* and *p* are scalars, so is *out*, otherwise an array is returned.

See also:

numpy.power

Examples

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
```

```
>>> np.emath.power(2, 2)
4
```

```
>>> np.emath.power([2, 4], 2)
array([ 4, 16])
```

```
>>> np.emath.power([2, 4], -2)
array([0.25  ,  0.0625])
```

```
>>> np.emath.power([-2, 4], 2)
array([ 4.-0.j, 16.+0.j])
```

```
>>> np.emath.power([2, 4], [2, 4])
array([ 4, 256])
```

lib.scimath.**sqrt**(*x*)

Compute the square root of x.

For negative input elements, a complex value is returned (unlike *numpy.sqrt* which returns NaN).

Parameters

x
[array_like] The input value(s).

Returns

out
[ndarray or scalar] The square root of *x*. If *x* was a scalar, so is *out*, otherwise an array is returned.

See also:

numpy.sqrt

Examples

For real, non-negative inputs this works just like *numpy.sqrt*:

```
>>> import numpy as np
```

```
>>> np.emath.sqrt(1)
1.0
>>> np.emath.sqrt([1, 4])
array([1.,  2.])
```

But it automatically handles negative inputs:

```
>>> np.emath.sqrt(-1)
1j
>>> np.emath.sqrt([-1,4])
array([0.+1.j, 2.+0.j])
```

Different results are expected because: floating point 0.0 and -0.0 are distinct.

For more control, explicitly use complex() as follows:

```
>>> np.emath.sqrt(complex(-4.0, 0.0))
2j
>>> np.emath.sqrt(complex(-4.0, -0.0))
-2j
```

Utilities that manipulate strides to achieve desirable effects.

An explanation of strides can be found in the *The N-dimensional array (ndarray)*.

Functions

as_strided(x[, shape, strides, subok, writeable])	Create a view into the array with the given shape and strides.
sliding_window_view(x, window_shape[, axis, ...])	Create a sliding window view into the array with the given window shape.

lib.stride_tricks.**as_strided**(*x*, *shape=None*, *strides=None*, *subok=False*, *writeable=True*)

Create a view into the array with the given shape and strides.

> **Warning:** This function has to be used with extreme care, see notes.

Parameters

x
[ndarray] Array to create a new.

shape
[sequence of int, optional] The shape of the new array. Defaults to `x.shape`.

strides
[sequence of int, optional] The strides of the new array. Defaults to `x.strides`.

subok
[bool, optional] If True, subclasses are preserved.

writeable
[bool, optional] If set to False, the returned array will always be readonly. Otherwise it will be writable if the original array was. It is advisable to set this to False if possible (see Notes).

Returns

view
[ndarray]

See also:

broadcast_to
broadcast an array to a given shape.

reshape
reshape an array.

lib.stride_tricks.sliding_window_view
userfriendly and safe function for a creation of sliding window views.

Notes

`as_strided` creates a view into the array given the exact strides and shape. This means it manipulates the internal data structure of ndarray and, if done incorrectly, the array elements can point to invalid memory and can corrupt results or crash your program. It is advisable to always use the original `x.strides` when calculating new strides to avoid reliance on a contiguous memory layout.

Furthermore, arrays created with this function often contain self overlapping memory, so that two elements are identical. Vectorized write operations on such arrays will typically be unpredictable. They may even give different results for small, large, or transposed arrays.

Since writing to these arrays has to be tested and done with great care, you may want to use `writeable=False` to avoid accidental write operations.

For these reasons it is advisable to avoid `as_strided` when possible.

`lib.stride_tricks.`**`sliding_window_view`**(*x*, *window_shape*, *axis=None*, ***, *subok=False*, *writeable=False*)

Create a sliding window view into the array with the given window shape.

Also known as rolling or moving window, the window slides across all dimensions of the array and extracts subsets of the array at all window positions.

New in version 1.20.0.

Parameters

x
[array_like] Array to create the sliding window view from.

window_shape
[int or tuple of int] Size of window over each axis that takes part in the sliding window. If *axis* is not present, must have same length as the number of input array dimensions. Single integers *i* are treated as if they were the tuple *(i,)*.

axis
[int or tuple of int, optional] Axis or axes along which the sliding window is applied. By default, the sliding window is applied to all axes and *window_shape[i]* will refer to axis *i* of *x*. If *axis* is given as a *tuple of int*, *window_shape[i]* will refer to the axis *axis[i]* of *x*. Single integers *i* are treated as if they were the tuple *(i,)*.

subok
[bool, optional] If True, sub-classes will be passed-through, otherwise the returned array will be forced to be a base-class array (default).

writeable
[bool, optional] When true, allow writing to the returned view. The default is false, as this should be used with caution: the returned view contains the same memory location multiple times, so writing to one location will cause others to change.

Returns

view
[ndarray] Sliding window view of the array. The sliding window dimensions are inserted at the end, and the original dimensions are trimmed as required by the size of the sliding window. That is, `view.shape = x_shape_trimmed + window_shape`, where `x_shape_trimmed` is `x.shape` with every entry reduced by one less than the corresponding window size.

See also:

lib.stride_tricks.as_strided
: A lower-level and less safe routine for creating arbitrary views from custom shape and strides.

broadcast_to
: broadcast an array to a given shape.

Notes

For many applications using a sliding window view can be convenient, but potentially very slow. Often specialized solutions exist, for example:

- `scipy.signal.fftconvolve`
- filtering functions in `scipy.ndimage`
- moving window functions provided by bottleneck.

As a rough estimate, a sliding window approach with an input size of *N* and a window size of *W* will scale as *O(N*W)* where frequently a special algorithm can achieve *O(N)*. That means that the sliding window variant for a window size of 100 can be a 100 times slower than a more specialized version.

Nevertheless, for small window sizes, when no custom algorithm exists, or as a prototyping and developing tool, this function can be a good solution.

Examples

```
>>> import numpy as np
>>> from numpy.lib.stride_tricks import sliding_window_view
>>> x = np.arange(6)
>>> x.shape
(6,)
>>> v = sliding_window_view(x, 3)
>>> v.shape
(4, 3)
>>> v
array([[0, 1, 2],
       [1, 2, 3],
       [2, 3, 4],
       [3, 4, 5]])
```

This also works in more dimensions, e.g.

```
>>> i, j = np.ogrid[:3, :4]
>>> x = 10*i + j
>>> x.shape
(3, 4)
>>> x
array([[ 0,  1,  2,  3],
       [10, 11, 12, 13],
       [20, 21, 22, 23]])
>>> shape = (2,2)
>>> v = sliding_window_view(x, shape)
>>> v.shape
(2, 3, 2, 2)
>>> v
array([[[[ 0,  1],
         [10, 11]],
```

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```
        [[ 1,  2],
         [11, 12]],
        [[ 2,  3],
         [12, 13]]],
       [[[10, 11],
         [20, 21]],
        [[11, 12],
         [21, 22]],
        [[12, 13],
         [22, 23]]]])
```

The axis can be specified explicitly:

```
>>> v = sliding_window_view(x, 3, 0)
>>> v.shape
(1, 4, 3)
>>> v
array([[[ 0, 10, 20],
        [ 1, 11, 21],
        [ 2, 12, 22],
        [ 3, 13, 23]]])
```

The same axis can be used several times. In that case, every use reduces the corresponding original dimension:

```
>>> v = sliding_window_view(x, (2, 3), (1, 1))
>>> v.shape
(3, 1, 2, 3)
>>> v
array([[[[ 0,  1,  2],
         [ 1,  2,  3]]],
       [[[10, 11, 12],
         [11, 12, 13]]],
       [[[20, 21, 22],
         [21, 22, 23]]]])
```

Combining with stepped slicing (*::step*), this can be used to take sliding views which skip elements:

```
>>> x = np.arange(7)
>>> sliding_window_view(x, 5)[:, ::2]
array([[0, 2, 4],
       [1, 3, 5],
       [2, 4, 6]])
```

or views which move by multiple elements

```
>>> x = np.arange(7)
>>> sliding_window_view(x, 3)[::2, :]
array([[0, 1, 2],
       [2, 3, 4],
       [4, 5, 6]])
```

A common application of `sliding_window_view` is the calculation of running statistics. The simplest example is the moving average:

```
>>> x = np.arange(6)
>>> x.shape
```

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```
(6,)
>>> v = sliding_window_view(x, 3)
>>> v.shape
(4, 3)
>>> v
array([[0, 1, 2],
       [1, 2, 3],
       [2, 3, 4],
       [3, 4, 5]])
>>> moving_average = v.mean(axis=-1)
>>> moving_average
array([1., 2., 3., 4.])
```

Note that a sliding window approach is often **not** optimal (see Notes).

Record Arrays (`numpy.rec`)

Record arrays expose the fields of structured arrays as properties.

Most commonly, ndarrays contain elements of a single type, e.g. floats, integers, bools etc. However, it is possible for elements to be combinations of these using structured types, such as:

```
>>> import numpy as np
>>> a = np.array([(1, 2.0), (1, 2.0)],
...     dtype=[('x', np.int64), ('y', np.float64)])
>>> a
array([(1, 2.), (1, 2.)], dtype=[('x', '<i8'), ('y', '<f8')])
```

Here, each element consists of two fields: x (and int), and y (a float). This is known as a structured array. The different fields are analogous to columns in a spread-sheet. The different fields can be accessed as one would a dictionary:

```
>>> a['x']
array([1, 1])
```

```
>>> a['y']
array([2., 2.])
```

Record arrays allow us to access fields as properties:

```
>>> ar = np.rec.array(a)
>>> ar.x
array([1, 1])
>>> ar.y
array([2., 2.])
```

Functions

array(obj[, dtype, shape, offset, strides, ...])	Construct a record array from a wide-variety of objects.
find_duplicate(list)	Find duplication in a list, return a list of duplicated elements
format_parser(formats, names, titles[, ...])	Class to convert formats, names, titles description to a dtype.
fromarrays(arrayList[, dtype, shape, ...])	Create a record array from a (flat) list of arrays
fromfile(fd[, dtype, shape, offset, ...])	Create an array from binary file data
fromrecords(recList[, dtype, shape, ...])	Create a recarray from a list of records in text form.
fromstring(datastring[, dtype, shape, ...])	Create a record array from binary data

rec.**array**(*obj*, *dtype=None*, *shape=None*, *offset=0*, *strides=None*, *formats=None*, *names=None*, *titles=None*, *aligned=False*, *byteorder=None*, *copy=True*)

Construct a record array from a wide-variety of objects.

A general-purpose record array constructor that dispatches to the appropriate *recarray* creation function based on the inputs (see Notes).

Parameters

obj
[any] Input object. See Notes for details on how various input types are treated.

dtype
[data-type, optional] Valid dtype for array.

shape
[int or tuple of ints, optional] Shape of each array.

offset
[int, optional] Position in the file or buffer to start reading from.

strides
[tuple of ints, optional] Buffer (*buf*) is interpreted according to these strides (strides define how many bytes each array element, row, column, etc. occupy in memory).

formats, names, titles, aligned, byteorder
If *dtype* is `None`, these arguments are passed to *numpy.format_parser* to construct a dtype. See that function for detailed documentation.

copy
[bool, optional] Whether to copy the input object (True), or to use a reference instead. This option only applies when the input is an ndarray or recarray. Defaults to True.

Returns

np.recarray
Record array created from the specified object.

Notes

If *obj* is `None`, then call the *recarray* constructor. If *obj* is a string, then call the *fromstring* constructor. If *obj* is a list or a tuple, then if the first object is an *ndarray*, call *fromarrays*, otherwise call *fromrecords*. If *obj* is a *recarray*, then make a copy of the data in the recarray (if `copy=True`) and use the new formats, names, and titles. If *obj* is a file, then call *fromfile*. Finally, if obj is an *ndarray*, then return `obj.view(recarray)`, making a copy of the data if `copy=True`.

Examples

```
>>> a = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
>>> a
array([[1, 2, 3],
       [4, 5, 6],
       [7, 8, 9]])
```

```
>>> np.rec.array(a)
rec.array([[1, 2, 3],
           [4, 5, 6],
           [7, 8, 9]],
          dtype=int64)
```

```
>>> b = [(1, 1), (2, 4), (3, 9)]
>>> c = np.rec.array(b, formats = ['i2', 'f2'], names = ('x', 'y'))
>>> c
rec.array([(1, 1.), (2, 4.), (3, 9.)],
          dtype=[('x', '<i2'), ('y', '<f2')])
```

```
>>> c.x
array([1, 2, 3], dtype=int16)
```

```
>>> c.y
array([1.,  4.,  9.], dtype=float16)
```

```
>>> r = np.rec.array(['abc','def'], names=['col1','col2'])
>>> print(r.col1)
abc
```

```
>>> r.col1
array('abc', dtype='<U3')
```

```
>>> r.col2
array('def', dtype='<U3')
```

`rec.`**`find_duplicate`**(*list*)

Find duplication in a list, return a list of duplicated elements

`class` `numpy.rec.`**`format_parser`**(*formats*, *names*, *titles*, *aligned=False*, *byteorder=None*)

Class to convert formats, names, titles description to a dtype.

After constructing the format_parser object, the dtype attribute is the converted data-type: `dtype = format_parser(formats, names, titles).dtype`

Parameters

formats
[str or list of str] The format description, either specified as a string with comma-separated format descriptions in the form `'f8, i4, S5'`, or a list of format description strings in the form `['f8', 'i4', 'S5']`.

names
[str or list/tuple of str] The field names, either specified as a comma-separated string in the form `'col1, col2, col3'`, or as a list or tuple of strings in the form `['col1', 'col2', 'col3']`. An empty list can be used, in that case default field names ('f0', 'f1', …) are used.

titles
[sequence] Sequence of title strings. An empty list can be used to leave titles out.

aligned
[bool, optional] If True, align the fields by padding as the C-compiler would. Default is False.

byteorder
[str, optional] If specified, all the fields will be changed to the provided byte-order. Otherwise, the default byte-order is used. For all available string specifiers, see *dtype.newbyteorder*.

See also:

numpy.dtype*, *numpy.typename

Examples

```
>>> import numpy as np
>>> np.rec.format_parser(['<f8', '<i4'], ['col1', 'col2'],
...                      ['T1', 'T2']).dtype
dtype([(('T1', 'col1'), '<f8'), (('T2', 'col2'), '<i4')])
```

names and/or *titles* can be empty lists. If *titles* is an empty list, titles will simply not appear. If *names* is empty, default field names will be used.

```
>>> np.rec.format_parser(['f8', 'i4', 'a5'], ['col1', 'col2', 'col3'],
...                      []).dtype
dtype([('col1', '<f8'), ('col2', '<i4'), ('col3', '<S5')])
>>> np.rec.format_parser(['<f8', '<i4', '<a5'], [], []).dtype
dtype([('f0', '<f8'), ('f1', '<i4'), ('f2', 'S5')])
```

Attributes

dtype
[dtype] The converted data-type.

`rec.`**`fromarrays`**(*arrayList*, *dtype=None*, *shape=None*, *formats=None*, *names=None*, *titles=None*, *aligned=False*, *byteorder=None*)

Create a record array from a (flat) list of arrays

Parameters

arrayList
[list or tuple] List of array-like objects (such as lists, tuples, and ndarrays).

dtype
[data-type, optional] valid dtype for all arrays

shape
: [int or tuple of ints, optional] Shape of the resulting array. If not provided, inferred from `arrayList[0]`.

formats, names, titles, aligned, byteorder
: If *dtype* is `None`, these arguments are passed to *numpy.rec.format_parser* to construct a dtype. See that function for detailed documentation.

Returns

np.recarray
: Record array consisting of given arrayList columns.

Examples

```
>>> x1=np.array([1,2,3,4])
>>> x2=np.array(['a','dd','xyz','12'])
>>> x3=np.array([1.1,2,3,4])
>>> r = np.rec.fromarrays([x1,x2,x3],names='a,b,c')
>>> print(r[1])
(2, 'dd', 2.0) # may vary
>>> x1[1]=34
>>> r.a
array([1, 2, 3, 4])
```

```
>>> x1 = np.array([1, 2, 3, 4])
>>> x2 = np.array(['a', 'dd', 'xyz', '12'])
>>> x3 = np.array([1.1, 2, 3,4])
>>> r = np.rec.fromarrays(
...     [x1, x2, x3],
...     dtype=np.dtype([('a', np.int32), ('b', 'S3'), ('c', np.float32)]))
>>> r
rec.array([(1, b'a', 1.1), (2, b'dd', 2. ), (3, b'xyz', 3. ),
           (4, b'12', 4. )],
          dtype=[('a', '<i4'), ('b', 'S3'), ('c', '<f4')])
```

`rec.`**`fromfile`**(*fd*, *dtype=None*, *shape=None*, *offset=0*, *formats=None*, *names=None*, *titles=None*, *aligned=False*, *byteorder=None*)

Create an array from binary file data

Parameters

fd
: [str or file type] If file is a string or a path-like object then that file is opened, else it is assumed to be a file object. The file object must support random access (i.e. it must have tell and seek methods).

dtype
: [data-type, optional] valid dtype for all arrays

shape
: [int or tuple of ints, optional] shape of each array.

offset
: [int, optional] Position in the file to start reading from.

formats, names, titles, aligned, byteorder
: If *dtype* is `None`, these arguments are passed to *numpy.format_parser* to construct a dtype. See that function for detailed documentation

Returns

np.recarray
record array consisting of data enclosed in file.

Examples

```
>>> from tempfile import TemporaryFile
>>> a = np.empty(10,dtype='f8,i4,a5')
>>> a[5] = (0.5,10,'abcde')
>>>
>>> fd=TemporaryFile()
>>> a = a.view(a.dtype.newbyteorder('<'))
>>> a.tofile(fd)
>>>
>>> _ = fd.seek(0)
>>> r=np.rec.fromfile(fd, formats='f8,i4,a5', shape=10,
... byteorder='<')
>>> print(r[5])
(0.5, 10, b'abcde')
>>> r.shape
(10,)
```

`rec.`**`fromrecords`**(*recList*, *dtype=None*, *shape=None*, *formats=None*, *names=None*, *titles=None*, *aligned=False*, *byteorder=None*)

Create a recarray from a list of records in text form.

Parameters

recList
[sequence] data in the same field may be heterogeneous - they will be promoted to the highest data type.

dtype
[data-type, optional] valid dtype for all arrays

shape
[int or tuple of ints, optional] shape of each array.

formats, names, titles, aligned, byteorder
If `dtype` is `None`, these arguments are passed to *numpy.format_parser* to construct a dtype. See that function for detailed documentation.

If both *formats* and `dtype` are None, then this will auto-detect formats. Use list of tuples rather than list of lists for faster processing.

Returns

np.recarray
record array consisting of given recList rows.

Examples

```
>>> r=np.rec.fromrecords([(456,'dbe',1.2),(2,'de',1.3)],
... names='col1,col2,col3')
>>> print(r[0])
(456, 'dbe', 1.2)
>>> r.col1
array([456,   2])
>>> r.col2
array(['dbe', 'de'], dtype='<U3')
>>> import pickle
>>> pickle.loads(pickle.dumps(r))
rec.array([(456, 'dbe', 1.2), (  2, 'de', 1.3)],
          dtype=[('col1', '<i8'), ('col2', '<U3'), ('col3', '<f8')])
```

rec.**fromstring**(*datastring*, *dtype=None*, *shape=None*, *offset=0*, *formats=None*, *names=None*, *titles=None*, *aligned=False*, *byteorder=None*)

Create a record array from binary data

Note that despite the name of this function it does not accept *str* instances.

Parameters

datastring
: [bytes-like] Buffer of binary data

dtype
: [data-type, optional] Valid dtype for all arrays

shape
: [int or tuple of ints, optional] Shape of each array.

offset
: [int, optional] Position in the buffer to start reading from.

formats, names, titles, aligned, byteorder
: If `dtype` is `None`, these arguments are passed to *numpy.format_parser* to construct a dtype. See that function for detailed documentation.

Returns

np.recarray
: Record array view into the data in datastring. This will be readonly if *datastring* is readonly.

See also:

numpy.frombuffer

Examples

```
>>> a = b'\x01\x02\x03abc'
>>> np.rec.fromstring(a, dtype='u1,u1,u1,S3')
rec.array([(1, 2, 3, b'abc')],
        dtype=[('f0', 'u1'), ('f1', 'u1'), ('f2', 'u1'), ('f3', 'S3')])
```

```
>>> grades_dtype = [('Name', (np.str_, 10)), ('Marks', np.float64),
...                 ('GradeLevel', np.int32)]
>>> grades_array = np.array([('Sam', 33.3, 3), ('Mike', 44.4, 5),
```

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```
...                           ('Aadi', 66.6, 6)], dtype=grades_dtype)
>>> np.rec.fromstring(grades_array.tobytes(), dtype=grades_dtype)
rec.array([('Sam', 33.3, 3), ('Mike', 44.4, 5), ('Aadi', 66.6, 6)],
          dtype=[('Name', '<U10'), ('Marks', '<f8'), ('GradeLevel', '<i4')])
```

```
>>> s = '\x01\x02\x03abc'
>>> np.rec.fromstring(s, dtype='u1,u1,u1,S3')
Traceback (most recent call last):
   ...
TypeError: a bytes-like object is required, not 'str'
```

Also, the *numpy.recarray* class and the *numpy.record* scalar dtype are present in this namespace.

Version information

The `numpy.version` submodule includes several constants that expose more detailed information about the exact version of the installed `numpy` package:

`numpy.version.`**`version`**

Version string for the installed package - matches `numpy.__version__`.

`numpy.version.`**`full_version`**

Version string - the same as `numpy.version.version`.

`numpy.version.`**`short_version`**

Version string without any local build identifiers.

Examples

```
>>> np.__version__
'2.1.0.dev0+git20240319.2ea7ce0'  # may vary
>>> np.version.short_version
'2.1.0.dev0'  # may vary
```

`numpy.version.`**`git_revision`**

String containing the git hash of the commit from which `numpy` was built.

`numpy.version.`**`release`**

`True` if this version is a `numpy` release, `False` if a dev version.

Legacy fixed-width string functionality

Legacy

This submodule is considered legacy and will no longer receive updates. This could also mean it will be removed in future NumPy versions. The string operations in this module, as well as the *numpy.char.chararray* class, are planned to be deprecated in the future. Use *numpy.strings* instead.

The *numpy.char* module provides a set of vectorized string operations for arrays of type *numpy.str_* or *numpy.bytes_*. For example

```
>>> import numpy as np
>>> np.char.capitalize(["python", "numpy"])
array(['Python', 'Numpy'], dtype='<U6')
>>> np.char.add(["num", "doc"], ["py", "umentation"])
array(['numpy', 'documentation'], dtype='<U13')
```

The methods in this module are based on the methods in `string`

String operations

add(x1, x2, /[, out, where, casting, order, ...])	Add arguments element-wise.
multiply(a, i)	Return (a * i), that is string multiple concatenation, element-wise.
mod(a, values)	Return (a % i), that is pre-Python 2.6 string formatting (interpolation), element-wise for a pair of array_likes of str or unicode.
capitalize(a)	Return a copy of `a` with only the first character of each element capitalized.
center(a, width[, fillchar])	Return a copy of *a* with its elements centered in a string of length *width*.
decode(a[, encoding, errors])	Calls `bytes.decode` element-wise.
encode(a[, encoding, errors])	Calls `str.encode` element-wise.
expandtabs(a[, tabsize])	Return a copy of each string element where all tab characters are replaced by one or more spaces.
join(sep, seq)	Return a string which is the concatenation of the strings in the sequence *seq*.
ljust(a, width[, fillchar])	Return an array with the elements of *a* left-justified in a string of length *width*.
lower(a)	Return an array with the elements converted to lowercase.
lstrip(a[, chars])	For each element in *a*, return a copy with the leading characters removed.
partition(a, sep)	Partition each element in *a* around *sep*.
replace(a, old, new[, count])	For each element in `a`, return a copy of the string with occurrences of substring `old` replaced by `new`.
rjust(a, width[, fillchar])	Return an array with the elements of *a* right-justified in a string of length *width*.
rpartition(a, sep)	Partition (split) each element around the right-most separator.
rsplit(a[, sep, maxsplit])	For each element in *a*, return a list of the words in the string, using *sep* as the delimiter string.
rstrip(a[, chars])	For each element in *a*, return a copy with the trailing characters removed.
split(a[, sep, maxsplit])	For each element in *a*, return a list of the words in the string, using *sep* as the delimiter string.
splitlines(a[, keepends])	For each element in *a*, return a list of the lines in the element, breaking at line boundaries.
strip(a[, chars])	For each element in *a*, return a copy with the leading and trailing characters removed.
swapcase(a)	Return element-wise a copy of the string with uppercase characters converted to lowercase and vice versa.
title(a)	Return element-wise title cased version of string or unicode.
translate(a, table[, deletechars])	For each element in *a*, return a copy of the string where all characters occurring in the optional argument *deletechars* are removed, and the remaining characters have been mapped through the given translation table.
upper(a)	Return an array with the elements converted to uppercase.
zfill(a, width)	Return the numeric string left-filled with zeros.

`char.add`(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'add'>**

Add arguments element-wise.

Parameters

x1, x2
[array_like] The arrays to be added. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

add
[ndarray or scalar] The sum of *x1* and *x2*, element-wise. This is a scalar if both *x1* and *x2* are scalars.

Notes

Equivalent to *x1* + *x2* in terms of array broadcasting.

Examples

```
>>> import numpy as np
>>> np.add(1.0, 4.0)
5.0
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> np.add(x1, x2)
array([[  0.,   2.,   4.],
       [  3.,   5.,   7.],
       [  6.,   8.,  10.]])
```

The + operator can be used as a shorthand for `np.add` on ndarrays.

```
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> x1 + x2
array([[ 0.,  2.,  4.],
       [ 3.,  5.,  7.],
       [ 6.,  8., 10.]])
```

`char.`**`multiply`**(*a*, *i*)

Return (a * i), that is string multiple concatenation, element-wise.

Values in `i` of less than 0 are treated as 0 (which yields an empty string).

Parameters

a
[array_like, with *np.bytes_* or *np.str_* dtype]

i
[array_like, with any integer dtype]

Returns

out
[ndarray] Output array of str or unicode, depending on input types

Notes

This is a thin wrapper around np.strings.multiply that raises *ValueError* when `i` is not an integer. It only exists for backwards-compatibility.

Examples

```
>>> import numpy as np
>>> a = np.array(["a", "b", "c"])
>>> np.strings.multiply(a, 3)
array(['aaa', 'bbb', 'ccc'], dtype='<U3')
>>> i = np.array([1, 2, 3])
>>> np.strings.multiply(a, i)
array(['a', 'bb', 'ccc'], dtype='<U3')
>>> np.strings.multiply(np.array(['a']), i)
array(['a', 'aa', 'aaa'], dtype='<U3')
>>> a = np.array(['a', 'b', 'c', 'd', 'e', 'f']).reshape((2, 3))
>>> np.strings.multiply(a, 3)
array([['aaa', 'bbb', 'ccc'],
       ['ddd', 'eee', 'fff']], dtype='<U3')
>>> np.strings.multiply(a, i)
array([['a', 'bb', 'ccc'],
       ['d', 'ee', 'fff']], dtype='<U3')
```

`char.`**`mod`**(*a*, *values*)

Return (a % i), that is pre-Python 2.6 string formatting (interpolation), element-wise for a pair of array_likes of str or unicode.

Parameters

a
[array_like, with *np.bytes_* or *np.str_* dtype]

values
[array_like of values] These values will be element-wise interpolated into the string.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

Examples

```
>>> import numpy as np
>>> a = np.array(["NumPy is a %s library"])
>>> np.strings.mod(a, values=["Python"])
array(['NumPy is a Python library'], dtype='<U25')
```

```
>>> a = np.array([b'%d bytes', b'%d bits'])
>>> values = np.array([8, 64])
>>> np.strings.mod(a, values)
array([b'8 bytes', b'64 bits'], dtype='|S7')
```

char.**capitalize**(*a*)

Return a copy of `a` with only the first character of each element capitalized.

Calls `str.capitalize` element-wise.

For byte strings, this method is locale-dependent.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array of strings to capitalize.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

str.capitalize

Examples

```
>>> import numpy as np
>>> c = np.array(['a1b2','1b2a','b2a1','2a1b'],'S4'); c
array(['a1b2', '1b2a', 'b2a1', '2a1b'],
    dtype='|S4')
>>> np.strings.capitalize(c)
array(['A1b2', '1b2a', 'B2a1', '2a1b'],
    dtype='|S4')
```

char.**center**(*a*, *width*, *fillchar=' '*)

Return a copy of *a* with its elements centered in a string of length *width*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

width
[array_like, with any integer dtype] The length of the resulting strings, unless `width < str_len(a)`.

fillchar
: [array-like, with `StringDType`, `bytes_`, or `str_` dtype] Optional padding character to use (default is space).

Returns

out
: [ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.center`

Notes

While it is possible for `a` and `fillchar` to have different dtypes, passing a non-ASCII character in `fillchar` when `a` is of dtype "S" is not allowed, and a `ValueError` is raised.

Examples

```
>>> import numpy as np
>>> c = np.array(['a1b2','1b2a','b2a1','2a1b']); c
array(['a1b2', '1b2a', 'b2a1', '2a1b'], dtype='<U4')
>>> np.strings.center(c, width=9)
array(['   a1b2  ', '   1b2a  ', '   b2a1  ', '   2a1b  '], dtype='<U9')
>>> np.strings.center(c, width=9, fillchar='*')
array(['***a1b2**', '***1b2a**', '***b2a1**', '***2a1b**'], dtype='<U9')
>>> np.strings.center(c, width=1)
array(['a1b2', '1b2a', 'b2a1', '2a1b'], dtype='<U4')
```

`char.`**`decode`**(*a*, *encoding=None*, *errors=None*)

Calls `bytes.decode` element-wise.

The set of available codecs comes from the Python standard library, and may be extended at runtime. For more information, see the `codecs` module.

Parameters

a
: [array_like, with `bytes_` dtype]

encoding
: [str, optional] The name of an encoding

errors
: [str, optional] Specifies how to handle encoding errors

Returns

out
: [ndarray]

See also:

`bytes.decode`

Notes

The type of the result will depend on the encoding specified.

Examples

```
>>> import numpy as np
>>> c = np.array([b'\x81\xc1\x81\xc1\x81\xc1', b'@@\x81\xc1@@',
...               b'\x81\x82\xc2\xc1\xc2\x82\x81'])
>>> c
array([b'\x81\xc1\x81\xc1\x81\xc1', b'@@\x81\xc1@@',
       b'\x81\x82\xc2\xc1\xc2\x82\x81'], dtype='|S7')
>>> np.strings.decode(c, encoding='cp037')
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
```

`char.`**`encode`**(*a*, *encoding=None*, *errors=None*)

Calls `str.encode` element-wise.

The set of available codecs comes from the Python standard library, and may be extended at runtime. For more information, see the `codecs` module.

Parameters

a
[array_like, with `StringDType` or `str_` dtype]

encoding
[str, optional] The name of an encoding

errors
[str, optional] Specifies how to handle encoding errors

Returns

out
[ndarray]

See also:

`str.encode`

Notes

The type of the result will depend on the encoding specified.

Examples

```
>>> import numpy as np
>>> a = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> np.strings.encode(a, encoding='cp037')
array([b'\x81\xc1\x81\xc1\x81\xc1', b'@@\x81\xc1@@',
   b'\x81\x82\xc2\xc1\xc2\x82\x81'], dtype='|S7')
```

char.**expandtabs**(*a*, *tabsize=8*)

Return a copy of each string element where all tab characters are replaced by one or more spaces.

Calls str.expandtabs element-wise.

Return a copy of each string element where all tab characters are replaced by one or more spaces, depending on the current column and the given *tabsize*. The column number is reset to zero after each newline occurring in the string. This doesn't understand other non-printing characters or escape sequences.

Parameters

a
[array-like, with StringDType, bytes_, or str_ dtype] Input array

tabsize
[int, optional] Replace tabs with *tabsize* number of spaces. If not given defaults to 8 spaces.

Returns

out
[ndarray] Output array of StringDType, bytes_ or str_ dtype, depending on input type

See also:

str.expandtabs

Examples

```
>>> import numpy as np
>>> a = np.array(['         Hello   world'])
>>> np.strings.expandtabs(a, tabsize=4)
array(['        Hello   world'], dtype='<U21')
```

char.**join**(*sep*, *seq*)

Return a string which is the concatenation of the strings in the sequence *seq*.

Calls str.join element-wise.

Parameters

sep
[array-like, with StringDType, bytes_, or str_ dtype]

seq
[array-like, with StringDType, bytes_, or str_ dtype]

Returns

out
[ndarray] Output array of StringDType, bytes_ or str_ dtype, depending on input types

See also:

str.join

Examples

```
>>> import numpy as np
>>> np.strings.join('-', 'osd')
array('o-s-d', dtype='<U5')
```

```
>>> np.strings.join(['-', '.'], ['ghc', 'osd'])
array(['g-h-c', 'o.s.d'], dtype='<U5')
```

char.**ljust**(*a*, *width*, *fillchar=' '*)

Return an array with the elements of *a* left-justified in a string of length *width*.

Parameters

a
[array-like, with StringDType, bytes_, or str_ dtype]

width
[array_like, with any integer dtype] The length of the resulting strings, unless width < str_len(a).

fillchar
[array-like, with StringDType, bytes_, or str_ dtype] Optional character to use for padding (default is space).

Returns

out
[ndarray] Output array of StringDType, bytes_ or str_ dtype, depending on input types

See also:

str.ljust

Notes

While it is possible for a and fillchar to have different dtypes, passing a non-ASCII character in fillchar when a is of dtype "S" is not allowed, and a ValueError is raised.

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> np.strings.ljust(c, width=3)
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> np.strings.ljust(c, width=9)
array(['aAaAaA   ', '  aA     ', 'abBABba  '], dtype='<U9')
```

char.**lower**(*a*)

Return an array with the elements converted to lowercase.

Call str.lower element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.lower`

Examples

```
>>> import numpy as np
>>> c = np.array(['A1B C', '1BCA', 'BCA1']); c
array(['A1B C', '1BCA', 'BCA1'], dtype='<U5')
>>> np.strings.lower(c)
array(['a1b c', '1bca', 'bca1'], dtype='<U5')
```

`char.`**`lstrip`**(*a*, *chars=None*)

For each element in *a*, return a copy with the leading characters removed.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

chars
[scalar with the same dtype as `a`, optional] The `chars` argument is a string specifying the set of characters to be removed. If `None`, the `chars` argument defaults to removing whitespace. The `chars` argument is not a prefix or suffix; rather, all combinations of its values are stripped.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.lstrip`

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> c
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
# The 'a' variable is unstripped from c[1] because of leading whitespace.
>>> np.strings.lstrip(c, 'a')
array(['AaAaA', '  aA  ', 'bBABba'], dtype='<U7')
>>> np.strings.lstrip(c, 'A') # leaves c unchanged
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> (np.strings.lstrip(c, ' ') == np.strings.lstrip(c, '')).all()
np.False_
```

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```
>>> (np.strings.lstrip(c, ' ') == np.strings.lstrip(c)).all()
np.True_
```

char.**partition**(*a*, *sep*)

Partition each element in *a* around *sep*.

Calls `str.partition` element-wise.

For each element in *a*, split the element as the first occurrence of *sep*, and return 3 strings containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return 3 strings containing the string itself, followed by two empty strings.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array

sep
[{str, unicode}] Separator to split each string element in *a*.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types. The output array will have an extra dimension with 3 elements per input element.

See also:

str.partition

Examples

```
>>> import numpy as np
>>> x = np.array(["Numpy is nice!"])
>>> np.char.partition(x, " ")
array([['Numpy', ' ', 'is nice!']], dtype='<U8')
```

char.**replace**(*a*, *old*, *new*, *count=-1*)

For each element in `a`, return a copy of the string with occurrences of substring `old` replaced by `new`.

Parameters

a
[array_like, with `bytes_` or `str_` dtype]

old, new
[array_like, with `bytes_` or `str_` dtype]

count
[array_like, with `int_` dtype] If the optional argument `count` is given, only the first `count` occurrences are replaced.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.replace`

Examples

```
>>> import numpy as np
>>> a = np.array(["That is a mango", "Monkeys eat mangos"])
>>> np.strings.replace(a, 'mango', 'banana')
array(['That is a banana', 'Monkeys eat bananas'], dtype='<U19')
```

```
>>> a = np.array(["The dish is fresh", "This is it"])
>>> np.strings.replace(a, 'is', 'was')
array(['The dwash was fresh', 'Thwas was it'], dtype='<U19')
```

char.**rjust**(*a*, *width*, *fillchar=' '*)

Return an array with the elements of *a* right-justified in a string of length *width*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

width
[array_like, with any integer dtype] The length of the resulting strings, unless `width < str_len(a)`.

fillchar
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Optional padding character to use (default is space).

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.rjust`

Notes

While it is possible for `a` and `fillchar` to have different dtypes, passing a non-ASCII character in `fillchar` when `a` is of dtype "S" is not allowed, and a `ValueError` is raised.

Examples

```
>>> import numpy as np
>>> a = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> np.strings.rjust(a, width=3)
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> np.strings.rjust(a, width=9)
array(['   aAaAaA', '     aA  ', '  abBABba'], dtype='<U9')
```

char.**rpartition**(*a*, *sep*)

Partition (split) each element around the right-most separator.

Calls `str.rpartition` element-wise.

For each element in *a*, split the element as the last occurrence of *sep*, and return 3 strings containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return 3 strings containing the string itself, followed by two empty strings.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array

sep
[str or unicode] Right-most separator to split each element in array.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types. The output array will have an extra dimension with 3 elements per input element.

See also:

`str.rpartition`

Examples

```
>>> import numpy as np
>>> a = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> np.char.rpartition(a, 'A')
array([['aAaAa', 'A', ''],
   ['  a', 'A', '  '],
   ['abB', 'A', 'Bba']], dtype='<U5')
```

char.**rsplit**(*a*, *sep=None*, *maxsplit=None*)

For each element in *a*, return a list of the words in the string, using *sep* as the delimiter string.

Calls `str.rsplit` element-wise.

Except for splitting from the right, *`rsplit`* behaves like *`split`*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

sep
[str or unicode, optional] If *sep* is not specified or None, any whitespace string is a separator.

maxsplit
[int, optional] If *maxsplit* is given, at most *maxsplit* splits are done, the rightmost ones.

Returns

out
[ndarray] Array of list objects

See also:

`str.rsplit`, ***`split`***

Examples

```
>>> import numpy as np
>>> a = np.array(['aAaAaA', 'abBABba'])
>>> np.strings.rsplit(a, 'A')
array([list(['a', 'a', 'a', '']),
       list(['abB', 'Bba'])], dtype=object)
```

char.**rstrip**(*a*, *chars=None*)

For each element in *a*, return a copy with the trailing characters removed.

Parameters

a
[array-like, with StringDType, bytes_, or str_ dtype]

chars
[scalar with the same dtype as a, optional] The chars argument is a string specifying the set of characters to be removed. If None, the chars argument defaults to removing whitespace. The chars argument is not a prefix or suffix; rather, all combinations of its values are stripped.

Returns

out
[ndarray] Output array of StringDType, bytes_ or str_ dtype, depending on input types

See also:

str.rstrip

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', 'abBABba'])
>>> c
array(['aAaAaA', 'abBABba'], dtype='<U7')
>>> np.strings.rstrip(c, 'a')
array(['aAaAaA', 'abBABb'], dtype='<U7')
>>> np.strings.rstrip(c, 'A')
array(['aAaAa', 'abBABba'], dtype='<U7')
```

char.**split**(*a*, *sep=None*, *maxsplit=None*)

For each element in *a*, return a list of the words in the string, using *sep* as the delimiter string.

Calls str.split element-wise.

Parameters

a
[array-like, with StringDType, bytes_, or str_ dtype]

sep
[str or unicode, optional] If *sep* is not specified or None, any whitespace string is a separator.

maxsplit
[int, optional] If *maxsplit* is given, at most *maxsplit* splits are done.

Returns

out
[ndarray] Array of list objects

See also:

`str.split`, *`rsplit`*

Examples

```
>>> import numpy as np
>>> x = np.array("Numpy is nice!")
>>> np.strings.split(x, " ")
array(list(['Numpy', 'is', 'nice!']), dtype=object)
```

```
>>> np.strings.split(x, " ", 1)
array(list(['Numpy', 'is nice!']), dtype=object)
```

`char.`**`splitlines`**(*a*, *keepends=None*)

For each element in *a*, return a list of the lines in the element, breaking at line boundaries.

Calls `str.splitlines` element-wise.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

keepends
[bool, optional] Line breaks are not included in the resulting list unless keepends is given and true.

Returns

out
[ndarray] Array of list objects

See also:

`str.splitlines`

Examples

```
>>> np.char.splitlines("first line\nsecond line")
array(list(['first line', 'second line']), dtype=object)
>>> a = np.array(["first\nsecond", "third\nfourth"])
>>> np.char.splitlines(a)
array([list(['first', 'second']), list(['third', 'fourth'])], dtype=object)
```

`char.`**`strip`**(*a*, *chars=None*)

For each element in *a*, return a copy with the leading and trailing characters removed.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

chars
: [scalar with the same dtype as `a`, optional] The `chars` argument is a string specifying the set of characters to be removed. If `None`, the `chars` argument defaults to removing whitespace. The `chars` argument is not a prefix or suffix; rather, all combinations of its values are stripped.

Returns

out
: [ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.strip`

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> c
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> np.strings.strip(c)
array(['aAaAaA', 'aA', 'abBABba'], dtype='<U7')
# 'a' unstripped from c[1] because of leading whitespace.
>>> np.strings.strip(c, 'a')
array(['AaAaA', '  aA  ', 'bBABb'], dtype='<U7')
# 'A' unstripped from c[1] because of trailing whitespace.
>>> np.strings.strip(c, 'A')
array(['aAaAa', '  aA  ', 'abBABba'], dtype='<U7')
```

`char.`**`swapcase`**`(`*a*`)`

Return element-wise a copy of the string with uppercase characters converted to lowercase and vice versa.

Calls `str.swapcase` element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters

a
: [array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array.

Returns

out
: [ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.swapcase`

Examples

```
>>> import numpy as np
>>> c=np.array(['a1B c','1b Ca','b Ca1','cA1b'],'S5'); c
array(['a1B c', '1b Ca', 'b Ca1', 'cA1b'],
    dtype='|S5')
>>> np.strings.swapcase(c)
array(['A1b C', '1B cA', 'B cA1', 'Ca1B'],
    dtype='|S5')
```

`char.`**`title`**(*a*)

Return element-wise title cased version of string or unicode.

Title case words start with uppercase characters, all remaining cased characters are lowercase.

Calls `str.title` element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.title`

Examples

```
>>> import numpy as np
>>> c=np.array(['a1b c','1b ca','b ca1','ca1b'],'S5'); c
array(['a1b c', '1b ca', 'b ca1', 'ca1b'],
    dtype='|S5')
>>> np.strings.title(c)
array(['A1B C', '1B Ca', 'B Ca1', 'Ca1B'],
    dtype='|S5')
```

`char.`**`translate`**(*a*, *table*, *deletechars=None*)

For each element in *a*, return a copy of the string where all characters occurring in the optional argument *deletechars* are removed, and the remaining characters have been mapped through the given translation table.

Calls `str.translate` element-wise.

Parameters

a
[array-like, with *np.bytes_* or *np.str_* dtype]

table
[str of length 256]

deletechars
[str]

Returns

out
[ndarray] Output array of str or unicode, depending on input type

See also:

`str.translate`

Examples

```
>>> import numpy as np
>>> a = np.array(['a1b c', '1bca', 'bca1'])
>>> table = a[0].maketrans('abc', '123')
>>> deletechars = ' '
>>> np.char.translate(a, table, deletechars)
array(['112 3', '1231', '2311'], dtype='<U5')
```

`char.`**`upper`**(*a*)

Return an array with the elements converted to uppercase.

Calls `str.upper` element-wise.

For 8-bit strings, this method is locale-dependent.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] Input array.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input types

See also:

`str.upper`

Examples

```
>>> import numpy as np
>>> c = np.array(['a1b c', '1bca', 'bca1']); c
array(['a1b c', '1bca', 'bca1'], dtype='<U5')
>>> np.strings.upper(c)
array(['A1B C', '1BCA', 'BCA1'], dtype='<U5')
```

`char.`**`zfill`**(*a*, *width*)

Return the numeric string left-filled with zeros. A leading sign prefix (+/−) is handled by inserting the padding after the sign character rather than before.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

width
[array_like, with any integer dtype] Width of string to left-fill elements in *a*.

Returns

out
[ndarray] Output array of `StringDType`, `bytes_` or `str_` dtype, depending on input type

See also:

`str.zfill`

Examples

```
>>> import numpy as np
>>> np.strings.zfill(['1', '-1', '+1'], 3)
array(['001', '-01', '+01'], dtype='<U3')
```

Comparison

Unlike the standard numpy comparison operators, the ones in the *char* module strip trailing whitespace characters before performing the comparison.

equal(x1, x2)	Return (x1 == x2) element-wise.
not_equal(x1, x2)	Return (x1 != x2) element-wise.
greater_equal(x1, x2)	Return (x1 >= x2) element-wise.
less_equal(x1, x2)	Return (x1 <= x2) element-wise.
greater(x1, x2)	Return (x1 > x2) element-wise.
less(x1, x2)	Return (x1 < x2) element-wise.
compare_chararrays(a1, a2, cmp, rstrip)	Performs element-wise comparison of two string arrays using the comparison operator specified by *cmp*.

`char.`**`equal`**(*x1*, *x2*)

Return (x1 == x2) element-wise.

Unlike *`numpy.equal`*, this comparison is performed by first stripping whitespace characters from the end of the string. This behavior is provided for backward-compatibility with numarray.

Parameters

x1, x2
[array_like of str or unicode] Input arrays of the same shape.

Returns

out
[ndarray] Output array of bools.

See also:

`not_equal`, ***`greater_equal`***, ***`less_equal`***, ***`greater`***, ***`less`***

Examples

```
>>> import numpy as np
>>> y = "aa "
>>> x = "aa"
>>> np.char.equal(x, y)
array(True)
```

char.**not_equal**(*x1*, *x2*)

Return (x1 != x2) element-wise.

Unlike *numpy.not_equal*, this comparison is performed by first stripping whitespace characters from the end of the string. This behavior is provided for backward-compatibility with numarray.

Parameters

x1, x2
[array_like of str or unicode] Input arrays of the same shape.

Returns

out
[ndarray] Output array of bools.

See also:

equal*, *greater_equal*, *less_equal*, *greater*, *less

Examples

```
>>> import numpy as np
>>> x1 = np.array(['a', 'b', 'c'])
>>> np.char.not_equal(x1, 'b')
array([ True, False,  True])
```

char.**greater_equal**(*x1*, *x2*)

Return (x1 >= x2) element-wise.

Unlike *numpy.greater_equal*, this comparison is performed by first stripping whitespace characters from the end of the string. This behavior is provided for backward-compatibility with numarray.

Parameters

x1, x2
[array_like of str or unicode] Input arrays of the same shape.

Returns

out
[ndarray] Output array of bools.

See also:

equal*, *not_equal*, *less_equal*, *greater*, *less

Examples

```
>>> import numpy as np
>>> x1 = np.array(['a', 'b', 'c'])
>>> np.char.greater_equal(x1, 'b')
array([False,  True,  True])
```

char.**less_equal**(*x1*, *x2*)

Return (x1 <= x2) element-wise.

Unlike *numpy.less_equal*, this comparison is performed by first stripping whitespace characters from the end of the string. This behavior is provided for backward-compatibility with numarray.

Parameters

x1, x2
: [array_like of str or unicode] Input arrays of the same shape.

Returns

out
: [ndarray] Output array of bools.

See also:

equal*, *not_equal*, *greater_equal*, *greater*, *less

Examples

```
>>> import numpy as np
>>> x1 = np.array(['a', 'b', 'c'])
>>> np.char.less_equal(x1, 'b')
array([ True,  True, False])
```

char.**greater**(*x1*, *x2*)

Return (x1 > x2) element-wise.

Unlike *numpy.greater*, this comparison is performed by first stripping whitespace characters from the end of the string. This behavior is provided for backward-compatibility with numarray.

Parameters

x1, x2
: [array_like of str or unicode] Input arrays of the same shape.

Returns

out
: [ndarray] Output array of bools.

See also:

equal*, *not_equal*, *greater_equal*, *less_equal*, *less

Examples

```
>>> import numpy as np
>>> x1 = np.array(['a', 'b', 'c'])
>>> np.char.greater(x1, 'b')
array([False, False,  True])
```

char.**less**(*x1*, *x2*)

Return (x1 < x2) element-wise.

Unlike *numpy.greater*, this comparison is performed by first stripping whitespace characters from the end of the string. This behavior is provided for backward-compatibility with numarray.

Parameters

x1, x2
[array_like of str or unicode] Input arrays of the same shape.

Returns

out
[ndarray] Output array of bools.

See also:

equal*, *not_equal*, *greater_equal*, *less_equal*, *greater

Examples

```
>>> import numpy as np
>>> x1 = np.array(['a', 'b', 'c'])
>>> np.char.less(x1, 'b')
array([True, False, False])
```

char.**compare_chararrays**(*a1*, *a2*, *cmp*, *rstrip*)

Performs element-wise comparison of two string arrays using the comparison operator specified by *cmp*.

Parameters

a1, a2
[array_like] Arrays to be compared.

cmp
[{“<”, “<=”, “==”, “>=”, “>”, “!=”}] Type of comparison.

rstrip
[Boolean] If True, the spaces at the end of Strings are removed before the comparison.

Returns

out
[ndarray] The output array of type Boolean with the same shape as a and b.

Raises

ValueError
If *cmp* is not valid.

TypeError
If at least one of *a* or *b* is a non-string array

Examples

```
>>> import numpy as np
>>> a = np.array(["a", "b", "cde"])
>>> b = np.array(["a", "a", "dec"])
>>> np.char.compare_chararrays(a, b, ">", True)
array([False,  True, False])
```

String information

count(a, sub[, start, end])	Returns an array with the number of non-overlapping occurrences of substring `sub` in the range [`start`, `end`).
endswith(a, suffix[, start, end])	Returns a boolean array which is *True* where the string element in `a` ends with `suffix`, otherwise *False*.
find(a, sub[, start, end])	For each element, return the lowest index in the string where substring `sub` is found, such that `sub` is contained in the range [`start`, `end`).
index(a, sub[, start, end])	Like *find*, but raises `ValueError` when the substring is not found.
isalpha(x, /[, out, where, casting, order, ...])	Returns true for each element if all characters in the data interpreted as a string are alphabetic and there is at least one character, false otherwise.
isalnum(x, /[, out, where, casting, order, ...])	Returns true for each element if all characters in the string are alphanumeric and there is at least one character, false otherwise.
isdecimal(x, /[, out, where, casting, ...])	For each element, return True if there are only decimal characters in the element.
isdigit(x, /[, out, where, casting, order, ...])	Returns true for each element if all characters in the string are digits and there is at least one character, false otherwise.
islower(x, /[, out, where, casting, order, ...])	Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character, false otherwise.
isnumeric(x, /[, out, where, casting, ...])	For each element, return True if there are only numeric characters in the element.
isspace(x, /[, out, where, casting, order, ...])	Returns true for each element if there are only whitespace characters in the string and there is at least one character, false otherwise.
istitle(x, /[, out, where, casting, order, ...])	Returns true for each element if the element is a titlecased string and there is at least one character, false otherwise.
isupper(x, /[, out, where, casting, order, ...])	Return true for each element if all cased characters in the string are uppercase and there is at least one character, false otherwise.
rfind(a, sub[, start, end])	For each element, return the highest index in the string where substring `sub` is found, such that `sub` is contained in the range [`start`, `end`).
rindex(a, sub[, start, end])	Like *rfind*, but raises `ValueError` when the substring *sub* is not found.
startswith(a, prefix[, start, end])	Returns a boolean array which is *True* where the string element in `a` starts with `prefix`, otherwise *False*.
str_len(x, /[, out, where, casting, order, ...])	Returns the length of each element.

`char.`**`count`**(*a*, *sub*, *start=0*, *end=None*)

Returns an array with the number of non-overlapping occurrences of substring `sub` in the range [`start`, `end`).

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

sub
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] The substring to search for.

start, end
[array_like, with any integer dtype] The range to look in, interpreted as in slice notation.

Returns

y
[ndarray] Output array of ints

See also:

`str.count`

Examples

```
>>> import numpy as np
>>> c = np.array(['aAaAaA', '  aA  ', 'abBABba'])
>>> c
array(['aAaAaA', '  aA  ', 'abBABba'], dtype='<U7')
>>> np.strings.count(c, 'A')
array([3, 1, 1])
>>> np.strings.count(c, 'aA')
array([3, 1, 0])
>>> np.strings.count(c, 'A', start=1, end=4)
array([2, 1, 1])
>>> np.strings.count(c, 'A', start=1, end=3)
array([1, 0, 0])
```

`char.`**`endswith`**(*a*, *suffix*, *start=0*, *end=None*)

Returns a boolean array which is *True* where the string element in `a` ends with `suffix`, otherwise *False*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

suffix
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

start, end
[array_like, with any integer dtype] With `start`, test beginning at that position. With `end`, stop comparing at that position.

Returns

out
[ndarray] Output array of bools

See also:

`str.endswith`

Examples

```
>>> import numpy as np
>>> s = np.array(['foo', 'bar'])
>>> s
array(['foo', 'bar'], dtype='<U3')
>>> np.strings.endswith(s, 'ar')
array([False,  True])
>>> np.strings.endswith(s, 'a', start=1, end=2)
array([False,  True])
```

char.**find**(*a*, *sub*, *start=0*, *end=None*)

For each element, return the lowest index in the string where substring `sub` is found, such that `sub` is contained in the range [`start`, `end`).

Parameters

a
[array_like, with `StringDType`, `bytes_` or `str_` dtype]

sub
[array_like, with *np.bytes_* or *np.str_* dtype] The substring to search for.

start, end
[array_like, with any integer dtype] The range to look in, interpreted as in slice notation.

Returns

y
[ndarray] Output array of ints

See also:

`str.find`

Examples

```
>>> import numpy as np
>>> a = np.array(["NumPy is a Python library"])
>>> np.strings.find(a, "Python")
array([11])
```

char.**index**(*a*, *sub*, *start=0*, *end=None*)

Like *find*, but raises `ValueError` when the substring is not found.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

sub
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

start, end
[array_like, with any integer dtype, optional]

Returns

out
[ndarray] Output array of ints.

See also:

find, str.index

Examples

```
>>> import numpy as np
>>> a = np.array(["Computer Science"])
>>> np.strings.index(a, "Science", start=0, end=None)
array([9])
```

char.**isalpha**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isalpha'>**

Returns true for each element if all characters in the data interpreted as a string are alphabetic and there is at least one character, false otherwise.

For byte strings (i.e. bytes), alphabetic characters are those byte values in the sequence b'abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ'. For Unicode strings, alphabetic characters are those characters defined in the Unicode character database as "Letter".

Parameters

x
: [array_like, with StringDType, bytes_, or str_ dtype]

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default out=None, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

str.isalpha

Examples

```
>>> import numpy as np
>>> a = np.array(['a', 'b', '0'])
>>> np.strings.isalpha(a)
array([ True,  True, False])
```

```
>>> a = np.array([['a', 'b', '0'], ['c', '1', '2']])
>>> np.strings.isalpha(a)
array([[ True,  True, False], [ True, False, False]])
```

char.**isalnum**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isalnum'>**

Returns true for each element if all characters in the string are alphanumeric and there is at least one character, false otherwise.

Parameters

x
: [array_like, with `StringDType`, `bytes_` or `str_` dtype]

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray] Output array of bool This is a scalar if *x* is a scalar.

See also:

str.isalnum

Examples

```
>>> import numpy as np
>>> a = np.array(['a', '1', 'a1', '(', ''])
>>> np.strings.isalnum(a)
array([ True,  True,  True, False, False])
```

char.**isdecimal**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isdecimal'>**

For each element, return True if there are only decimal characters in the element.

Decimal characters include digit characters, and all characters that can be used to form decimal-radix numbers, e.g. `U+0660, ARABIC-INDIC DIGIT ZERO`.

Parameters

x
[array_like, with `StringDType` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isdecimal`

Examples

```
>>> import numpy as np
>>> np.strings.isdecimal(['12345', '4.99', '123ABC', ''])
array([ True, False, False, False])
```

`char.`**`isdigit`**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isdigit'>**

Returns true for each element if all characters in the string are digits and there is at least one character, false otherwise.

For byte strings, digits are the byte values in the sequence b'0123456789'. For Unicode strings, digits include decimal characters and digits that need special handling, such as the compatibility superscript digits. This also covers digits which cannot be used to form numbers in base 10, like the Kharosthi numbers.

Parameters

x
[array_like, with `StringDType`, `bytes_`, or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isdigit`

Examples

```
>>> import numpy as np
>>> a = np.array(['a', 'b', '0'])
>>> np.strings.isdigit(a)
array([False, False,  True])
>>> a = np.array([['a', 'b', '0'], ['c', '1', '2']])
>>> np.strings.isdigit(a)
array([[False, False,  True], [False,  True,  True]])
```

`char.`**`islower`**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **`= <ufunc 'islower'>`**

Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character, false otherwise.

Parameters

x
[array_like, with `StringDType`, `bytes_` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.islower`

Examples

```
>>> import numpy as np
>>> np.strings.islower("GHC")
array(False)
>>> np.strings.islower("ghc")
array(True)
```

`char.isnumeric`(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isnumeric'>**

For each element, return True if there are only numeric characters in the element.

Numeric characters include digit characters, and all characters that have the Unicode numeric value property, e.g. `U+2155, VULGAR FRACTION ONE FIFTH`.

Parameters

x
[array_like, with `StringDType` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isnumeric`

Examples

```
>>> import numpy as np
>>> np.strings.isnumeric(['123', '123abc', '9.0', '1/4', 'VIII'])
array([ True, False, False, False, False])
```

`char.isspace`(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isspace'>**

Returns true for each element if there are only whitespace characters in the string and there is at least one character, false otherwise.

For byte strings, whitespace characters are the ones in the sequence b' tnrx0bf'. For Unicode strings, a character is whitespace, if, in the Unicode character database, its general category is Zs ("Separator, space"), or its bidirectional class is one of WS, B, or S.

Parameters

x
[array_like, with `StringDType`, `bytes_`, or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isspace`

Examples

```
>>> np.char.isspace(list("a b c"))
array([False,  True, False,  True, False])
>>> np.char.isspace(b'\x0a \x0b \x0c')
np.True_
>>> np.char.isspace(b'\x0a \x0b \x0c N')
np.False_
```

`char.`**`istitle`**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **`= <ufunc 'istitle'>`**

Returns true for each element if the element is a titlecased string and there is at least one character, false otherwise.

Parameters

x
[array_like, with `StringDType`, `bytes_` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.istitle`

Examples

```
>>> import numpy as np
>>> np.strings.istitle("Numpy Is Great")
array(True)
```

```
>>> np.strings.istitle("Numpy is great")
array(False)
```

`char.`**`isupper`**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isupper'>**

Return true for each element if all cased characters in the string are uppercase and there is at least one character, false otherwise.

Parameters

x
[array_like, with `StringDType`, `bytes_` or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray] Output array of bools This is a scalar if *x* is a scalar.

See also:

`str.isupper`

Examples

```
>>> import numpy as np
>>> np.strings.isupper("GHC")
array(True)
>>> a = np.array(["hello", "HELLO", "Hello"])
>>> np.strings.isupper(a)
array([False,  True, False])
```

`char.`**`rfind`**(*a*, *sub*, *start=0*, *end=None*)

For each element, return the highest index in the string where substring `sub` is found, such that `sub` is contained in the range [`start`, `end`).

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

sub
[array-like, with `StringDType`, `bytes_`, or `str_` dtype] The substring to search for.

start, end
[array_like, with any integer dtype] The range to look in, interpreted as in slice notation.

Returns

y
[ndarray] Output array of ints

See also:

`str.rfind`

Examples

```
>>> import numpy as np
>>> a = np.array(["Computer Science"])
>>> np.strings.rfind(a, "Science", start=0, end=None)
array([9])
>>> np.strings.rfind(a, "Science", start=0, end=8)
array([-1])
>>> b = np.array(["Computer Science", "Science"])
>>> np.strings.rfind(b, "Science", start=0, end=None)
array([9, 0])
```

`char.`**`rindex`**(*a*, *sub*, *start=0*, *end=None*)

Like *`rfind`*, but raises `ValueError` when the substring *sub* is not found.

Parameters

a
[array-like, with *np.bytes_* or *np.str_* dtype]

sub
[array-like, with *np.bytes_* or *np.str_* dtype]

start, end
[array-like, with any integer dtype, optional]

Returns

out
[ndarray] Output array of ints.

See also:

rfind, **str.rindex**

Examples

```
>>> a = np.array(["Computer Science"])
>>> np.strings.rindex(a, "Science", start=0, end=None)
array([9])
```

char.**startswith**(*a*, *prefix*, *start=0*, *end=None*)

Returns a boolean array which is *True* where the string element in `a` starts with `prefix`, otherwise *False*.

Parameters

a
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

prefix
[array-like, with `StringDType`, `bytes_`, or `str_` dtype]

start, end
[array_like, with any integer dtype] With `start`, test beginning at that position. With `end`, stop comparing at that position.

Returns

out
[ndarray] Output array of bools

See also:

str.startswith

Examples

```
>>> import numpy as np
>>> s = np.array(['foo', 'bar'])
>>> s
array(['foo', 'bar'], dtype='<U3')
>>> np.strings.startswith(s, 'fo')
array([True,  False])
>>> np.strings.startswith(s, 'o', start=1, end=2)
array([True,  False])
```

char.**str_len**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'str_len'>**

Returns the length of each element. For byte strings, this is the number of bytes, while, for Unicode strings, it is the number of Unicode code points.

Parameters

x
[array_like, with `StringDType`, `bytes_`, or `str_` dtype]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Output array of ints This is a scalar if *x* is a scalar.

See also:

`len`

Examples

```
>>> import numpy as np
>>> a = np.array(['Grace Hopper Conference', 'Open Source Day'])
>>> np.strings.str_len(a)
array([23, 15])
>>> a = np.array(['P', 'o'])
>>> np.strings.str_len(a)
array([1, 1])
>>> a = np.array([['hello', 'world'], ['P', 'o']])
>>> np.strings.str_len(a)
array([[5, 5], [1, 1]])
```

Convenience class

array(obj[, itemsize, copy, unicode, order])	Create a *chararray*.
asarray(obj[, itemsize, unicode, order])	Convert the input to a *chararray*, copying the data only if necessary.
chararray(shape[, itemsize, unicode, ...])	Provides a convenient view on arrays of string and unicode values.

`char.`**`array`**(*obj*, *itemsize=None*, *copy=True*, *unicode=None*, *order=None*)

Create a *chararray*.

Note: This class is provided for numarray backward-compatibility. New code (not concerned with numarray compatibility) should use arrays of type *bytes_* or *str_* and use the free functions in *numpy.char* for fast

vectorized string operations instead.

Versus a NumPy array of dtype *bytes_* or *str_*, this class adds the following functionality:

1) values automatically have whitespace removed from the end when indexed

2) comparison operators automatically remove whitespace from the end when comparing values

3) vectorized string operations are provided as methods (e.g. *chararray.endswith*) and infix operators (e.g. `+, *, %`)

Parameters

obj
[array of str or unicode-like]

itemsize
[int, optional] *itemsize* is the number of characters per scalar in the resulting array. If *itemsize* is None, and *obj* is an object array or a Python list, the *itemsize* will be automatically determined. If *itemsize* is provided and *obj* is of type str or unicode, then the *obj* string will be chunked into *itemsize* pieces.

copy
[bool, optional] If true (default), then the object is copied. Otherwise, a copy will only be made if `__array__` returns a copy, if obj is a nested sequence, or if a copy is needed to satisfy any of the other requirements (*itemsize*, unicode, *order*, etc.).

unicode
[bool, optional] When true, the resulting *chararray* can contain Unicode characters, when false only 8-bit characters. If unicode is None and *obj* is one of the following:

- a *chararray*,
- an ndarray of type *str_* or *bytes_*
- a Python `str` or `bytes` object,

then the unicode setting of the output array will be automatically determined.

order
[{'C', 'F', 'A'}, optional] Specify the order of the array. If order is 'C' (default), then the array will be in C-contiguous order (last-index varies the fastest). If order is 'F', then the returned array will be in Fortran-contiguous order (first-index varies the fastest). If order is 'A', then the returned array may be in any order (either C-, Fortran-contiguous, or even discontiguous).

Examples

```
>>> import numpy as np
>>> char_array = np.char.array(['hello', 'world', 'numpy','array'])
>>> char_array
chararray(['hello', 'world', 'numpy', 'array'], dtype='<U5')
```

`char.`**`asarray`**(*obj*, *itemsize=None*, *unicode=None*, *order=None*)

Convert the input to a *chararray*, copying the data only if necessary.

Versus a NumPy array of dtype *bytes_* or *str_*, this class adds the following functionality:

1) values automatically have whitespace removed from the end when indexed

2) comparison operators automatically remove whitespace from the end when comparing values

3) vectorized string operations are provided as methods (e.g. *chararray.endswith*) and infix operators (e.g. +, *, %)

Parameters

obj
[array of str or unicode-like]

itemsize
[int, optional] *itemsize* is the number of characters per scalar in the resulting array. If *itemsize* is None, and *obj* is an object array or a Python list, the *itemsize* will be automatically determined. If *itemsize* is provided and *obj* is of type str or unicode, then the *obj* string will be chunked into *itemsize* pieces.

unicode
[bool, optional] When true, the resulting *chararray* can contain Unicode characters, when false only 8-bit characters. If unicode is None and *obj* is one of the following:

- a *chararray*,
- an ndarray of type *str_* or *unicode_*
- a Python str or unicode object,

then the unicode setting of the output array will be automatically determined.

order
[{'C', 'F'}, optional] Specify the order of the array. If order is 'C' (default), then the array will be in C-contiguous order (last-index varies the fastest). If order is 'F', then the returned array will be in Fortran-contiguous order (first-index varies the fastest).

Examples

```
>>> import numpy as np
>>> np.char.asarray(['hello', 'world'])
chararray(['hello', 'world'], dtype='<U5')
```

class numpy.char.**chararray**(*shape*, *itemsize=1*, *unicode=False*, *buffer=None*, *offset=0*, *strides=None*, *order=None*)

Provides a convenient view on arrays of string and unicode values.

Note: The *chararray* class exists for backwards compatibility with Numarray, it is not recommended for new development. Starting from numpy 1.4, if one needs arrays of strings, it is recommended to use arrays of `dtype object_`, *bytes_* or *str_*, and use the free functions in the *numpy.char* module for fast vectorized string operations.

Versus a NumPy array of dtype *bytes_* or *str_*, this class adds the following functionality:

1) values automatically have whitespace removed from the end when indexed
2) comparison operators automatically remove whitespace from the end when comparing values
3) vectorized string operations are provided as methods (e.g. *endswith*) and infix operators (e.g. `"+", "*", "%"`)

chararrays should be created using *numpy.char.array* or *numpy.char.asarray*, rather than this constructor directly.

This constructor creates the array, using *buffer* (with *offset* and `strides`) if it is not `None`. If *buffer* is `None`, then constructs a new array with `strides` in "C order", unless both `len(shape) >= 2` and `order='F'`, in which case `strides` is in "Fortran order".

Parameters

shape
[tuple] Shape of the array.

itemsize
[int, optional] Length of each array element, in number of characters. Default is 1.

unicode
[bool, optional] Are the array elements of type unicode (True) or string (False). Default is False.

buffer
[object exposing the buffer interface or str, optional] Memory address of the start of the array data. Default is None, in which case a new array is created.

offset
[int, optional] Fixed stride displacement from the beginning of an axis? Default is 0. Needs to be >=0.

strides
[array_like of ints, optional] Strides for the array (see *`strides`* for full description). Default is None.

order
[{'C', 'F'}, optional] The order in which the array data is stored in memory: 'C' -> "row major" order (the default), 'F' -> "column major" (Fortran) order.

Examples

```
>>> import numpy as np
>>> charar = np.char.chararray((3, 3))
>>> charar[:] = 'a'
>>> charar
chararray([[b'a', b'a', b'a'],
           [b'a', b'a', b'a'],
           [b'a', b'a', b'a']], dtype='|S1')
```

```
>>> charar = np.char.chararray(charar.shape, itemsize=5)
>>> charar[:] = 'abc'
>>> charar
chararray([[b'abc', b'abc', b'abc'],
           [b'abc', b'abc', b'abc'],
           [b'abc', b'abc', b'abc']], dtype='|S5')
```

Attributes

`T`
View of the transposed array.

`base`
Base object if memory is from some other object.

`ctypes`
An object to simplify the interaction of the array with the ctypes module.

data
Python buffer object pointing to the start of the array's data.

device
dtype
Data-type of the array's elements.

flags
Information about the memory layout of the array.

flat
A 1-D iterator over the array.

imag
The imaginary part of the array.

itemset
itemsize
Length of one array element in bytes.

mT
View of the matrix transposed array.

nbytes
Total bytes consumed by the elements of the array.

ndim
Number of array dimensions.

newbyteorder
ptp
real
The real part of the array.

shape
Tuple of array dimensions.

size
Number of elements in the array.

strides
Tuple of bytes to step in each dimension when traversing an array.

Methods

astype(dtype[, order, casting, subok, copy])	Copy of the array, cast to a specified type.
argsort([axis, kind, order])	Returns the indices that would sort this array.
copy([order])	Return a copy of the array.
count(sub[, start, end])	Returns an array with the number of non-overlapping occurrences of substring *sub* in the range [*start*, *end*].
decode([encoding, errors])	Calls `bytes.decode` element-wise.
dump(file)	Dump a pickle of the array to the specified file.
dumps()	Returns the pickle of the array as a string.
encode([encoding, errors])	Calls `str.encode` element-wise.
endswith(suffix[, start, end])	Returns a boolean array which is *True* where the string element in *self* ends with *suffix*, otherwise *False*.

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expandtabs([tabsize])	Return a copy of each string element where all tab characters are replaced by one or more spaces.
fill(value)	Fill the array with a scalar value.
find(sub[, start, end])	For each element, return the lowest index in the string where substring *sub* is found.
flatten([order])	Return a copy of the array collapsed into one dimension.
getfield(dtype[, offset])	Returns a field of the given array as a certain type.
index(sub[, start, end])	Like *find*, but raises `ValueError` when the substring is not found.
isalnum()	Returns true for each element if all characters in the string are alphanumeric and there is at least one character, false otherwise.
isalpha()	Returns true for each element if all characters in the string are alphabetic and there is at least one character, false otherwise.
isdecimal()	For each element in *self*, return True if there are only decimal characters in the element.
isdigit()	Returns true for each element if all characters in the string are digits and there is at least one character, false otherwise.
islower()	Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character, false otherwise.
isnumeric()	For each element in *self*, return True if there are only numeric characters in the element.
isspace()	Returns true for each element if there are only whitespace characters in the string and there is at least one character, false otherwise.
istitle()	Returns true for each element if the element is a titlecased string and there is at least one character, false otherwise.
isupper()	Returns true for each element if all cased characters in the string are uppercase and there is at least one character, false otherwise.
item(*args)	Copy an element of an array to a standard Python scalar and return it.
join(seq)	Return a string which is the concatenation of the strings in the sequence *seq*.
ljust(width[, fillchar])	Return an array with the elements of *self* left-justified in a string of length *width*.
lower()	Return an array with the elements of *self* converted to lowercase.
lstrip([chars])	For each element in *self*, return a copy with the leading characters removed.
nonzero()	Return the indices of the elements that are non-zero.
put(indices, values[, mode])	Set `a.flat[n] = values[n]` for all *n* in indices.
ravel([order])	Return a flattened array.
repeat(repeats[, axis])	Repeat elements of an array.
replace(old, new[, count])	For each element in *self*, return a copy of the string with all occurrences of substring *old* replaced by *new*.

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`reshape`(shape, /, *[, order, copy])	Returns an array containing the same data with a new shape.
`resize`(new_shape[, refcheck])	Change shape and size of array in-place.
`rfind`(sub[, start, end])	For each element in *self*, return the highest index in the string where substring *sub* is found, such that *sub* is contained within [*start*, *end*].
`rindex`(sub[, start, end])	Like `rfind`, but raises `ValueError` when the substring *sub* is not found.
`rjust`(width[, fillchar])	Return an array with the elements of *self* right-justified in a string of length *width*.
`rsplit`([sep, maxsplit])	For each element in *self*, return a list of the words in the string, using *sep* as the delimiter string.
`rstrip`([chars])	For each element in *self*, return a copy with the trailing characters removed.
`searchsorted`(v[, side, sorter])	Find indices where elements of v should be inserted in a to maintain order.
`setfield`(val, dtype[, offset])	Put a value into a specified place in a field defined by a data-type.
`setflags`([write, align, uic])	Set array flags WRITEABLE, ALIGNED, WRITEBACKIFCOPY, respectively.
`sort`([axis, kind, order])	Sort an array in-place.
`split`([sep, maxsplit])	For each element in *self*, return a list of the words in the string, using *sep* as the delimiter string.
`splitlines`([keepends])	For each element in *self*, return a list of the lines in the element, breaking at line boundaries.
`squeeze`([axis])	Remove axes of length one from *a*.
`startswith`(prefix[, start, end])	Returns a boolean array which is *True* where the string element in *self* starts with *prefix*, otherwise *False*.
`strip`([chars])	For each element in *self*, return a copy with the leading and trailing characters removed.
`swapaxes`(axis1, axis2)	Return a view of the array with *axis1* and *axis2* interchanged.
`swapcase`()	For each element in *self*, return a copy of the string with uppercase characters converted to lowercase and vice versa.
`take`(indices[, axis, out, mode])	Return an array formed from the elements of *a* at the given indices.
`title`()	For each element in *self*, return a titlecased version of the string: words start with uppercase characters, all remaining cased characters are lowercase.
`tofile`(fid[, sep, format])	Write array to a file as text or binary (default).
`tolist`()	Return the array as an `a.ndim`-levels deep nested list of Python scalars.
`tostring`([order])	A compatibility alias for *tobytes*, with exactly the same behavior.
`translate`(table[, deletechars])	For each element in *self*, return a copy of the string where all characters occurring in the optional argument *deletechars* are removed, and the remaining characters have been mapped through the given translation table.
`transpose`(*axes)	Returns a view of the array with axes transposed.

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upper()	Return an array with the elements of *self* converted to uppercase.
view([dtype][, type])	New view of array with the same data.
zfill(width)	Return the numeric string left-filled with zeros in a string of length *width*.

method

char.chararray.**astype**(*dtype*, *order='K'*, *casting='unsafe'*, *subok=True*, *copy=True*)

Copy of the array, cast to a specified type.

Parameters

dtype
[str or dtype] Typecode or data-type to which the array is cast.

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout order of the result. 'C' means C order, 'F' means Fortran order, 'A' means 'F' order if all the arrays are Fortran contiguous, 'C' order otherwise, and 'K' means as close to the order the array elements appear in memory as possible. Default is 'K'.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'unsafe' for backwards compatibility.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.
- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

subok
[bool, optional] If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

copy
[bool, optional] By default, astype always returns a newly allocated array. If this is set to false, and the dtype, *order*, and *subok* requirements are satisfied, the input array is returned instead of a copy.

Returns

arr_t
[ndarray] Unless copy is False and the other conditions for returning the input array are satisfied (see description for copy input parameter), *arr_t* is a new array of the same shape as the input array, with dtype, order given by dtype, *order*.

Raises

ComplexWarning
When casting from complex to float or int. To avoid this, one should use `a.real.astype(t)`.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 2.5])
>>> x
array([1. ,  2. ,  2.5])
```

```
>>> x.astype(int)
array([1, 2, 2])
```

method

char.chararray.**argsort**(*axis=-1*, *kind=None*, *order=None*)

Returns the indices that would sort this array.

Refer to *numpy.argsort* for full documentation.

See also:

numpy.argsort
equivalent function

method

char.chararray.**copy**(*order='C'*)

Return a copy of the array.

Parameters

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout of the copy. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible. (Note that this function and *numpy.copy* are very similar but have different default values for their order= arguments, and this function always passes sub-classes through.)

See also:

numpy.copy
Similar function with different default behavior

numpy.copyto

Notes

This function is the preferred method for creating an array copy. The function *numpy.copy* is similar, but it defaults to using order 'K', and will not pass sub-classes through by default.

Examples

```
>>> import numpy as np
>>> x = np.array([[1,2,3],[4,5,6]], order='F')
```

```
>>> y = x.copy()
```

```
>>> x.fill(0)
```

```
>>> x
array([[0, 0, 0],
       [0, 0, 0]])
```

```
>>> y
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> y.flags['C_CONTIGUOUS']
True
```

For arrays containing Python objects (e.g. dtype=object), the copy is a shallow one. The new array will contain the same object which may lead to surprises if that object can be modified (is mutable):

```
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> b = a.copy()
>>> b[2][0] = 10
>>> a
array([1, 'm', list([10, 3, 4])], dtype=object)
```

To ensure all elements within an `object` array are copied, use `copy.deepcopy`:

```
>>> import copy
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> c = copy.deepcopy(a)
>>> c[2][0] = 10
>>> c
array([1, 'm', list([10, 3, 4])], dtype=object)
>>> a
array([1, 'm', list([2, 3, 4])], dtype=object)
```

method

`char.chararray.`**`count`**(*sub*, *start=0*, *end=None*)

Returns an array with the number of non-overlapping occurrences of substring *sub* in the range [*start*, *end*].

See also:

char.count

method

`char.chararray.`**`decode`**(*encoding=None*, *errors=None*)

Calls `bytes.decode` element-wise.

See also:

char.decode

method

char.chararray.**dump**(*file*)

Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

Parameters

file
[str or Path] A string naming the dump file.

method

char.chararray.**dumps**()

Returns the pickle of the array as a string. pickle.loads will convert the string back to an array.

Parameters

None

method

char.chararray.**encode**(*encoding=None*, *errors=None*)

Calls `str.encode` element-wise.

See also:

char.encode

method

char.chararray.**endswith**(*suffix*, *start=0*, *end=None*)

Returns a boolean array which is *True* where the string element in *self* ends with *suffix*, otherwise *False*.

See also:

char.endswith

method

char.chararray.**expandtabs**(*tabsize=8*)

Return a copy of each string element where all tab characters are replaced by one or more spaces.

See also:

char.expandtabs

method

char.chararray.**fill**(*value*)

Fill the array with a scalar value.

Parameters

value
[scalar] All elements of *a* will be assigned this value.

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2])
>>> a.fill(0)
>>> a
array([0, 0])
>>> a = np.empty(2)
>>> a.fill(1)
>>> a
array([1.,  1.])
```

Fill expects a scalar value and always behaves the same as assigning to a single array element. The following is a rare example where this distinction is important:

```
>>> a = np.array([None, None], dtype=object)
>>> a[0] = np.array(3)
>>> a
array([array(3), None], dtype=object)
>>> a.fill(np.array(3))
>>> a
array([array(3), array(3)], dtype=object)
```

Where other forms of assignments will unpack the array being assigned:

```
>>> a[...] = np.array(3)
>>> a
array([3, 3], dtype=object)
```

method

char.chararray.**find**(*sub*, *start=0*, *end=None*)

For each element, return the lowest index in the string where substring *sub* is found.

See also:

char.find

method

char.chararray.**flatten**(*order='C'*)

Return a copy of the array collapsed into one dimension.

Parameters

order
[{'C', 'F', 'A', 'K'}, optional] 'C' means to flatten in row-major (C-style) order. 'F' means to flatten in column-major (Fortran- style) order. 'A' means to flatten in column-major order if *a* is Fortran *contiguous* in memory, row-major order otherwise. 'K' means to flatten *a* in the order the elements occur in memory. The default is 'C'.

Returns

y
[ndarray] A copy of the input array, flattened to one dimension.

See also:

ravel
Return a flattened array.

flat
A 1-D flat iterator over the array.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,2], [3,4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

method

char.chararray.**getfield**(*dtype*, *offset=0*)

Returns a field of the given array as a certain type.

A field is a view of the array data with a given data-type. The values in the view are determined by the given type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits in the array dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with a 32-bit integer (4 bytes), the offset needs to be between 0 and 12 bytes.

Parameters

dtype
[str or dtype] The data type of the view. The dtype size of the view can not be larger than that of the array itself.

offset
[int] Number of bytes to skip before beginning the element view.

Examples

```
>>> import numpy as np
>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[1.+1.j,  0.+0.j],
       [0.+0.j,  2.+4.j]])
>>> x.getfield(np.float64)
array([[1.,  0.],
       [0.,  2.]])
```

By choosing an offset of 8 bytes we can select the complex part of the array for our view:

```
>>> x.getfield(np.float64, offset=8)
array([[1.,  0.],
       [0.,  4.]])
```

method

char.chararray.**index**(*sub*, *start=0*, *end=None*)

Like *find*, but raises `ValueError` when the substring is not found.

See also:

char.index

method

char.chararray.**isalnum**()

Returns true for each element if all characters in the string are alphanumeric and there is at least one character, false otherwise.

See also:

char.isalnum

method

char.chararray.**isalpha**()

Returns true for each element if all characters in the string are alphabetic and there is at least one character, false otherwise.

See also:

char.isalpha

method

char.chararray.**isdecimal**()

For each element in *self*, return True if there are only decimal characters in the element.

See also:

char.isdecimal

method

char.chararray.**isdigit**()

Returns true for each element if all characters in the string are digits and there is at least one character, false otherwise.

See also:

char.isdigit

method

char.chararray.**islower**()

Returns true for each element if all cased characters in the string are lowercase and there is at least one cased character, false otherwise.

See also:

char.islower

method

char.chararray.**isnumeric**()

For each element in *self*, return True if there are only numeric characters in the element.

See also:

char.isnumeric

method

char.chararray.**isspace**()

Returns true for each element if there are only whitespace characters in the string and there is at least one character, false otherwise.

See also:

char.isspace

method

char.chararray.**istitle**()

Returns true for each element if the element is a titlecased string and there is at least one character, false otherwise.

See also:

char.istitle

method

char.chararray.**isupper**()

Returns true for each element if all cased characters in the string are uppercase and there is at least one character, false otherwise.

See also:

char.isupper

method

char.chararray.**item**(**args*)

Copy an element of an array to a standard Python scalar and return it.

Parameters

***args**
[Arguments (variable number and type)]

- none: in this case, the method only works for arrays with one element (*a.size == 1*), which element is copied into a standard Python scalar object and returned.
- int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.
- tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.

Returns

z
: [Standard Python scalar object] A copy of the specified element of the array as a suitable Python scalar

Notes

When the data type of *a* is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

item is very similar to a[args], except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python's optimized math.

Examples

```
>>> import numpy as np
>>> np.random.seed(123)
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[2, 2, 6],
       [1, 3, 6],
       [1, 0, 1]])
>>> x.item(3)
1
>>> x.item(7)
0
>>> x.item((0, 1))
2
>>> x.item((2, 2))
1
```

For an array with object dtype, elements are returned as-is.

```
>>> a = np.array([np.int64(1)], dtype=object)
>>> a.item() #return np.int64
np.int64(1)
```

method

char.chararray.**join**(*seq*)

Return a string which is the concatenation of the strings in the sequence *seq*.

See also:

char.join

method

char.chararray.**ljust**(*width*, *fillchar=' '*)

Return an array with the elements of *self* left-justified in a string of length *width*.

See also:

char.ljust

method

char.chararray.**lower**()

Return an array with the elements of *self* converted to lowercase.

See also:

char.lower

method

char.chararray.**lstrip**(*chars=None*)

For each element in *self*, return a copy with the leading characters removed.

See also:

char.lstrip

method

char.chararray.**nonzero**()

Return the indices of the elements that are non-zero.

Refer to *numpy.nonzero* for full documentation.

See also:

numpy.nonzero
equivalent function

method

char.chararray.**put**(*indices*, *values*, *mode='raise'*)

Set `a.flat[n] = values[n]` for all *n* in indices.

Refer to *numpy.put* for full documentation.

See also:

numpy.put
equivalent function

method

char.chararray.**ravel**([*order*])

Return a flattened array.

Refer to *numpy.ravel* for full documentation.

See also:

numpy.ravel
equivalent function

ndarray.flat
a flat iterator on the array.

method

char.chararray.**repeat**(*repeats*, *axis=None*)

Repeat elements of an array.

Refer to *numpy.repeat* for full documentation.

See also:

numpy.repeat
equivalent function

method

char.chararray.**replace**(*old*, *new*, *count=None*)

For each element in *self*, return a copy of the string with all occurrences of substring *old* replaced by *new*.

See also:

char.replace

method

char.chararray.**reshape**(*shape*, */*, ***, *order='C'*, *copy=None*)

Returns an array containing the same data with a new shape.

Refer to *numpy.reshape* for full documentation.

See also:

numpy.reshape
equivalent function

Notes

Unlike the free function *numpy.reshape*, this method on *ndarray* allows the elements of the shape parameter to be passed in as separate arguments. For example, `a.reshape(10, 11)` is equivalent to `a.reshape((10, 11))`.

method

char.chararray.**resize**(*new_shape*, *refcheck=True*)

Change shape and size of array in-place.

Parameters

new_shape
[tuple of ints, or *n* ints] Shape of resized array.

refcheck
[bool, optional] If False, reference count will not be checked. Default is True.

Returns

None

Raises

ValueError
If *a* does not own its own data or references or views to it exist, and the data memory must be changed. PyPy only: will always raise if the data memory must be changed, since there is no reliable way to determine if references or views to it exist.

SystemError
If the *order* keyword argument is specified. This behaviour is a bug in NumPy.

See also:

resize
Return a new array with the specified shape.

Notes

This reallocates space for the data area if necessary.

Only contiguous arrays (data elements consecutive in memory) can be resized.

The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set *refcheck* to False.

Examples

Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and reshaped:

```
>>> import numpy as np
```

```
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
>>> a
array([[0],
       [1]])
```

```
>>> a = np.array([[0, 1], [2, 3]], order='F')
>>> a.resize((2, 1))
>>> a
array([[0],
       [2]])
```

Enlarging an array: as above, but missing entries are filled with zeros:

```
>>> b = np.array([[0, 1], [2, 3]])
>>> b.resize(2, 3) # new_shape parameter doesn't have to be a tuple
>>> b
array([[0, 1, 2],
       [3, 0, 0]])
```

Referencing an array prevents resizing…

```
>>> c = a
>>> a.resize((1, 1))
Traceback (most recent call last):
...
ValueError: cannot resize an array that references or is referenced ...
```

Unless *refcheck* is False:

```
>>> a.resize((1, 1), refcheck=False)
>>> a
array([[0]])
>>> c
array([[0]])
```

method

char.chararray.**rfind**(*sub*, *start=0*, *end=None*)

For each element in *self*, return the highest index in the string where substring *sub* is found, such that *sub* is contained within [*start*, *end*].

See also:

char.rfind

method

char.chararray.**rindex**(*sub*, *start=0*, *end=None*)

Like *rfind*, but raises `ValueError` when the substring *sub* is not found.

See also:

char.rindex

method

char.chararray.**rjust**(*width*, *fillchar=' '*)

Return an array with the elements of *self* right-justified in a string of length *width*.

See also:

char.rjust

method

char.chararray.**rsplit**(*sep=None*, *maxsplit=None*)

For each element in *self*, return a list of the words in the string, using *sep* as the delimiter string.

See also:

char.rsplit

method

char.chararray.**rstrip**(*chars=None*)

For each element in *self*, return a copy with the trailing characters removed.

See also:

char.rstrip

method

char.chararray.**searchsorted**(*v*, *side='left'*, *sorter=None*)

Find indices where elements of v should be inserted in a to maintain order.

For full documentation, see *numpy.searchsorted*

See also:

numpy.searchsorted
equivalent function

method

char.chararray.**setfield**(*val*, *dtype*, *offset=0*)

Put a value into a specified place in a field defined by a data-type.

Place *val* into *a*'s field defined by *dtype* and beginning *offset* bytes into the field.

Parameters

val
[object] Value to be placed in field.

dtype
[dtype object] Data-type of the field in which to place *val*.

offset
[int, optional] The number of bytes into the field at which to place *val*.

Returns

None

See also:

getfield

Examples

```
>>> import numpy as np
>>> x = np.eye(3)
>>> x.getfield(np.float64)
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
>>> x.setfield(3, np.int32)
>>> x.getfield(np.int32)
array([[3, 3, 3],
       [3, 3, 3],
       [3, 3, 3]], dtype=int32)
>>> x
array([[1.0e+000, 1.5e-323, 1.5e-323],
       [1.5e-323, 1.0e+000, 1.5e-323],
       [1.5e-323, 1.5e-323, 1.0e+000]])
>>> x.setfield(np.eye(3), np.int32)
>>> x
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
```

method

char.chararray.**setflags**(*write=None*, *align=None*, *uic=None*)

Set array flags WRITEABLE, ALIGNED, WRITEBACKIFCOPY, respectively.

These Boolean-valued flags affect how numpy interprets the memory area used by *a* (see Notes below). The ALIGNED flag can only be set to True if the data is actually aligned according to the type. The WRITEBACKIFCOPY flag can never be set to True. The flag WRITEABLE can only be set to True if the array owns its own memory, or the ultimate owner of the memory exposes a writeable buffer interface, or is a string. (The exception for string is made so that unpickling can be done without copying memory.)

Parameters

write
[bool, optional] Describes whether or not *a* can be written to.

align
[bool, optional] Describes whether or not *a* is aligned properly for its type.

uic
[bool, optional] Describes whether or not *a* is a copy of another "base" array.

Notes

Array flags provide information about how the memory area used for the array is to be interpreted. There are 7 Boolean flags in use, only three of which can be changed by the user: WRITEBACKIFCOPY, WRITEABLE, and ALIGNED.

WRITEABLE (W) the data area can be written to;

ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);

WRITEBACKIFCOPY (X) this array is a copy of some other array (referenced by .base). When the C-API function PyArray_ResolveWritebackIfCopy is called, the base array will be updated with the contents of this array.

All flags can be accessed using the single (upper case) letter as well as the full name.

Examples

```
>>> import numpy as np
>>> y = np.array([[3, 1, 7],
...               [2, 0, 0],
...               [8, 5, 9]])
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
>>> y.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
  OWNDATA : True
  WRITEABLE : True
  ALIGNED : True
  WRITEBACKIFCOPY : False
>>> y.setflags(write=0, align=0)
>>> y.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
```

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```
  OWNDATA : True
  WRITEABLE : False
  ALIGNED : False
  WRITEBACKIFCOPY : False
>>> y.setflags(uic=1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set WRITEBACKIFCOPY flag to True
```

method

`char.chararray.`**`sort`**(*axis=-1*, *kind=None*, *order=None*)

Sort an array in-place. Refer to *numpy.sort* for full documentation.

Parameters

axis
[int, optional] Axis along which to sort. Default is -1, which means sort along the last axis.

kind
[{'quicksort', 'mergesort', 'heapsort', 'stable'}, optional] Sorting algorithm. The default is 'quicksort'. Note that both 'stable' and 'mergesort' use timsort under the covers and, in general, the actual implementation will vary with datatype. The 'mergesort' option is retained for backwards compatibility.

order
[str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

See also:

numpy.sort
Return a sorted copy of an array.

numpy.argsort
Indirect sort.

numpy.lexsort
Indirect stable sort on multiple keys.

numpy.searchsorted
Find elements in sorted array.

numpy.partition
Partial sort.

Notes

See *numpy.sort* for notes on the different sorting algorithms.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,4], [3,1]])
>>> a.sort(axis=1)
>>> a
array([[1, 4],
       [1, 3]])
>>> a.sort(axis=0)
>>> a
array([[1, 3],
       [1, 4]])
```

Use the *order* keyword to specify a field to use when sorting a structured array:

```
>>> a = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
>>> a.sort(order='y')
>>> a
array([(b'c', 1), (b'a', 2)],
      dtype=[('x', 'S1'), ('y', '<i8')])
```

method

char.chararray.**split**(*sep=None*, *maxsplit=None*)

For each element in *self*, return a list of the words in the string, using *sep* as the delimiter string.

See also:

char.split

method

char.chararray.**splitlines**(*keepends=None*)

For each element in *self*, return a list of the lines in the element, breaking at line boundaries.

See also:

char.splitlines

method

char.chararray.**squeeze**(*axis=None*)

Remove axes of length one from *a*.

Refer to *numpy.squeeze* for full documentation.

See also:

numpy.squeeze
equivalent function

method

char.chararray.**startswith**(*prefix*, *start=0*, *end=None*)

Returns a boolean array which is *True* where the string element in *self* starts with *prefix*, otherwise *False*.

See also:

char.startswith

method

char.chararray.**strip**(*chars=None*)

For each element in *self*, return a copy with the leading and trailing characters removed.

See also:

char.strip

method

char.chararray.**swapaxes**(*axis1*, *axis2*)

Return a view of the array with *axis1* and *axis2* interchanged.

Refer to *numpy.swapaxes* for full documentation.

See also:

numpy.swapaxes
equivalent function

method

char.chararray.**swapcase**()

For each element in *self*, return a copy of the string with uppercase characters converted to lowercase and vice versa.

See also:

char.swapcase

method

char.chararray.**take**(*indices*, *axis=None*, *out=None*, *mode='raise'*)

Return an array formed from the elements of *a* at the given indices.

Refer to *numpy.take* for full documentation.

See also:

numpy.take
equivalent function

method

char.chararray.**title**()

For each element in *self*, return a titlecased version of the string: words start with uppercase characters, all remaining cased characters are lowercase.

See also:

char.title

method

char.chararray.**tofile**(*fid*, *sep=''*, *format='%s'*)

Write array to a file as text or binary (default).

Data is always written in 'C' order, independent of the order of *a*. The data produced by this method can be recovered using the function fromfile().

Parameters

fid
[file or str or Path] An open file object, or a string containing a filename.

sep
[str] Separator between array items for text output. If "" (empty), a binary file is written, equivalent to `file.write(a.tobytes())`.

format
[str] Format string for text file output. Each entry in the array is formatted to text by first converting it to the closest Python type, and then using "format" % item.

Notes

This is a convenience function for quick storage of array data. Information on endianness and precision is lost, so this method is not a good choice for files intended to archive data or transport data between machines with different endianness. Some of these problems can be overcome by outputting the data as text files, at the expense of speed and file size.

When fid is a file object, array contents are directly written to the file, bypassing the file object's `write` method. As a result, tofile cannot be used with files objects supporting compression (e.g., GzipFile) or file-like objects that do not support `fileno()` (e.g., BytesIO).

method

char.chararray.**tolist**()

Return the array as an `a.ndim`-levels deep nested list of Python scalars.

Return a copy of the array data as a (nested) Python list. Data items are converted to the nearest compatible builtin Python type, via the *item* function.

If `a.ndim` is 0, then since the depth of the nested list is 0, it will not be a list at all, but a simple Python scalar.

Parameters

none

Returns

y
[object, or list of object, or list of list of object, or …] The possibly nested list of array elements.

Notes

The array may be recreated via `a = np.array(a.tolist())`, although this may sometimes lose precision.

Examples

For a 1D array, `a.tolist()` is almost the same as `list(a)`, except that `tolist` changes numpy scalars to Python scalars:

```
>>> import numpy as np
>>> a = np.uint32([1, 2])
>>> a_list = list(a)
>>> a_list
[np.uint32(1), np.uint32(2)]
>>> type(a_list[0])
<class 'numpy.uint32'>
>>> a_tolist = a.tolist()
>>> a_tolist
[1, 2]
>>> type(a_tolist[0])
<class 'int'>
```

Additionally, for a 2D array, `tolist` applies recursively:

```
>>> a = np.array([[1, 2], [3, 4]])
>>> list(a)
[array([1, 2]), array([3, 4])]
>>> a.tolist()
[[1, 2], [3, 4]]
```

The base case for this recursion is a 0D array:

```
>>> a = np.array(1)
>>> list(a)
Traceback (most recent call last):
  ...
TypeError: iteration over a 0-d array
>>> a.tolist()
1
```

method

`char.chararray.`**`tostring`**(*order='C'*)

A compatibility alias for *tobytes*, with exactly the same behavior.

Despite its name, it returns `bytes` not `str`s.

Deprecated since version 1.19.0.

method

`char.chararray.`**`translate`**(*table*, *deletechars=None*)

For each element in *self*, return a copy of the string where all characters occurring in the optional argument *deletechars* are removed, and the remaining characters have been mapped through the given translation table.

See also:

char.translate

method

char.chararray.**transpose**(**axes*)

Returns a view of the array with axes transposed.

Refer to *numpy.transpose* for full documentation.

Parameters

axes
[None, tuple of ints, or *n* ints]

- None or no argument: reverses the order of the axes.
- tuple of ints: *i* in the *j*-th place in the tuple means that the array's *i*-th axis becomes the transposed array's *j*-th axis.
- *n* ints: same as an n-tuple of the same ints (this form is intended simply as a "convenience" alternative to the tuple form).

Returns

p
[ndarray] View of the array with its axes suitably permuted.

See also:

transpose
Equivalent function.

ndarray.T
Array property returning the array transposed.

ndarray.reshape
Give a new shape to an array without changing its data.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

```
>>> a = np.array([1, 2, 3, 4])
>>> a
array([1, 2, 3, 4])
>>> a.transpose()
array([1, 2, 3, 4])
```

method

char.chararray.**upper**()

Return an array with the elements of *self* converted to uppercase.

See also:

char.upper

method

char.chararray.**view**(*[dtype][, type]*)

New view of array with the same data.

Note: Passing None for `dtype` is different from omitting the parameter, since the former invokes `dtype(None)` which is an alias for `dtype('float64')`.

Parameters

dtype
[data-type or ndarray sub-class, optional] Data-type descriptor of the returned view, e.g., float32 or int16. Omitting it results in the view having the same data-type as *a*. This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the `type` parameter).

type
[Python type, optional] Type of the returned view, e.g., ndarray or matrix. Again, omission of the parameter results in type preservation.

Notes

`a.view()` is used two different ways:

`a.view(some_dtype)` or `a.view(dtype=some_dtype)` constructs a view of the array's memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

`a.view(ndarray_subclass)` or `a.view(type=ndarray_subclass)` just returns an instance of *ndarray_subclass* that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For `a.view(some_dtype)`, if `some_dtype` has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the last axis of `a` must be contiguous. This axis will be resized in the result.

Changed in version 1.23.0: Only the last axis needs to be contiguous. Previously, the entire array had to be C-contiguous.

Examples

```
>>> import numpy as np
>>> x = np.array([(-1, 2)], dtype=[('a', np.int8), ('b', np.int8)])
```

Viewing array data using a different type and dtype:

```
>>> nonneg = np.dtype([("a", np.uint8), ("b", np.uint8)])
>>> y = x.view(dtype=nonneg, type=np.recarray)
>>> x["a"]
array([-1], dtype=int8)
>>> y.a
array([255], dtype=uint8)
```

Creating a view on a structured array so it can be used in calculations

```
>>> x = np.array([(1, 2),(3,4)], dtype=[('a', np.int8), ('b', np.int8)])
>>> xv = x.view(dtype=np.int8).reshape(-1,2)
>>> xv
array([[1, 2],
       [3, 4]], dtype=int8)
>>> xv.mean(0)
array([2.,  3.])
```

Making changes to the view changes the underlying array

```
>>> xv[0,1] = 20
>>> x
array([(1, 20), (3,  4)], dtype=[('a', 'i1'), ('b', 'i1')])
```

Using a view to convert an array to a recarray:

```
>>> z = x.view(np.recarray)
>>> z.a
array([1, 3], dtype=int8)
```

Views share data:

```
>>> x[0] = (9, 10)
>>> z[0]
np.record((9, 10), dtype=[('a', 'i1'), ('b', 'i1')])
```

Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.:

```
>>> x = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.int16)
>>> y = x[:, ::2]
>>> y
array([[1, 3],
       [4, 6]], dtype=int16)
>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
    ...
ValueError: To change to a dtype of a different size, the last axis must be␣
↪contiguous
>>> z = y.copy()
>>> z.view(dtype=[('width', np.int16), ('length', np.int16)])
```

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```
array([[(1, 3)],
       [(4, 6)]], dtype=[('width', '<i2'), ('length', '<i2')])
```

However, views that change dtype are totally fine for arrays with a contiguous last axis, even if the rest of the axes are not C-contiguous:

```
>>> x = np.arange(2 * 3 * 4, dtype=np.int8).reshape(2, 3, 4)
>>> x.transpose(1, 0, 2).view(np.int16)
array([[[ 256,  770],
        [3340, 3854]],

       [[1284, 1798],
        [4368, 4882]],

       [[2312, 2826],
        [5396, 5910]]], dtype=int16)
```

method

`char.chararray.zfill(width)`

Return the numeric string left-filled with zeros in a string of length *width*.

See also:

char.zfill

Packaging (`numpy.distutils`)

Warning: `numpy.distutils` is deprecated, and will be removed for Python >= 3.12. For more details, see *Status of numpy.distutils and migration advice*

Warning: Note that `setuptools` does major releases often and those may contain changes that break *numpy.distutils*, which will *not* be updated anymore for new `setuptools` versions. It is therefore recommended to set an upper version bound in your build configuration for the last known version of `setuptools` that works with your build.

NumPy provides enhanced distutils functionality to make it easier to build and install sub-packages, auto-generate code, and extension modules that use Fortran-compiled libraries. A useful *Configuration* class is also provided in *numpy.distutils.misc_util* that can make it easier to construct keyword arguments to pass to the setup function (by passing the dictionary obtained from the todict() method of the class). More information is available in the *numpy.distutils user guide*.

The choice and location of linked libraries such as BLAS and LAPACK as well as include paths and other such build options can be specified in a `site.cfg` file located in the NumPy root repository or a `.numpy-site.cfg` file in your home directory. See the `site.cfg.example` example file included in the NumPy repository or sdist for documentation.

Modules in `numpy.distutils`

distutils.misc_util

numpy.distutils.misc_util.**all_strings**(*lst*)

Return True if all items in lst are string objects.

numpy.distutils.misc_util.**allpath**(*name*)

Convert a /-separated pathname to one using the OS's path separator.

numpy.distutils.misc_util.**appendpath**(*prefix*, *path*)

numpy.distutils.misc_util.**as_list**(*seq*)

numpy.distutils.misc_util.**blue_text**(*s*)

numpy.distutils.misc_util.**cyan_text**(*s*)

numpy.distutils.misc_util.**cyg2win32**(*path: str*) → str

Convert a path from Cygwin-native to Windows-native.

Uses the cygpath utility (part of the Base install) to do the actual conversion. Falls back to returning the original path if this fails.

Handles the default `/cygdrive` mount prefix as well as the `/proc/cygdrive` portable prefix, custom cygdrive prefixes such as `/` or `/mnt`, and absolute paths such as `/usr/src/` or `/home/username`

Parameters

path
[str] The path to convert

Returns

converted_path
[str] The converted path

Notes

Documentation for cygpath utility: https://cygwin.com/cygwin-ug-net/cygpath.html Documentation for the C function it wraps: https://cygwin.com/cygwin-api/func-cygwin-conv-path.html

numpy.distutils.misc_util.**default_config_dict**(*name=None*, *parent_name=None*, *local_path=None*)

Return a configuration dictionary for usage in configuration() function defined in file setup_<name>.py.

numpy.distutils.misc_util.**dict_append**(*d*, ***kws*)

numpy.distutils.misc_util.**dot_join**(**args*)

numpy.distutils.misc_util.**exec_mod_from_location**(*modname*, *modfile*)

Use importlib machinery to import a module *modname* from the file *modfile*. Depending on the *spec.loader*, the module may not be registered in sys.modules.

numpy.distutils.misc_util.**filter_sources**(*sources*)

Return four lists of filenames containing C, C++, Fortran, and Fortran 90 module sources, respectively.

numpy.distutils.misc_util.**generate_config_py**(*target*)

Generate config.py file containing system_info information used during building the package.

Usage:

config['py_modules'].append((packagename, '__config__',generate_config_py))

numpy.distutils.misc_util.**get_build_architecture**()

numpy.distutils.misc_util.**get_cmd**(*cmdname*, *_cache={}*)

numpy.distutils.misc_util.**get_data_files**(*data*)

numpy.distutils.misc_util.**get_dependencies**(*sources*)

numpy.distutils.misc_util.**get_ext_source_files**(*ext*)

numpy.distutils.misc_util.**get_frame**(*level=0*)

Return frame object from call stack with given level.

numpy.distutils.misc_util.**get_info**(*pkgname*, *dirs=None*)

Return an info dict for a given C library.

The info dict contains the necessary options to use the C library.

Parameters

pkgname

[str] Name of the package (should match the name of the .ini file, without the extension, e.g. foo for the file foo.ini).

dirs

[sequence, optional] If given, should be a sequence of additional directories where to look for npy-pkg-config files. Those directories are searched prior to the NumPy directory.

Returns

info

[dict] The dictionary with build information.

Raises

PkgNotFound

If the package is not found.

See also:

Configuration.add_npy_pkg_config, *Configuration.add_installed_library*
get_pkg_info

Examples

To get the necessary information for the npymath library from NumPy:

```
>>> npymath_info = np.distutils.misc_util.get_info('npymath')
>>> npymath_info
{'define_macros': [], 'libraries': ['npymath'], 'library_dirs':
['.../numpy/_core/lib'], 'include_dirs': ['.../numpy/_core/include']}
```

This info dict can then be used as input to a *Configuration* instance:

```
config.add_extension('foo', sources=['foo.c'], extra_info=npymath_info)
```

numpy.distutils.misc_util.**get_language**(*sources*)

Determine language value (c,f77,f90) from sources

numpy.distutils.misc_util.**get_lib_source_files**(*lib*)

numpy.distutils.misc_util.**get_mathlibs**(*path=None*)

Return the MATHLIB line from numpyconfig.h

numpy.distutils.misc_util.**get_num_build_jobs**()

Get number of parallel build jobs set by the –parallel command line argument of setup.py If the command did not receive a setting the environment variable NPY_NUM_BUILD_JOBS is checked. If that is unset, return the number of processors on the system, with a maximum of 8 (to prevent overloading the system if there a lot of CPUs).

Returns

out
[int] number of parallel jobs that can be run

numpy.distutils.misc_util.**get_numpy_include_dirs**()

numpy.distutils.misc_util.**get_pkg_info**(*pkgname*, *dirs=None*)

Return library info for the given package.

Parameters

pkgname
[str] Name of the package (should match the name of the .ini file, without the extension, e.g. foo for the file foo.ini).

dirs
[sequence, optional] If given, should be a sequence of additional directories where to look for npy-pkg-config files. Those directories are searched prior to the NumPy directory.

Returns

pkginfo
[class instance] The *LibraryInfo* instance containing the build information.

Raises

PkgNotFound
If the package is not found.

See also:

Configuration.add_npy_pkg_config, ***Configuration.add_installed_library***
get_info

numpy.distutils.misc_util.**get_script_files**(*scripts*)

numpy.distutils.misc_util.**gpaths**(*paths*, *local_path=''*, *include_non_existing=True*)

Apply glob to paths and prepend local_path if needed.

numpy.distutils.misc_util.**green_text**(*s*)

numpy.distutils.misc_util.**has_cxx_sources**(*sources*)

Return True if sources contains C++ files

numpy.distutils.misc_util.**has_f_sources**(*sources*)

Return True if sources contains Fortran files

numpy.distutils.misc_util.**is_local_src_dir**(*directory*)

Return true if directory is local directory.

numpy.distutils.misc_util.**is_sequence**(*seq*)

numpy.distutils.misc_util.**is_string**(*s*)

numpy.distutils.misc_util.**mingw32**()

Return true when using mingw32 environment.

numpy.distutils.misc_util.**minrelpath**(*path*)

Resolve and '.' from path.

numpy.distutils.misc_util.**njoin**(**path*)

Join two or more pathname components + - convert a /-separated pathname to one using the OS's path separator. - resolve and from path.

Either passing n arguments as in njoin('a','b'), or a sequence of n names as in njoin(['a','b']) is handled, or a mixture of such arguments.

numpy.distutils.misc_util.**red_text**(*s*)

numpy.distutils.misc_util.**sanitize_cxx_flags**(*cxxflags*)

Some flags are valid for C but not C++. Prune them.

numpy.distutils.misc_util.**terminal_has_colors**()

numpy.distutils.misc_util.**yellow_text**(*s*)

ccompiler	
ccompiler_opt	Provides the *CCompilerOpt* class, used for handling the CPU/hardware optimization, starting from parsing the command arguments, to managing the relation between the CPU baseline and dispatch-able features, also generating the required C headers and ending with compiling the sources with proper compiler's flags.
cpuinfo.cpu	
core.Extension(name, sources[, ...])	**Parameters**
exec_command	exec_command
log.set_verbosity(v[, force])	
system_info.get_info(name[, notfound_action])	notfound_action:
system_info.get_standard_file(fname)	Returns a list of files named 'fname' from 1) System-wide directory (directory-location of this module) 2) Users HOME directory (os.environ['HOME']) 3) Local directory

Functions

CCompiler_compile(self, sources[, ...])	Compile one or more source files.
CCompiler_customize(self, dist[, need_cxx])	Do any platform-specific customization of a compiler instance.
CCompiler_customize_cmd(self, cmd[, ignore])	Customize compiler using distutils command.
CCompiler_cxx_compiler(self)	Return the C++ compiler.
CCompiler_find_executables(self)	Does nothing here, but is called by the get_version method and can be overridden by subclasses.
CCompiler_get_version(self[, force, ok_status])	Return compiler version, or None if compiler is not available.
CCompiler_object_filenames(self, ...[, ...])	Return the name of the object files for the given source files.
CCompiler_show_customization(self)	Print the compiler customizations to stdout.
CCompiler_spawn(self, cmd[, display, env])	Execute a command in a sub-process.
gen_lib_options(compiler, library_dirs, ...)	
new_compiler([plat, compiler, verbose, ...])	
replace_method(klass, method_name, func)	
simple_version_match([pat, ignore, start])	Simple matching of version numbers, for use in CCompiler and FCompiler.

distutils.ccompiler.**CCompiler_compile**(*self*, *sources*, *output_dir=None*, *macros=None*, *include_dirs=None*, *debug=0*, *extra_preargs=None*, *extra_postargs=None*, *depends=None*)

Compile one or more source files.

Please refer to the Python distutils API reference for more details.

Parameters

sources
[list of str] A list of filenames

output_dir
[str, optional] Path to the output directory.

macros
[list of tuples] A list of macro definitions.

include_dirs
[list of str, optional] The directories to add to the default include file search path for this compilation only.

debug
[bool, optional] Whether or not to output debug symbols in or alongside the object file(s).

extra_preargs, extra_postargs
[?] Extra pre- and post-arguments.

depends
[list of str, optional] A list of file names that all targets depend on.

Returns

objects
[list of str] A list of object file names, one per source file *sources*.

Raises

CompileError
If compilation fails.

distutils.ccompiler.**CCompiler_customize**(*self*, *dist*, *need_cxx=0*)

Do any platform-specific customization of a compiler instance.

This method calls `distutils.sysconfig.customize_compiler` for platform-specific customization, as well as optionally remove a flag to suppress spurious warnings in case C++ code is being compiled.

Parameters

dist
[object] This parameter is not used for anything.

need_cxx
[bool, optional] Whether or not C++ has to be compiled. If so (True), the `"-Wstrict-prototypes"` option is removed to prevent spurious warnings. Default is False.

Returns

None

Notes

All the default options used by distutils can be extracted with:

```
from distutils import sysconfig
sysconfig.get_config_vars('CC', 'CXX', 'OPT', 'BASECFLAGS',
                          'CCSHARED', 'LDSHARED', 'SO')
```

distutils.ccompiler.**CCompiler_customize_cmd**(*self*, *cmd*, *ignore=()*)

Customize compiler using distutils command.

Parameters

cmd
[class instance] An instance inheriting from `distutils.cmd.Command`.

ignore
[sequence of str, optional] List of `distutils.ccompiler.CCompiler` commands (without `'set_'`) that should not be altered. Strings that are checked for are: `('include_dirs', 'define', 'undef', 'libraries', 'library_dirs', 'rpath', 'link_objects')`.

Returns

None

distutils.ccompiler.**CCompiler_cxx_compiler**(*self*)

Return the C++ compiler.

Parameters

None

Returns

cxx
[class instance] The C++ compiler, as a `distutils.ccompiler.CCompiler` instance.

`distutils.ccompiler.`**`CCompiler_find_executables`**(*self*)

Does nothing here, but is called by the get_version method and can be overridden by subclasses. In particular it is redefined in the *FCompiler* class where more documentation can be found.

`distutils.ccompiler.`**`CCompiler_get_version`**(*self*, *force=False*, *ok_status=[0]*)

Return compiler version, or None if compiler is not available.

Parameters

force
[bool, optional] If True, force a new determination of the version, even if the compiler already has a version attribute. Default is False.

ok_status
[list of int, optional] The list of status values returned by the version look-up process for which a version string is returned. If the status value is not in *ok_status*, None is returned. Default is `[0]`.

Returns

version
[str or None] Version string, in the format of `distutils.version.LooseVersion`.

`distutils.ccompiler.`**`CCompiler_object_filenames`**(*self*, *source_filenames*, *strip_dir=0*, *output_dir=''*)

Return the name of the object files for the given source files.

Parameters

source_filenames
[list of str] The list of paths to source files. Paths can be either relative or absolute, this is handled transparently.

strip_dir
[bool, optional] Whether to strip the directory from the returned paths. If True, the file name prepended by *output_dir* is returned. Default is False.

output_dir
[str, optional] If given, this path is prepended to the returned paths to the object files.

Returns

obj_names
[list of str] The list of paths to the object files corresponding to the source files in *source_filenames*.

`distutils.ccompiler.`**`CCompiler_show_customization`**(*self*)

Print the compiler customizations to stdout.

Parameters

None

Returns

None

Notes

Printing is only done if the distutils log threshold is < 2.

distutils.ccompiler.**CCompiler_spawn**(*self*, *cmd*, *display=None*, *env=None*)

Execute a command in a sub-process.

Parameters

cmd
[str] The command to execute.

display
[str or sequence of str, optional] The text to add to the log file kept by *numpy.distutils*. If not given, *display* is equal to `cmd`.

env
[a dictionary for environment variables, optional]

Returns

None

Raises

DistutilsExecError
If the command failed, i.e. the exit status was not 0.

distutils.ccompiler.**gen_lib_options**(*compiler*, *library_dirs*, *runtime_library_dirs*, *libraries*)

distutils.ccompiler.**new_compiler**(*plat=None*, *compiler=None*, *verbose=None*, *dry_run=0*, *force=0*)

distutils.ccompiler.**replace_method**(*klass*, *method_name*, *func*)

distutils.ccompiler.**simple_version_match**(*pat='[-.\\d]+'*, *ignore=''*, *start=''*)

Simple matching of version numbers, for use in CCompiler and FCompiler.

Parameters

pat
[str, optional] A regular expression matching version numbers. Default is `r'[-.\d]+'`.

ignore
[str, optional] A regular expression matching patterns to skip. Default is `''`, in which case nothing is skipped.

start
[str, optional] A regular expression matching the start of where to start looking for version numbers. Default is `''`, in which case searching is started at the beginning of the version string given to *matcher*.

Returns

matcher
[callable] A function that is appropriate to use as the `.version_match` attribute of a `distutils.ccompiler.CCompiler` class. *matcher* takes a single parameter, a version string.

Provides the *CCompilerOpt* class, used for handling the CPU/hardware optimization, starting from parsing the command arguments, to managing the relation between the CPU baseline and dispatch-able features, also generating the required C headers and ending with compiling the sources with proper compiler's flags.

CCompilerOpt doesn't provide runtime detection for the CPU features, instead only focuses on the compiler side, but it creates abstract C headers that can be used later for the final runtime dispatching process.

Functions

new_ccompiler_opt(compiler, dispatch_hpath, ...)	Create a new instance of 'CCompilerOpt' and generate the dispatch header which contains the #definitions and headers of platform-specific instruction-sets for the enabled CPU baseline and dispatch-able features.

distutils.ccompiler_opt.**new_ccompiler_opt**(*compiler*, *dispatch_hpath*, ***kwargs*)

Create a new instance of 'CCompilerOpt' and generate the dispatch header which contains the #definitions and headers of platform-specific instruction-sets for the enabled CPU baseline and dispatch-able features.

Parameters

compiler
[CCompiler instance]

dispatch_hpath
[str] path of the dispatch header

****kwargs: passed as-is to `CCompilerOpt(...)`**
Returns
——-
new instance of CCompilerOpt

Classes

CCompilerOpt(ccompiler[, cpu_baseline, ...])	A helper class for *CCompiler* aims to provide extra build options to effectively control of compiler optimizations that are directly related to CPU features.

class numpy.distutils.ccompiler_opt.**CCompilerOpt**(*ccompiler*, *cpu_baseline='min'*, *cpu_dispatch='max'*, *cache_path=None*)

A helper class for *CCompiler* aims to provide extra build options to effectively control of compiler optimizations that are directly related to CPU features.

Attributes

conf_cache_factors
conf_tmp_path

Methods

cache_flush()	Force update the cache.
cc_normalize_flags(flags)	Remove the conflicts that caused due gathering implied features flags.
conf_features_partial()	Return a dictionary of supported CPU features by the platform, and accumulate the rest of undefined options in `conf_features`, the returned dict has same rules and notes in class attribute `conf_features`, also its override any options that been set in 'conf_features'.
cpu_baseline_flags()	Returns a list of final CPU baseline compiler flags
cpu_baseline_names()	return a list of final CPU baseline feature names
cpu_dispatch_names()	return a list of final CPU dispatch feature names
dist_compile(sources, flags[, ccompiler])	Wrap CCompiler.compile()
dist_error(*args)	Raise a compiler error
dist_fatal(*args)	Raise a distutils error
dist_info()	Return a tuple containing info about (platform, compiler, extra_args), required by the abstract class '_CCompiler' for discovering the platform environment.
dist_load_module(name, path)	Load a module from file, required by the abstract class '_Cache'.
dist_log(*args[, stderr])	Print a console message
dist_test(source, flags[, macros])	Return True if 'CCompiler.compile()' able to compile a source file with certain flags.
feature_ahead(names)	Return list of features in 'names' after remove any implied features and keep the origins.
feature_c_preprocessor(feature_name[, tabs])	Generate C preprocessor definitions and include headers of a CPU feature.
feature_detect(names)	Return a list of CPU features that required to be detected sorted from the lowest to highest interest.
feature_get_til(names, keyisfalse)	same as *feature_implies_c()* but stop collecting implied features when feature's option that provided through parameter 'keyisfalse' is False, also sorting the returned features.
feature_implies(names[, keep_origins])	Return a set of CPU features that implied by 'names'
feature_implies_c(names)	same as feature_implies() but combining 'names'
feature_is_exist(name)	Returns True if a certain feature is exist and covered within `_Config.conf_features`.
feature_names([names, force_flags, macros])	Returns a set of CPU feature names that supported by platform and the **C** compiler.
feature_sorted(names[, reverse])	Sort a list of CPU features ordered by the lowest interest.
feature_untied(names)	same as 'feature_ahead()' but if both features implied each other and keep the highest interest.
generate_dispatch_header(header_path)	Generate the dispatch header which contains the #definitions and headers for platform-specific instruction-sets for the enabled CPU baseline and dispatch-able features.
is_cached()	Returns True if the class loaded from the cache file
me(cb)	A static method that can be treated as a decorator to dynamically cache certain methods.
parse_targets(source)	Fetch and parse configuration statements that required for defining the targeted CPU features, statements should be declared in the top of source in between **C** comment and start with a special mark **@targets**.
try_dispatch(sources[, src_dir, ccompiler])	Compile one or more dispatch-able sources and generates object files, also generates abstract C config head-

method

distutils.ccompiler_opt.CCompilerOpt.**cache_flush**()

Force update the cache.

method

distutils.ccompiler_opt.CCompilerOpt.**cc_normalize_flags**(*flags*)

Remove the conflicts that caused due gathering implied features flags.

Parameters

'flags' list, compiler flags
flags should be sorted from the lowest to the highest interest.

Returns

list, filtered from any conflicts.

Examples

```
>>> self.cc_normalize_flags(['-march=armv8.2-a+fp16', '-march=armv8.2-
↪a+dotprod'])
['armv8.2-a+fp16+dotprod']
```

```
>>> self.cc_normalize_flags(
    ['-msse', '-msse2', '-msse3', '-mssse3', '-msse4.1', '-msse4.2', '-mavx',
↪'-march=core-avx2']
)
['-march=core-avx2']
```

method

distutils.ccompiler_opt.CCompilerOpt.**conf_features_partial**()

Return a dictionary of supported CPU features by the platform, and accumulate the rest of undefined options in `conf_features`, the returned dict has same rules and notes in class attribute `conf_features`, also its override any options that been set in 'conf_features'.

method

distutils.ccompiler_opt.CCompilerOpt.**cpu_baseline_flags**()

Returns a list of final CPU baseline compiler flags

method

distutils.ccompiler_opt.CCompilerOpt.**cpu_baseline_names**()

return a list of final CPU baseline feature names

method

distutils.ccompiler_opt.CCompilerOpt.**cpu_dispatch_names**()

return a list of final CPU dispatch feature names

method

distutils.ccompiler_opt.CCompilerOpt.**dist_compile**(*sources*, *flags*, *ccompiler=None*, ***kwargs*)

Wrap CCompiler.compile()

method

static distutils.ccompiler_opt.CCompilerOpt.**dist_error**(**args*)

Raise a compiler error

method

static distutils.ccompiler_opt.CCompilerOpt.**dist_fatal**(**args*)

Raise a distutils error

method

distutils.ccompiler_opt.CCompilerOpt.**dist_info**()

Return a tuple containing info about (platform, compiler, extra_args), required by the abstract class '_CCompiler' for discovering the platform environment. This is also used as a cache factor in order to detect any changes happening from outside.

method

static distutils.ccompiler_opt.CCompilerOpt.**dist_load_module**(*name*, *path*)

Load a module from file, required by the abstract class '_Cache'.

method

static distutils.ccompiler_opt.CCompilerOpt.**dist_log**(**args*, *stderr=False*)

Print a console message

method

distutils.ccompiler_opt.CCompilerOpt.**dist_test**(*source*, *flags*, *macros=[]*)

Return True if 'CCompiler.compile()' able to compile a source file with certain flags.

method

distutils.ccompiler_opt.CCompilerOpt.**feature_ahead**(*names*)

Return list of features in 'names' after remove any implied features and keep the origins.

Parameters

'names': sequence
sequence of CPU feature names in uppercase.

Returns

list of CPU features sorted as-is 'names'

Examples

```
>>> self.feature_ahead(["SSE2", "SSE3", "SSE41"])
["SSE41"]
# assume AVX2 and FMA3 implies each other and AVX2
# is the highest interest
>>> self.feature_ahead(["SSE2", "SSE3", "SSE41", "AVX2", "FMA3"])
["AVX2"]
# assume AVX2 and FMA3 don't implies each other
>>> self.feature_ahead(["SSE2", "SSE3", "SSE41", "AVX2", "FMA3"])
["AVX2", "FMA3"]
```

method

distutils.ccompiler_opt.CCompilerOpt.**feature_c_preprocessor**(*feature_name*, *tabs=0*)

Generate C preprocessor definitions and include headers of a CPU feature.

Parameters

'feature_name': str
CPU feature name in uppercase.

'tabs': int
if > 0, align the generated strings to the right depend on number of tabs.

Returns

str, generated C preprocessor

Examples

```
>>> self.feature_c_preprocessor("SSE3")
/** SSE3 **/
#define NPY_HAVE_SSE3 1
#include <pmmintrin.h>
```

method

distutils.ccompiler_opt.CCompilerOpt.**feature_detect**(*names*)

Return a list of CPU features that required to be detected sorted from the lowest to highest interest.

method

distutils.ccompiler_opt.CCompilerOpt.**feature_get_til**(*names*, *keyisfalse*)

same as *feature_implies_c()* but stop collecting implied features when feature's option that provided through parameter 'keyisfalse' is False, also sorting the returned features.

method

distutils.ccompiler_opt.CCompilerOpt.**feature_implies**(*names*, *keep_origins=False*)

Return a set of CPU features that implied by 'names'

Parameters

names
[str or sequence of str] CPU feature name(s) in uppercase.

keep_origins
[bool] if False(default) then the returned set will not contain any features from 'names'. This case happens only when two features imply each other.

Examples

```
>>> self.feature_implies("SSE3")
{'SSE', 'SSE2'}
>>> self.feature_implies("SSE2")
{'SSE'}
>>> self.feature_implies("SSE2", keep_origins=True)
# 'SSE2' found here since 'SSE' and 'SSE2' imply each other
{'SSE', 'SSE2'}
```

method

distutils.ccompiler_opt.CCompilerOpt.**feature_implies_c**(*names*)

same as feature_implies() but combining 'names'

method

distutils.ccompiler_opt.CCompilerOpt.**feature_is_exist**(*name*)

Returns True if a certain feature is exist and covered within `_Config.conf_features`.

Parameters

'name': str
feature name in uppercase.

method

distutils.ccompiler_opt.CCompilerOpt.**feature_names**(*names=None*, *force_flags=None*, *macros=[]*)

Returns a set of CPU feature names that supported by platform and the **C** compiler.

Parameters

names
[sequence or None, optional] Specify certain CPU features to test it against the **C** compiler. if None(default), it will test all current supported features. **Note**: feature names must be in upper-case.

force_flags
[list or None, optional] If None(default), default compiler flags for every CPU feature will be used during the test.

macros
[list of tuples, optional] A list of C macro definitions.

method

distutils.ccompiler_opt.CCompilerOpt.**feature_sorted**(*names*, *reverse=False*)

Sort a list of CPU features ordered by the lowest interest.

Parameters

'names': sequence
sequence of supported feature names in uppercase.

'reverse': bool, optional
If true, the sorted features is reversed. (highest interest)

Returns

list, sorted CPU features

method

distutils.ccompiler_opt.CCompilerOpt.**feature_untied**(*names*)

same as 'feature_ahead()' but if both features implied each other and keep the highest interest.

Parameters

'names': sequence
sequence of CPU feature names in uppercase.

Returns

list of CPU features sorted as-is 'names'

Examples

```
>>> self.feature_untied(["SSE2", "SSE3", "SSE41"])
["SSE2", "SSE3", "SSE41"]
# assume AVX2 and FMA3 implies each other
>>> self.feature_untied(["SSE2", "SSE3", "SSE41", "FMA3", "AVX2"])
["SSE2", "SSE3", "SSE41", "AVX2"]
```

method

distutils.ccompiler_opt.CCompilerOpt.**generate_dispatch_header**(*header_path*)

Generate the dispatch header which contains the #definitions and headers for platform-specific instruction-sets for the enabled CPU baseline and dispatch-able features.

Its highly recommended to take a look at the generated header also the generated source files via *try_dispatch()* in order to get the full picture.

method

distutils.ccompiler_opt.CCompilerOpt.**is_cached**()

Returns True if the class loaded from the cache file

method

static distutils.ccompiler_opt.CCompilerOpt.**me**(*cb*)

A static method that can be treated as a decorator to dynamically cache certain methods.

method

distutils.ccompiler_opt.CCompilerOpt.**parse_targets**(*source*)

Fetch and parse configuration statements that required for defining the targeted CPU features, statements should be declared in the top of source in between **C** comment and start with a special mark **@targets**.

Configuration statements are sort of keywords representing CPU features names, group of statements and policies, combined together to determine the required optimization.

Parameters

source
[str] the path of **C** source file.

Returns

- **bool, True if group has the 'baseline' option**
- **list, list of CPU features**
- **list, list of extra compiler flags**

method

distutils.ccompiler_opt.CCompilerOpt.**try_dispatch**(*sources*, *src_dir=None*, *ccompiler=None*, ***kwargs*)

Compile one or more dispatch-able sources and generates object files, also generates abstract C config headers and macros that used later for the final runtime dispatching process.

The mechanism behind it is to takes each source file that specified in 'sources' and branching it into several files depend on special configuration statements that must be declared in the top of each source which contains targeted CPU features, then it compiles every branched source with the proper compiler flags.

Parameters

sources
[list] Must be a list of dispatch-able sources file paths, and configuration statements must be declared inside each file.

src_dir
[str] Path of parent directory for the generated headers and wrapped sources. If None(default) the files will generated in-place.

ccompiler
[CCompiler] Distutils *CCompiler* instance to be used for compilation. If None (default), the provided instance during the initialization will be used instead.

****kwargs**
[any] Arguments to pass on to the *CCompiler.compile()*

Returns

list
[generated object files]

Raises

CompileError
Raises by *CCompiler.compile()* on compiling failure.

DistutilsError
Some errors during checking the sanity of configuration statements.

See also:

parse_targets
Parsing the configuration statements of dispatch-able sources.

cache_hash
cc_test_cexpr
cc_test_flags
feature_can_autovec
feature_extra_checks
feature_flags
feature_is_supported
feature_test
report

distutils.cpuinfo.**cpu = <numpy.distutils.cpuinfo.LinuxCPUInfo object>**

class numpy.distutils.core.**Extension**(*name*, *sources*, *include_dirs=None*, *define_macros=None*, *undef_macros=None*, *library_dirs=None*, *libraries=None*, *runtime_library_dirs=None*, *extra_objects=None*, *extra_compile_args=None*, *extra_link_args=None*, *export_symbols=None*, *swig_opts=None*, *depends=None*, *language=None*, *f2py_options=None*, *module_dirs=None*, *extra_c_compile_args=None*, *extra_cxx_compile_args=None*, *extra_f77_compile_args=None*, *extra_f90_compile_args=None*)

Parameters

name
[str] Extension name.

sources
[list of str] List of source file locations relative to the top directory of the package.

extra_compile_args
[list of str] Extra command line arguments to pass to the compiler.

extra_f77_compile_args
[list of str] Extra command line arguments to pass to the fortran77 compiler.

extra_f90_compile_args
[list of str] Extra command line arguments to pass to the fortran90 compiler.

Methods

has_cxx_sources
has_f2py_sources

exec_command

Implements exec_command function that is (almost) equivalent to commands.getstatusoutput function but on NT, DOS systems the returned status is actually correct (though, the returned status values may be different by a factor). In addition, exec_command takes keyword arguments for (re-)defining environment variables.

Provides functions:

exec_command — execute command in a specified directory and
in the modified environment.

find_executable — locate a command using info from environment
variable PATH. Equivalent to posix *which* command.

Author: Pearu Peterson <pearu@cens.ioc.ee> Created: 11 January 2003

Requires: Python 2.x

Successfully tested on:

os.na	sys.pla	comments
posix	linux2	Debian (sid) Linux, Python 2.1.3+, 2.2.3+, 2.3.3 PyCrust 0.9.3, Idle 1.0.2
posix	linux2	Red Hat 9 Linux, Python 2.1.3, 2.2.2, 2.3.2
posix	sunos5	SunOS 5.9, Python 2.2, 2.3.2
posix	dar-win	Darwin 7.2.0, Python 2.3
nt	win32	Windows Me Python 2.3(EE), Idle 1.0, PyCrust 0.7.2 Python 2.1.1 Idle 0.8
nt	win32	Windows 98, Python 2.1.1. Idle 0.8
nt	win32	Cygwin 98-4.10, Python 2.1.1(MSC) - echo tests fail i.e. redefining environment variables may not work. FIXED: don't use cygwin echo! Comment: also *cmd /c echo* will not work but redefining environment variables do work.
posix	cyg-win	Cygwin 98-4.10, Python 2.3.3(cygming special)
nt	win32	Windows XP, Python 2.3.3

Known bugs:

- Tests, that send messages to stderr, fail when executed from MSYS prompt because the messages are lost at some point.

Functions

exec_command(command[, execute_in, ...])	Return (status,output) of executed command.
filepath_from_subprocess_output(output)	Convert *bytes* in the encoding used by a subprocess into a filesystem-appropriate *str*.
find_executable(exe[, path, _cache])	Return full path of a executable or None.
forward_bytes_to_stdout(val)	Forward bytes from a subprocess call to the console, without attempting to decode them.
get_pythonexe()	
temp_file_name()	

distutils.exec_command.**exec_command**(*command*, *execute_in=''*, *use_shell=None*, *use_tee=None*, *_with_python=1*, ***env*)

Return (status,output) of executed command.

Deprecated since version 1.17: Use subprocess.Popen instead

Parameters

command
[str] A concatenated string of executable and arguments.

execute_in
[str] Before running command `cd execute_in` and after `cd -`.

use_shell
[{bool, None}, optional] If True, execute `sh -c command`. Default None (True)

use_tee
[{bool, None}, optional] If True use tee. Default None (True)

Returns

res
[str] Both stdout and stderr messages.

Notes

On NT, DOS systems the returned status is correct for external commands. Wild cards will not work for non-posix systems or when use_shell=0.

distutils.exec_command.**filepath_from_subprocess_output**(*output*)

Convert *bytes* in the encoding used by a subprocess into a filesystem-appropriate *str*.

Inherited from *exec_command*, and possibly incorrect.

distutils.exec_command.**find_executable**(*exe*, *path=None*, *_cache={}*)

Return full path of a executable or None.

Symbolic links are not followed.

distutils.exec_command.**forward_bytes_to_stdout**(*val*)

Forward bytes from a subprocess call to the console, without attempting to decode them.

The assumption is that the subprocess call already returned bytes in a suitable encoding.

distutils.exec_command.**get_pythonexe**()

distutils.exec_command.**temp_file_name**()

distutils.log.**set_verbosity**(*v*, *force=False*)

distutils.system_info.**get_info**(*name*, *notfound_action=0*)

notfound_action:
0 - do nothing 1 - display warning message 2 - raise error

distutils.system_info.**get_standard_file**(*fname*)

Returns a list of files named 'fname' from 1) System-wide directory (directory-location of this module) 2) Users HOME directory (os.environ['HOME']) 3) Local directory

Configuration class

class numpy.distutils.misc_util.**Configuration**(*package_name=None*, *parent_name=None*, *top_path=None*, *package_path=None*, ***attrs*)

Construct a configuration instance for the given package name. If *parent_name* is not None, then construct the package as a sub-package of the *parent_name* package. If *top_path* and *package_path* are None then they are assumed equal to the path of the file this instance was created in. The setup.py files in the numpy distribution are good examples of how to use the *Configuration* instance.

todict()

Return a dictionary compatible with the keyword arguments of distutils setup function.

Examples

```
>>> setup(**config.todict())
```

get_distribution()

Return the distutils distribution object for self.

get_subpackage(*subpackage_name*, *subpackage_path=None*, *parent_name=None*, *caller_level=1*)

Return list of subpackage configurations.

Parameters

subpackage_name
[str or None] Name of the subpackage to get the configuration. '*' in subpackage_name is handled as a wildcard.

subpackage_path
[str] If None, then the path is assumed to be the local path plus the subpackage_name. If a setup.py file is not found in the subpackage_path, then a default configuration is used.

parent_name
[str] Parent name.

add_subpackage(*subpackage_name*, *subpackage_path=None*, *standalone=False*)

Add a sub-package to the current Configuration instance.

This is useful in a setup.py script for adding sub-packages to a package.

Parameters

subpackage_name
[str] name of the subpackage

subpackage_path
[str] if given, the subpackage path such as the subpackage is in subpackage_path / subpackage_name. If None,the subpackage is assumed to be located in the local path / subpackage_name.

standalone
[bool]

add_data_files(**files*)

Add data files to configuration data_files.

Parameters

files
[sequence] Argument(s) can be either

- 2-sequence (<datadir prefix>,<path to data file(s)>)
- paths to data files where python datadir prefix defaults to package dir.

Notes

The form of each element of the files sequence is very flexible allowing many combinations of where to get the files from the package and where they should ultimately be installed on the system. The most basic usage is for an element of the files argument sequence to be a simple filename. This will cause that file from the local path to be installed to the installation path of the self.name package (package path). The file argument can also be a relative path in which case the entire relative path will be installed into the package directory. Finally, the file can be an absolute path name in which case the file will be found at the absolute path name but installed to the package path.

This basic behavior can be augmented by passing a 2-tuple in as the file argument. The first element of the tuple should specify the relative path (under the package install directory) where the remaining sequence of files should be installed to (it has nothing to do with the file-names in the source distribution). The second element of the tuple is the sequence of files that should be installed. The files in this sequence can be filenames, relative paths, or absolute paths. For absolute paths the file will be installed in the top-level package installation directory (regardless of the first argument). Filenames and relative path names will be installed in the package install directory under the path name given as the first element of the tuple.

Rules for installation paths:

1. file.txt -> (., file.txt)-> parent/file.txt
2. foo/file.txt -> (foo, foo/file.txt) -> parent/foo/file.txt
3. /foo/bar/file.txt -> (., /foo/bar/file.txt) -> parent/file.txt
4. `*.txt` -> parent/a.txt, parent/b.txt
5. foo/`*.txt`` -> parent/foo/a.txt, parent/foo/b.txt
6. `*/*.txt` -> (`*`, `*/*.txt`) -> parent/c/a.txt, parent/d/b.txt

7. (sun, file.txt) -> parent/sun/file.txt
8. (sun, bar/file.txt) -> parent/sun/file.txt
9. (sun, /foo/bar/file.txt) -> parent/sun/file.txt
10. (sun, *.txt) -> parent/sun/a.txt, parent/sun/b.txt
11. (sun, bar/*.txt) -> parent/sun/a.txt, parent/sun/b.txt
12. (sun/*, */*.txt) -> parent/sun/c/a.txt, parent/d/b.txt

An additional feature is that the path to a data-file can actually be a function that takes no arguments and returns the actual path(s) to the data-files. This is useful when the data files are generated while building the package.

Examples

Add files to the list of data_files to be included with the package.

```
>>> self.add_data_files('foo.dat',
...     ('fun', ['gun.dat', 'nun/pun.dat', '/tmp/sun.dat']),
...     'bar/cat.dat',
...     '/full/path/to/can.dat')
```

will install these data files to:

```
<package install directory>/
 foo.dat
 fun/
   gun.dat
   nun/
     pun.dat
 sun.dat
 bar/
   car.dat
 can.dat
```

where <package install directory> is the package (or sub-package) directory such as '/usr/lib/python2.4/site-packages/mypackage' ('C: Python2.4 Lib site-packages mypackage') or '/usr/lib/python2.4/site- packages/mypackage/mysubpackage' ('C: Python2.4 Lib site-packages mypackage mysubpackage').

add_data_dir(*data_path*)

Recursively add files under data_path to data_files list.

Recursively add files under data_path to the list of data_files to be installed (and distributed). The data_path can be either a relative path-name, or an absolute path-name, or a 2-tuple where the first argument shows where in the install directory the data directory should be installed to.

Parameters

data_path
[seq or str] Argument can be either

- 2-sequence (<datadir suffix>, <path to data directory>)
- path to data directory where python datadir suffix defaults to package dir.

Notes

Rules for installation paths:

```
foo/bar -> (foo/bar, foo/bar) -> parent/foo/bar
(gun, foo/bar) -> parent/gun
foo/* -> (foo/a, foo/a), (foo/b, foo/b) -> parent/foo/a, parent/foo/b
(gun, foo/*) -> (gun, foo/a), (gun, foo/b) -> gun
(gun/*, foo/*) -> parent/gun/a, parent/gun/b
/foo/bar -> (bar, /foo/bar) -> parent/bar
(gun, /foo/bar) -> parent/gun
(fun/*/gun/*, sun/foo/bar) -> parent/fun/foo/gun/bar
```

Examples

For example suppose the source directory contains fun/foo.dat and fun/bar/car.dat:

```
>>> self.add_data_dir('fun')
>>> self.add_data_dir(('sun', 'fun'))
>>> self.add_data_dir(('gun', '/full/path/to/fun'))
```

Will install data-files to the locations:

```
<package install directory>/
  fun/
    foo.dat
    bar/
      car.dat
  sun/
    foo.dat
    bar/
      car.dat
  gun/
    foo.dat
    car.dat
```

add_include_dirs(**paths*)

Add paths to configuration include directories.

Add the given sequence of paths to the beginning of the include_dirs list. This list will be visible to all extension modules of the current package.

add_headers(**files*)

Add installable headers to configuration.

Add the given sequence of files to the beginning of the headers list. By default, headers will be installed under <python- include>/<self.name.replace('.','/')>/ directory. If an item of files is a tuple, then its first argument specifies the actual installation location relative to the <python-include> path.

Parameters

files

[str or seq] Argument(s) can be either:

- 2-sequence (<includedir suffix>,<path to header file(s)>)
- path(s) to header file(s) where python includedir suffix will default to package name.

add_extension(*name*, *sources*, ***kw*)

Add extension to configuration.

Create and add an Extension instance to the ext_modules list. This method also takes the following optional keyword arguments that are passed on to the Extension constructor.

Parameters

name
[str] name of the extension

sources
[seq] list of the sources. The list of sources may contain functions (called source generators) which must take an extension instance and a build directory as inputs and return a source file or list of source files or None. If None is returned then no sources are generated. If the Extension instance has no sources after processing all source generators, then no extension module is built.

include_dirs
define_macros
undef_macros
library_dirs
libraries
runtime_library_dirs
extra_objects
extra_compile_args
extra_link_args
extra_f77_compile_args
extra_f90_compile_args
export_symbols
swig_opts
depends
The depends list contains paths to files or directories that the sources of the extension module depend on. If any path in the depends list is newer than the extension module, then the module will be rebuilt.

language
f2py_options
module_dirs
extra_info
[dict or list] dict or list of dict of keywords to be appended to keywords.

Notes

The self.paths(...) method is applied to all lists that may contain paths.

add_library(*name*, *sources*, ***build_info*)

Add library to configuration.

Parameters

name
[str] Name of the extension.

sources
[sequence] List of the sources. The list of sources may contain functions (called source generators) which must take an extension instance and a build directory as inputs and return a source file or list of source files or None. If None is returned then no sources are generated. If

the Extension instance has no sources after processing all source generators, then no extension module is built.

build_info
[dict, optional] The following keys are allowed:

- depends
- macros
- include_dirs
- extra_compiler_args
- extra_f77_compile_args
- extra_f90_compile_args
- f2py_options
- language

add_scripts(**files*)

Add scripts to configuration.

Add the sequence of files to the beginning of the scripts list. Scripts will be installed under the <prefix>/bin/ directory.

add_installed_library(*name*, *sources*, *install_dir*, *build_info=None*)

Similar to add_library, but the specified library is installed.

Most C libraries used with `distutils` are only used to build python extensions, but libraries built through this method will be installed so that they can be reused by third-party packages.

Parameters

name
[str] Name of the installed library.

sources
[sequence] List of the library's source files. See *add_library* for details.

install_dir
[str] Path to install the library, relative to the current sub-package.

build_info
[dict, optional] The following keys are allowed:

- depends
- macros
- include_dirs
- extra_compiler_args
- extra_f77_compile_args
- extra_f90_compile_args
- f2py_options
- language

Returns

None

See also:

add_library, *add_npy_pkg_config*, *get_info*

Notes

The best way to encode the options required to link against the specified C libraries is to use a "libname.ini" file, and use *get_info* to retrieve the required options (see *add_npy_pkg_config* for more information).

add_npy_pkg_config(*template*, *install_dir*, *subst_dict=None*)

Generate and install a npy-pkg config file from a template.

The config file generated from *template* is installed in the given install directory, using *subst_dict* for variable substitution.

Parameters

template
[str] The path of the template, relatively to the current package path.

install_dir
[str] Where to install the npy-pkg config file, relatively to the current package path.

subst_dict
[dict, optional] If given, any string of the form `@key@` will be replaced by `subst_dict[key]` in the template file when installed. The install prefix is always available through the variable `@prefix@`, since the install prefix is not easy to get reliably from setup.py.

See also:

add_installed_library, *get_info*

Notes

This works for both standard installs and in-place builds, i.e. the `@prefix@` refer to the source directory for in-place builds.

Examples

```
config.add_npy_pkg_config('foo.ini.in', 'lib', {'foo': bar})
```

Assuming the foo.ini.in file has the following content:

```
[meta]
Name=@foo@
Version=1.0
Description=dummy description

[default]
Cflags=-I@prefix@/include
Libs=
```

The generated file will have the following content:

```
[meta]
Name=bar
Version=1.0
Description=dummy description

[default]
Cflags=-Iprefix_dir/include
Libs=
```

and will be installed as foo.ini in the 'lib' subpath.

When cross-compiling with numpy distutils, it might be necessary to use modified npy-pkg-config files. Using the default/generated files will link with the host libraries (i.e. libnpymath.a). For cross-compilation you of-course need to link with target libraries, while using the host Python installation.

You can copy out the numpy/_core/lib/npy-pkg-config directory, add a pkgdir value to the .ini files and set NPY_PKG_CONFIG_PATH environment variable to point to the directory with the modified npy-pkg-config files.

Example npymath.ini modified for cross-compilation:

```
[meta]
Name=npymath
Description=Portable, core math library implementing C99 standard
Version=0.1

[variables]
pkgname=numpy._core
pkgdir=/build/arm-linux-gnueabi/sysroot/usr/lib/python3.7/site-packages/numpy/
↪_core
prefix=${pkgdir}
libdir=${prefix}/lib
includedir=${prefix}/include

[default]
Libs=-L${libdir} -lnpymath
Cflags=-I${includedir}
Requires=mlib

[msvc]
Libs=/LIBPATH:${libdir} npymath.lib
Cflags=/INCLUDE:${includedir}
Requires=mlib
```

paths(**paths*, ***kws*)

Apply glob to paths and prepend local_path if needed.

Applies glob.glob(…) to each path in the sequence (if needed) and prepends the local_path if needed. Because this is called on all source lists, this allows wildcard characters to be specified in lists of sources for extension modules and libraries and scripts and allows path-names be relative to the source directory.

get_config_cmd()

Returns the numpy.distutils config command instance.

get_build_temp_dir()

Return a path to a temporary directory where temporary files should be placed.

have_f77c()

Check for availability of Fortran 77 compiler.

Use it inside source generating function to ensure that setup distribution instance has been initialized.

Notes

True if a Fortran 77 compiler is available (because a simple Fortran 77 code was able to be compiled successfully).

have_f90c()

Check for availability of Fortran 90 compiler.

Use it inside source generating function to ensure that setup distribution instance has been initialized.

Notes

True if a Fortran 90 compiler is available (because a simple Fortran 90 code was able to be compiled successfully)

get_version(*version_file=None*, *version_variable=None*)

Try to get version string of a package.

Return a version string of the current package or None if the version information could not be detected.

Notes

This method scans files named __version__.py, <packagename>_version.py, version.py, and __svn_version__.py for string variables version, __version__, and <packagename>_version, until a version number is found.

make_svn_version_py(*delete=True*)

Appends a data function to the data_files list that will generate __svn_version__.py file to the current package directory.

Generate package __svn_version__.py file from SVN revision number, it will be removed after python exits but will be available when sdist, etc commands are executed.

Notes

If __svn_version__.py existed before, nothing is done.

This is intended for working with source directories that are in an SVN repository.

make_config_py(*name='__config__'*)

Generate package __config__.py file containing system_info information used during building the package.

This file is installed to the package installation directory.

get_info(**names*)

Get resources information.

Return information (from system_info.get_info) for all of the names in the argument list in a single dictionary.

Building installable C libraries

Conventional C libraries (installed through *add_library*) are not installed, and are just used during the build (they are statically linked). An installable C library is a pure C library, which does not depend on the python C runtime, and is installed such that it may be used by third-party packages. To build and install the C library, you just use the method *add_installed_library* instead of *add_library*, which takes the same arguments except for an additional `install_dir` argument:

```
.. hidden in a comment so as to be included in refguide but not rendered documentation
  >>> import numpy.distutils.misc_util
  >>> config = np.distutils.misc_util.Configuration(None, '', '.')
  >>> with open('foo.c', 'w') as f: pass

>>> config.add_installed_library('foo', sources=['foo.c'], install_dir='lib')
```

npy-pkg-config files

To make the necessary build options available to third parties, you could use the *npy-pkg-config* mechanism implemented in *numpy.distutils*. This mechanism is based on a .ini file which contains all the options. A .ini file is very similar to .pc files as used by the pkg-config unix utility:

```
[meta]
Name: foo
Version: 1.0
Description: foo library

[variables]
prefix = /home/user/local
libdir = ${prefix}/lib
includedir = ${prefix}/include

[default]
cflags = -I${includedir}
libs = -L${libdir} -lfoo
```

Generally, the file needs to be generated during the build, since it needs some information known at build time only (e.g. prefix). This is mostly automatic if one uses the *Configuration* method *add_npy_pkg_config*. Assuming we have a template file foo.ini.in as follows:

```
[meta]
Name: foo
Version: @version@
Description: foo library

[variables]
prefix = @prefix@
libdir = ${prefix}/lib
includedir = ${prefix}/include

[default]
cflags = -I${includedir}
libs = -L${libdir} -lfoo
```

and the following code in setup.py:

```
>>> config.add_installed_library('foo', sources=['foo.c'], install_dir='lib')
>>> subst = {'version': '1.0'}
>>> config.add_npy_pkg_config('foo.ini.in', 'lib', subst_dict=subst)
```

This will install the file foo.ini into the directory package_dir/lib, and the foo.ini file will be generated from foo.ini.in, where each `@version@` will be replaced by `subst_dict['version']`. The dictionary has an additional prefix substitution rule automatically added, which contains the install prefix (since this is not easy to get from setup.py).

Reusing a C library from another package

Info are easily retrieved from the *get_info* function in *numpy.distutils.misc_util*:

```
>>> info = np.distutils.misc_util.get_info('npymath')
>>> config.add_extension('foo', sources=['foo.c'], extra_info=info)
<numpy.distutils.extension.Extension('foo') at 0x...>
```

An additional list of paths to look for .ini files can be given to *get_info*.

Conversion of `.src` files

NumPy distutils supports automatic conversion of source files named <somefile>.src. This facility can be used to maintain very similar code blocks requiring only simple changes between blocks. During the build phase of setup, if a template file named <somefile>.src is encountered, a new file named <somefile> is constructed from the template and placed in the build directory to be used instead. Two forms of template conversion are supported. The first form occurs for files named <file>.ext.src where ext is a recognized Fortran extension (f, f90, f95, f77, for, ftn, pyf). The second form is used for all other cases. See *Conversion of .src files using templates*.

F2PY user guide and reference manual

The purpose of the `F2PY` *–Fortran to Python interface generator–* utility is to provide a connection between Python and Fortran. F2PY distributed as part of NumPy (`numpy.f2py`) and once installed is also available as a standalone command line tool. Originally created by Pearu Peterson, and older changelogs are in the historical reference.

F2PY facilitates creating/building native Python C/API extension modules that make it possible

- to call Fortran 77/90/95 external subroutines and Fortran 90/95 module subroutines as well as C functions;
- to access Fortran 77 `COMMON` blocks and Fortran 90/95 module data, including allocatable arrays

from Python.

Note: Fortran 77 is essentially feature complete, and an increasing amount of Modern Fortran is supported within F2PY. Most `iso_c_binding` interfaces can be compiled to native extension modules automatically with `f2py`. Bug reports welcome!

F2PY can be used either as a command line tool `f2py` or as a Python module `numpy.f2py`. While we try to provide the command line tool as part of the numpy setup, some platforms like Windows make it difficult to reliably put the executables on the `PATH`. If the `f2py` command is not available in your system, you may have to run it as a module:

```
python -m numpy.f2py
```

Using the `python -m` invocation is also good practice if you have multiple Python installs with NumPy in your system (outside of virtual environments) and you want to ensure you pick up a particular version of Python/F2PY.

If you run `f2py` with no arguments, and the line `numpy Version` at the end matches the NumPy version printed from `python -m numpy.f2py`, then you can use the shorter version. If not, or if you cannot run `f2py`, you should replace all calls to `f2py` mentioned in this guide with the longer version.

F2PY user guide

Three ways to wrap - getting started

Wrapping Fortran or C functions to Python using F2PY consists of the following steps:

- Creating the so-called *signature file* that contains descriptions of wrappers to Fortran or C functions, also called the signatures of the functions. For Fortran routines, F2PY can create an initial signature file by scanning Fortran source codes and tracking all relevant information needed to create wrapper functions.
  - Optionally, F2PY-created signature files can be edited to optimize wrapper functions, which can make them "smarter" and more "Pythonic".
- F2PY reads a signature file and writes a Python C/API module containing Fortran/C/Python bindings.
- F2PY compiles all sources and builds an extension module containing the wrappers.
  - In building the extension modules, F2PY uses `meson` and used to use `numpy.distutils` For different build systems, see *F2PY and build systems*.

Note:

See *1 Migrating to meson* for migration information.

- Depending on your operating system, you may need to install the Python development headers (which provide the file `Python.h`) separately. In Linux Debian-based distributions this package should be called `python3-dev`, in Fedora-based distributions it is `python3-devel`. For macOS, depending how Python was installed, your mileage may vary. In Windows, the headers are typically installed already, see *F2PY and Windows*.

Note: F2PY supports all the operating systems SciPy is tested on so their system dependencies panel is a good reference.

Depending on the situation, these steps can be carried out in a single composite command or step-by-step; in which case some steps can be omitted or combined with others.

Below, we describe three typical approaches of using F2PY with Fortran 77. These can be read in order of increasing effort, but also cater to different access levels depending on whether the Fortran code can be freely modified.

The following example Fortran 77 code will be used for illustration, save it as `fib1.f`:

```
C FILE: FIB1.F
      SUBROUTINE FIB(A,N)
C
C     CALCULATE FIRST N FIBONACCI NUMBERS
C
      INTEGER N
      REAL*8 A(N)
      DO I=1,N
         IF (I.EQ.1) THEN
            A(I) = 0.0D0
         ELSEIF (I.EQ.2) THEN
            A(I) = 1.0D0
         ELSE
            A(I) = A(I-1) + A(I-2)
```

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```
         ENDIF
      ENDDO
      END
C END FILE FIB1.F
```

Note: F2PY parses Fortran/C signatures to build wrapper functions to be used with Python. However, it is not a compiler, and does not check for additional errors in source code, nor does it implement the entire language standards. Some errors may pass silently (or as warnings) and need to be verified by the user.

The quick way

The quickest way to wrap the Fortran subroutine `FIB` for use in Python is to run

```
python -m numpy.f2py -c fib1.f -m fib1
```

or, alternatively, if the `f2py` command-line tool is available,

```
f2py -c fib1.f -m fib1
```

Note: Because the `f2py` command might not be available in all system, notably on Windows, we will use the `python -m numpy.f2py` command throughout this guide.

This command compiles and wraps `fib1.f` (`-c`) to create the extension module `fib1.so` (`-m`) in the current directory. A list of command line options can be seen by executing `python -m numpy.f2py`. Now, in Python the Fortran subroutine `FIB` is accessible via `fib1.fib`:

```
>>> import numpy as np
>>> import fib1
>>> print(fib1.fib.__doc__)
fib(a,[n])

Wrapper for ``fib``.

Parameters
----------
a : input rank-1 array('d') with bounds (n)

Other parameters
----------------
n : input int, optional
    Default: len(a)

>>> a = np.zeros(8, 'd')
>>> fib1.fib(a)
>>> print(a)
[  0.   1.   1.   2.   3.   5.   8.  13.]
```

Note:

- Note that F2PY recognized that the second argument `n` is the dimension of the first array argument `a`. Since

by default all arguments are input-only arguments, F2PY concludes that `n` can be optional with the default value `len(a)`.

- One can use different values for optional `n`:

```
>>> a1 = np.zeros(8, 'd')
>>> fib1.fib(a1, 6)
>>> print(a1)
[ 0.  1.  1.  2.  3.  5.  0.  0.]
```

but an exception is raised when it is incompatible with the input array `a`:

```
>>> fib1.fib(a, 10)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
fib.error: (len(a)>=n) failed for 1st keyword n: fib:n=10
>>>
```

F2PY implements basic compatibility checks between related arguments in order to avoid unexpected crashes.

- When a NumPy array that is Fortran contiguous and has a `dtype` corresponding to a presumed Fortran type is used as an input array argument, then its C pointer is directly passed to Fortran.

  Otherwise, F2PY makes a contiguous copy (with the proper `dtype`) of the input array and passes a C pointer of the copy to the Fortran subroutine. As a result, any possible changes to the (copy of) input array have no effect on the original argument, as demonstrated below:

```
>>> a = np.ones(8, 'i')
>>> fib1.fib(a)
>>> print(a)
[1 1 1 1 1 1 1 1]
```

  Clearly, this is unexpected, as Fortran typically passes by reference. That the above example worked with `dtype=float` is considered accidental.

  F2PY provides an `intent(inplace)` attribute that modifies the attributes of an input array so that any changes made by the Fortran routine will be reflected in the input argument. For example, if one specifies the `intent(inplace) a` directive (see *Attributes* for details), then the example above would read:

```
>>> a = np.ones(8, 'i')
>>> fib1.fib(a)
>>> print(a)
[  0.   1.   1.   2.   3.   5.   8.  13.]
```

  However, the recommended way to have changes made by Fortran subroutine propagate to Python is to use the `intent(out)` attribute. That approach is more efficient and also cleaner.

- The usage of `fib1.fib` in Python is very similar to using `FIB` in Fortran. However, using *in situ* output arguments in Python is poor style, as there are no safety mechanisms in Python to protect against wrong argument types. When using Fortran or C, compilers discover any type mismatches during the compilation process, but in Python the types must be checked at runtime. Consequently, using *in situ* output arguments in Python may lead to difficult to find bugs, not to mention the fact that the codes will be less readable when all required type checks are implemented.

Though the approach to wrapping Fortran routines for Python discussed so far is very straightforward, it has several drawbacks (see the comments above). The drawbacks are due to the fact that there is no way for F2PY to determine the actual intention of the arguments; that is, there is ambiguity in distinguishing between input and output arguments. Consequently, F2PY assumes that all arguments are input arguments by default.

There are ways (see below) to remove this ambiguity by "teaching" F2PY about the true intentions of function arguments, and F2PY is then able to generate more explicit, easier to use, and less error prone wrappers for Fortran functions.

The smart way

If we want to have more control over how F2PY will treat the interface to our Fortran code, we can apply the wrapping steps one by one.

- First, we create a signature file from `fib1.f` by running:

```
python -m numpy.f2py fib1.f -m fib2 -h fib1.pyf
```

  The signature file is saved to `fib1.pyf` (see the `-h` flag) and its contents are shown below.

```
!    -*- f90 -*-
python module fib2 ! in
    interface  ! in :fib2
        subroutine fib(a,n) ! in :fib2:fib1.f
            real*8 dimension(n) :: a
            integer optional,check(len(a)>=n),depend(a) :: n=len(a)
        end subroutine fib
    end interface
end python module fib2

! This file was auto-generated with f2py (version:2.28.198-1366).
! See http://cens.ioc.ee/projects/f2py2e/
```

- Next, we'll teach F2PY that the argument `n` is an input argument (using the `intent(in)` attribute) and that the result, i.e., the contents of `a` after calling the Fortran function `FIB`, should be returned to Python (using the `intent(out)` attribute). In addition, an array `a` should be created dynamically using the size determined by the input argument `n` (using the `depend(n)` attribute to indicate this dependence relation).

  The contents of a suitably modified version of `fib1.pyf` (saved as `fib2.pyf`) are as follows:

```
!    -*- f90 -*-
python module fib2
    interface
        subroutine fib(a,n)
            real*8 dimension(n),intent(out),depend(n) :: a
            integer intent(in) :: n
        end subroutine fib
    end interface
end python module fib2
```

- Finally, we build the extension module with `numpy.distutils` by running:

```
python -m numpy.f2py -c fib2.pyf fib1.f
```

In Python:

```
>>> import fib2
>>> print(fib2.fib.__doc__)
a = fib(n)

Wrapper for ``fib``.

```

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```
Parameters
----------
n : input int

Returns
-------
a : rank-1 array('d') with bounds (n)

>>> print(fib2.fib(8))
[  0.   1.   1.   2.   3.   5.   8.  13.]
```

Note:

- The signature of `fib2.fib` now more closely corresponds to the intention of the Fortran subroutine `FIB`: given the number `n`, `fib2.fib` returns the first `n` Fibonacci numbers as a NumPy array. The new Python signature `fib2.fib` also rules out the unexpected behaviour in `fib1.fib`.
- Note that by default, using a single `intent(out)` also implies `intent(hide)`. Arguments that have the `intent(hide)` attribute specified will not be listed in the argument list of a wrapper function.

For more details, see *Signature file*.

The quick and smart way

The "smart way" of wrapping Fortran functions, as explained above, is suitable for wrapping (e.g. third party) Fortran codes for which modifications to their source codes are not desirable nor even possible.

However, if editing Fortran codes is acceptable, then the generation of an intermediate signature file can be skipped in most cases. F2PY specific attributes can be inserted directly into Fortran source codes using F2PY directives. A F2PY directive consists of special comment lines (starting with `Cf2py` or `!f2py`, for example) which are ignored by Fortran compilers but interpreted by F2PY as normal lines.

Consider a modified version of the previous Fortran code with F2PY directives, saved as `fib3.f`:

```
C FILE: FIB3.F
      SUBROUTINE FIB(A,N)
C
C     CALCULATE FIRST N FIBONACCI NUMBERS
C
      INTEGER N
      REAL*8 A(N)
Cf2py intent(in) n
Cf2py intent(out) a
Cf2py depend(n) a
      DO I=1,N
         IF (I.EQ.1) THEN
            A(I) = 0.0D0
         ELSEIF (I.EQ.2) THEN
            A(I) = 1.0D0
         ELSE
            A(I) = A(I-1) + A(I-2)
         ENDIF
      ENDDO
```

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```
      END
C END FILE FIB3.F
```

Building the extension module can be now carried out in one command:

```
python -m numpy.f2py -c -m fib3 fib3.f
```

Notice that the resulting wrapper to `FIB` is as "smart" (unambiguous) as in the previous case:

```
>>> import fib3
>>> print(fib3.fib.__doc__)
a = fib(n)

Wrapper for ``fib``.

Parameters
----------
n : input int

Returns
-------
a : rank-1 array('d') with bounds (n)

>>> print(fib3.fib(8))
[  0.   1.   1.   2.   3.   5.   8.  13.]
```

Using F2PY

This page contains a reference to all command-line options for the `f2py` command, as well as a reference to internal functions of the `numpy.f2py` module.

Using `f2py` as a command-line tool

When used as a command-line tool, `f2py` has three major modes, distinguished by the usage of `-c` and `-h` switches.

1. Signature file generation

To scan Fortran sources and generate a signature file, use

```
f2py -h <filename.pyf> <options> <fortran files>   \
  [[ only: <fortran functions>  : ]                \
    [ skip: <fortran functions>  : ]]...           \
  [<fortran files> ...]
```

Note: A Fortran source file can contain many routines, and it is often not necessary to allow all routines to be usable from Python. In such cases, either specify which routines should be wrapped (in the `only: .. :` part) or which routines F2PY should ignore (in the `skip: .. :` part).

F2PY has no concept of a "per-file" `skip` or `only` list, so if functions are listed in `only`, no other functions will be taken from any other files.

If <filename.pyf> is specified as stdout, then signatures are written to standard output instead of a file.

Among other options (see below), the following can be used in this mode:

--overwrite-signature
Overwrites an existing signature file.

2. Extension module construction

To construct an extension module, use

```
f2py -m <modulename> <options> <fortran files>   \
  [[ only: <fortran functions>  : ]              \
    [ skip: <fortran functions>  : ]]...          \
  [<fortran files> ...]
```

The constructed extension module is saved as <modulename>module.c to the current directory.

Here <fortran files> may also contain signature files. Among other options (see below), the following options can be used in this mode:

--debug-capi
Adds debugging hooks to the extension module. When using this extension module, various diagnostic information about the wrapper is written to the standard output, for example, the values of variables, the steps taken, etc.

-include'<includefile>'
Add a CPP #include statement to the extension module source. <includefile> should be given in one of the following forms

```
"filename.ext"
<filename.ext>
```

The include statement is inserted just before the wrapper functions. This feature enables using arbitrary C functions (defined in <includefile>) in F2PY generated wrappers.

Note: This option is deprecated. Use usercode statement to specify C code snippets directly in signature files.

--[no-]wrap-functions
Create Fortran subroutine wrappers to Fortran functions. --wrap-functions is default because it ensures maximum portability and compiler independence.

--[no-]freethreading-compatible
Create a module that declares it does or doesn't require the GIL. The default is --no-freethreading-compatible for backwards compatibility. Inspect the fortran code you are wrapping for thread safety issues before passing --freethreading-compatible, as f2py does not analyze fortran code for thread safety issues.

--include-paths "<path1>:<path2>..."
Search include files from given directories.

Note: The paths are to be separated by the correct operating system separator pathsep, that is : on Linux / MacOS and ; on Windows. In CMake this corresponds to using $<SEMICOLON>.

--help-link [<list of resources names>]
List system resources found by `numpy_distutils/system_info.py`. For example, try `f2py --help-link lapack_opt`.

3. Building a module

To build an extension module, use

```
f2py -c <options> <fortran files>       \
  [[ only: <fortran functions>  : ]     \
    [ skip: <fortran functions>  : ]]... \
  [ <fortran/c source files> ] [ <.o, .a, .so files> ]
```

If `<fortran files>` contains a signature file, then the source for an extension module is constructed, all Fortran and C sources are compiled, and finally all object and library files are linked to the extension module `<modulename>.so` which is saved into the current directory.

If `<fortran files>` does not contain a signature file, then an extension module is constructed by scanning all Fortran source codes for routine signatures, before proceeding to build the extension module.

Warning: From Python 3.12 onwards, `distutils` has been removed. Use environment variables or native files to interact with `meson` instead. See its FAQ for more information.

Among other options (see below) and options described for previous modes, the following can be used.

Note: Changed in version 1.26.0: There are now two separate build backends which can be used, `distutils` and `meson`. Users are **strongly** recommended to switch to `meson` since it is the default above Python `3.12`.

Common build flags:

--backend <backend_type>
Specify the build backend for the compilation process. The supported backends are `meson` and `distutils`. If not specified, defaults to `distutils`. On Python 3.12 or higher, the default is `meson`.

--f77flags=<string>
Specify F77 compiler flags

--f90flags=<string>
Specify F90 compiler flags

--debug
Compile with debugging information

-l<libname>
Use the library `<libname>` when linking.

-D<macro>[=<defn=1>]
Define macro `<macro>` as `<defn>`.

-U<macro>
Define macro `<macro>`

-I<dir>
Append directory `<dir>` to the list of directories searched for include files.

-L<dir>
Add directory <dir> to the list of directories to be searched for -l.

The meson specific flags are:

--dep <dependency> meson only
Specify a meson dependency for the module. This may be passed multiple times for multiple dependencies. Dependencies are stored in a list for further processing. Example: --dep lapack --dep scalapack This will identify "lapack" and "scalapack" as dependencies and remove them from argv, leaving a dependencies list containing ["lapack", "scalapack"].

The older distutils flags are:

--help-fcompiler no meson
List the available Fortran compilers.

--fcompiler=<Vendor> no meson
Specify a Fortran compiler type by vendor.

--f77exec=<path> no meson
Specify the path to a F77 compiler

--f90exec=<path> no meson
Specify the path to a F90 compiler

--opt=<string> no meson
Specify optimization flags

--arch=<string> no meson
Specify architecture specific optimization flags

--noopt no meson
Compile without optimization flags

--noarch no meson
Compile without arch-dependent optimization flags

link-<resource> no meson
Link the extension module with <resource> as defined by numpy_distutils/system_info.py. E.g. to link with optimized LAPACK libraries (vecLib on MacOSX, ATLAS elsewhere), use --link-lapack_opt. See also --help-link switch.

Note: The f2py -c option must be applied either to an existing .pyf file (plus the source/object/library files) or one must specify the -m <modulename> option (plus the sources/object/library files). Use one of the following options:

```
f2py -c -m fib1 fib1.f
```

or

```
f2py -m fib1 fib1.f -h fib1.pyf
f2py -c fib1.pyf fib1.f
```

For more information, see the Building C and C++ Extensions Python documentation for details.

When building an extension module, a combination of the following macros may be required for non-gcc Fortran compilers:

```
-DPREPEND_FORTRAN
-DNO_APPEND_FORTRAN
-DUPPERCASE_FORTRAN
```

To test the performance of F2PY generated interfaces, use `-DF2PY_REPORT_ATEXIT`. Then a report of various timings is printed out at the exit of Python. This feature may not work on all platforms, and currently only Linux is supported.

To see whether F2PY generated interface performs copies of array arguments, use `-DF2PY_REPORT_ON_ARRAY_COPY=<int>`. When the size of an array argument is larger than `<int>`, a message about the copying is sent to `stderr`.

Other options

`-m <modulename>`
Name of an extension module. Default is `untitled`.

> **Warning:** Don't use this option if a signature file (`*.pyf`) is used.
>
> Changed in version 1.26.3: Will ignore `-m` if a `pyf` file is provided.

`--[no-]lower`
Do [not] lower the cases in `<fortran files>`. By default, `--lower` is assumed with `-h` switch, and `--no-lower` without the `-h` switch.

`-include<header>`
Writes additional headers in the C wrapper, can be passed multiple times, generates #include <header> each time. Note that this is meant to be passed in single quotes and without spaces, for example `'-include<stdbool.h>'`

`--build-dir <dirname>`
All F2PY generated files are created in `<dirname>`. Default is `tempfile.mkdtemp()`.

`--f2cmap <filename>`
Load Fortran-to-C `KIND` specifications from the given file.

`--quiet`
Run quietly.

`--verbose`
Run with extra verbosity.

`--skip-empty-wrappers`
Do not generate wrapper files unless required by the inputs. This is a backwards compatibility flag to restore pre 1.22.4 behavior.

`-v`
Print the F2PY version and exit.

Execute `f2py` without any options to get an up-to-date list of available options.

Python module `numpy.f2py`

Warning: Changed in version 2.0.0: There used to be a `f2py.compile` function, which was removed, users may wrap `python -m numpy.f2py` via `subprocess.run` manually, and set environment variables to interact with `meson` as required.

When using `numpy.f2py` as a module, the following functions can be invoked. Fortran to Python Interface Generator.

`numpy.f2py.`**`get_include`**`()`

Return the directory that contains the `fortranobject.c` and `.h` files.

Note: This function is not needed when building an extension with *`numpy.distutils`* directly from `.f` and/or `.pyf` files in one go.

Python extension modules built with f2py-generated code need to use `fortranobject.c` as a source file, and include the `fortranobject.h` header. This function can be used to obtain the directory containing both of these files.

Returns

include_path
[str] Absolute path to the directory containing `fortranobject.c` and `fortranobject.h`.

See also:

`numpy.get_include`
function that returns the numpy include directory

Notes

New in version 1.21.1.

Unless the build system you are using has specific support for f2py, building a Python extension using a `.pyf` signature file is a two-step process. For a module `mymod`:

- Step 1: run `python -m numpy.f2py mymod.pyf --quiet`. This generates `mymodmodule.c` and (if needed) `mymod-f2pywrappers.f` files next to `mymod.pyf`.
- Step 2: build your Python extension module. This requires the following source files:
  - `mymodmodule.c`
  - `mymod-f2pywrappers.f` (if it was generated in Step 1)
  - `fortranobject.c`

`numpy.f2py.`**`run_main`**`(`*`comline_list`*`)`

Equivalent to running:

```
f2py <args>
```

where `<args>=string.join(<list>,' ')`, but in Python. Unless `-h` is used, this function returns a dictionary containing information on generated modules and their dependencies on source files.

You cannot build extension modules with this function, that is, using `-c` is not allowed. Use the `compile` command instead.

Examples

The command `f2py -m scalar scalar.f` can be executed from Python as follows.

```
>>> import numpy.f2py
>>> r = numpy.f2py.run_main(['-m','scalar','doc/source/f2py/scalar.f'])
Reading fortran codes...
        Reading file 'doc/source/f2py/scalar.f' (format:fix,strict)
Post-processing...
        Block: scalar
                        Block: FOO
Building modules...
        Building module "scalar"...
        Wrote C/API module "scalar" to file "./scalarmodule.c"
>>> print(r)
{'scalar': {'h': ['/home/users/pearu/src_cvs/f2py/src/fortranobject.h'],
         'csrc': ['./scalarmodule.c',
                  '/home/users/pearu/src_cvs/f2py/src/fortranobject.c']}}
```

Automatic extension module generation

If you want to distribute your f2py extension module, then you only need to include the .pyf file and the Fortran code. The distutils extensions in NumPy allow you to define an extension module entirely in terms of this interface file. A valid `setup.py` file allowing distribution of the `add.f` module (as part of the package `f2py_examples` so that it would be loaded as `f2py_examples.add`) is:

```
def configuration(parent_package='', top_path=None)
    from numpy.distutils.misc_util import Configuration
    config = Configuration('f2py_examples',parent_package, top_path)
    config.add_extension('add', sources=['add.pyf','add.f'])
    return config

if __name__ == '__main__':
    from numpy.distutils.core import setup
    setup(**configuration(top_path='').todict())
```

Installation of the new package is easy using:

```
pip install .
```

assuming you have the proper permissions to write to the main site- packages directory for the version of Python you are using. For the resulting package to work, you need to create a file named `__init__.py` (in the same directory as `add.pyf`). Notice the extension module is defined entirely in terms of the `add.pyf` and `add.f` files. The conversion of the .pyf file to a .c file is handled by *`numpy.distutils`*.

F2PY examples

Below are some examples of F2PY usage. This list is not comprehensive, but can be used as a starting point when wrapping your own code.

Note: The best place to look for examples is the NumPy issue tracker, or the test cases for `f2py`. Some more use cases are in *Boilerplate reduction and templating*.

F2PY walkthrough: a basic extension module

Creating source for a basic extension module

Consider the following subroutine, contained in a file named `add.f`

```
C
      SUBROUTINE ZADD(A,B,C,N)
C
      DOUBLE COMPLEX A(*)
      DOUBLE COMPLEX B(*)
      DOUBLE COMPLEX C(*)
      INTEGER N
      DO 20 J = 1, N
         C(J) = A(J)+B(J)
 20   CONTINUE
      END
```

This routine simply adds the elements in two contiguous arrays and places the result in a third. The memory for all three arrays must be provided by the calling routine. A very basic interface to this routine can be automatically generated by f2py:

```
python -m numpy.f2py -m add add.f
```

This command will produce an extension module named `addmodule.c` in the current directory. This extension module can now be compiled and used from Python just like any other extension module.

Creating a compiled extension module

You can also get f2py to both compile `add.f` along with the produced extension module leaving only a shared-library extension file that can be imported from Python:

```
python -m numpy.f2py -c -m add add.f
```

This command produces a Python extension module compatible with your platform. This module may then be imported from Python. It will contain a method for each subroutine in `add`. The docstring of each method contains information about how the module method may be called:

```
>>> import add
>>> print(add.zadd.__doc__)
zadd(a,b,c,n)

Wrapper for ``zadd``.
```

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```
Parameters
----------
a : input rank-1 array('D') with bounds (*)
b : input rank-1 array('D') with bounds (*)
c : input rank-1 array('D') with bounds (*)
n : input int
```

Improving the basic interface

The default interface is a very literal translation of the Fortran code into Python. The Fortran array arguments are converted to NumPy arrays and the integer argument should be mapped to a `C` integer. The interface will attempt to convert all arguments to their required types (and shapes) and issue an error if unsuccessful. However, because `f2py` knows nothing about the semantics of the arguments (such that `C` is an output and `n` should really match the array sizes), it is possible to abuse this function in ways that can cause Python to crash. For example:

```
>>> add.zadd([1, 2, 3], [1, 2], [3, 4], 1000)
```

will cause a program crash on most systems. Under the hood, the lists are being converted to arrays but then the underlying `add` function is told to cycle way beyond the borders of the allocated memory.

In order to improve the interface, `f2py` supports directives. This is accomplished by constructing a signature file. It is usually best to start from the interfaces that `f2py` produces in that file, which correspond to the default behavior. To get `f2py` to generate the interface file use the `-h` option:

```
python -m numpy.f2py -h add.pyf -m add add.f
```

This command creates the `add.pyf` file in the current directory. The section of this file corresponding to `zadd` is:

```
subroutine zadd(a,b,c,n) ! in :add:add.f
   double complex dimension(*) :: a
   double complex dimension(*) :: b
   double complex dimension(*) :: c
   integer :: n
end subroutine zadd
```

By placing intent directives and checking code, the interface can be cleaned up quite a bit so the Python module method is both easier to use and more robust to malformed inputs.

```
subroutine zadd(a,b,c,n) ! in :add:add.f
   double complex dimension(n) :: a
   double complex dimension(n) :: b
   double complex intent(out),dimension(n) :: c
   integer intent(hide),depend(a) :: n=len(a)
end subroutine zadd
```

The intent directive, intent(out) is used to tell f2py that `c` is an output variable and should be created by the interface before being passed to the underlying code. The intent(hide) directive tells f2py to not allow the user to specify the variable, `n`, but instead to get it from the size of `a`. The depend(`a`) directive is necessary to tell f2py that the value of n depends on the input a (so that it won't try to create the variable n until the variable a is created).

After modifying `add.pyf`, the new Python module file can be generated by compiling both `add.f` and `add.pyf`:

```
python -m numpy.f2py -c add.pyf add.f
```

The new interface's docstring is:

```
>>> import add
>>> print(add.zadd.__doc__)
c = zadd(a,b)

Wrapper for ``zadd``.

Parameters
----------
a : input rank-1 array('D') with bounds (n)
b : input rank-1 array('D') with bounds (n)

Returns
-------
c : rank-1 array('D') with bounds (n)
```

Now, the function can be called in a much more robust way:

```
>>> add.zadd([1, 2, 3], [4, 5, 6])
array([5.+0.j, 7.+0.j, 9.+0.j])
```

Notice the automatic conversion to the correct format that occurred.

Inserting directives in Fortran source

The robust interface of the previous section can also be generated automatically by placing the variable directives as special comments in the original Fortran code.

Note: For projects where the Fortran code is being actively developed, this may be preferred.

Thus, if the source code is modified to contain:

```
C
      SUBROUTINE ZADD(A,B,C,N)
C
CF2PY INTENT(OUT) :: C
CF2PY INTENT(HIDE) :: N
CF2PY DOUBLE COMPLEX :: A(N)
CF2PY DOUBLE COMPLEX :: B(N)
CF2PY DOUBLE COMPLEX :: C(N)
      DOUBLE COMPLEX A(*)
      DOUBLE COMPLEX B(*)
      DOUBLE COMPLEX C(*)
      INTEGER N
      DO 20 J = 1, N
         C(J) = A(J) + B(J)
 20   CONTINUE
      END
```

Then, one can compile the extension module using:

```
python -m numpy.f2py -c -m add add.f
```

The resulting signature for the function add.zadd is exactly the same one that was created previously. If the original source code had contained `A(N)` instead of `A(*)` and so forth with `B` and `C`, then nearly the same interface can be obtained by

placing the `INTENT(OUT) :: C` comment line in the source code. The only difference is that `N` would be an optional input that would default to the length of `A`.

A filtering example

This example shows a function that filters a two-dimensional array of double precision floating-point numbers using a fixed averaging filter. The advantage of using Fortran to index into multi-dimensional arrays should be clear from this example.

```
C
      SUBROUTINE DFILTER2D(A,B,M,N)
C
      DOUBLE PRECISION A(M,N)
      DOUBLE PRECISION B(M,N)
      INTEGER N, M
CF2PY INTENT(OUT) :: B
CF2PY INTENT(HIDE) :: N
CF2PY INTENT(HIDE) :: M
      DO 20 I = 2,M-1
         DO 40 J = 2,N-1
            B(I,J) = A(I,J) +
     &           (A(I-1,J)+A(I+1,J) +
     &           A(I,J-1)+A(I,J+1) )*0.5D0 +
     &           (A(I-1,J-1) + A(I-1,J+1) +
     &           A(I+1,J-1) + A(I+1,J+1))*0.25D0
 40      CONTINUE
 20   CONTINUE
      END
```

This code can be compiled and linked into an extension module named filter using:

```
python -m numpy.f2py -c -m filter filter.f
```

This will produce an extension module in the current directory with a method named `dfilter2d` that returns a filtered version of the input.

`depends` keyword example

Consider the following code, saved in the file `myroutine.f90`:

```
subroutine s(n, m, c, x)
        implicit none
          integer, intent(in) :: n, m
          real(kind=8), intent(out), dimension(n,m) :: x
          real(kind=8), intent(in) :: c(:)

        x = 0.0d0
        x(1, 1) = c(1)

end subroutine s
```

Wrapping this with `python -m numpy.f2py -c myroutine.f90 -m myroutine`, we can do the following in Python:

```
>>> import numpy as np
>>> import myroutine
>>> x = myroutine.s(2, 3, np.array([5, 6, 7]))
>>> x
array([[5., 0., 0.],
   [0., 0., 0.]])
```

Now, instead of generating the extension module directly, we will create a signature file for this subroutine first. This is a common pattern for multi-step extension module generation. In this case, after running

```
python -m numpy.f2py myroutine.f90 -m myroutine -h myroutine.pyf
```

the following signature file is generated:

```
!    -*- f90 -*-
! Note: the context of this file is case sensitive.

python module myroutine ! in
    interface  ! in :myroutine
        subroutine s(n,m,c,x) ! in :myroutine:myroutine.f90
            integer intent(in) :: n
            integer intent(in) :: m
            real(kind=8) dimension(:),intent(in) :: c
            real(kind=8) dimension(n,m),intent(out),depend(m,n) :: x
        end subroutine s
    end interface
end python module myroutine

! This file was auto-generated with f2py (version:1.23.0.dev0+120.g4da01f42d).
! See:
! https://web.archive.org/web/20140822061353/http://cens.ioc.ee/projects/f2py2e
```

Now, if we run `python -m numpy.f2py -c myroutine.pyf myroutine.f90` we see an error; note that the signature file included a `depend(m,n)` statement for `x` which is not necessary. Indeed, editing the file above to read

```
!    -*- f90 -*-
! Note: the context of this file is case sensitive.

python module myroutine ! in
    interface  ! in :myroutine
        subroutine s(n,m,c,x) ! in :myroutine:myroutine.f90
            integer intent(in) :: n
            integer intent(in) :: m
            real(kind=8) dimension(:),intent(in) :: c
            real(kind=8) dimension(n,m),intent(out) :: x
        end subroutine s
    end interface
end python module myroutine

! This file was auto-generated with f2py (version:1.23.0.dev0+120.g4da01f42d).
! See:
! https://web.archive.org/web/20140822061353/http://cens.ioc.ee/projects/f2py2e
```

and running `f2py -c myroutine.pyf myroutine.f90` yields correct results.

Read more

- Wrapping C codes using f2py
- F2py section on the SciPy Cookbook
- F2py example: Interactive System for Ice sheet Simulation
- "Interfacing With Other Languages" section on the SciPy Cookbook.

F2PY reference manual

Signature file

The interface definition file (.pyf) is how you can fine-tune the interface between Python and Fortran. The syntax specification for signature files (`.pyf` files) is modeled on the Fortran 90/95 language specification. Almost all Fortran standard constructs are understood, both in free and fixed format (recall that Fortran 77 is a subset of Fortran 90/95). F2PY introduces some extensions to the Fortran 90/95 language specification that help in the design of the Fortran to Python interface, making it more "Pythonic".

Signature files may contain arbitrary Fortran code so that any Fortran 90/95 codes can be treated as signature files. F2PY silently ignores Fortran constructs that are irrelevant for creating the interface. However, this also means that syntax errors are not caught by F2PY and will only be caught when the library is built.

Note: Currently, F2PY may fail with some valid Fortran constructs. If this happens, you can check the NumPy GitHub issue tracker for possible workarounds or work-in-progress ideas.

In general, the contents of the signature files are case-sensitive. When scanning Fortran codes to generate a signature file, F2PY lowers all cases automatically except in multi-line blocks or when the `--no-lower` option is used.

The syntax of signature files is presented below.

Signature files syntax

Python module block

A signature file may contain one (recommended) or more `python module` blocks. The `python module` block describes the contents of a Python/C extension module `<modulename>module.c` that F2PY generates.

> **Warning:** Exception: if `<modulename>` contains a substring `__user__`, then the corresponding `python module` block describes the signatures of call-back functions (see *Call-back arguments*).

A `python module` block has the following structure:

```
python module <modulename>
  [<usercode statement>]...
  [
  interface
    <usercode statement>
    <Fortran block data signatures>
    <Fortran/C routine signatures>
  end [interface]
  ]...
```

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```
  [
  interface
    module <F90 modulename>
      [<F90 module data type declarations>]
      [<F90 module routine signatures>]
    end [module [<F90 modulename>]]
  end [interface]
  ]...
end [python module [<modulename>]]
```

Here brackets `[]` indicate an optional section, dots `...` indicate one or more of a previous section. So, `[]...` is to be read as zero or more of a previous section.

Fortran/C routine signatures

The signature of a Fortran routine has the following structure:

```
[<typespec>] function | subroutine <routine name> \
              [ ( [<arguments>] ) ] [ result ( <entityname> ) ]
  [<argument/variable type declarations>]
  [<argument/variable attribute statements>]
  [<use statements>]
  [<common block statements>]
  [<other statements>]
end [ function | subroutine [<routine name>] ]
```

From a Fortran routine signature F2PY generates a Python/C extension function that has the following signature:

```
def <routine name>(<required arguments>[,<optional arguments>]):
    ...
    return <return variables>
```

The signature of a Fortran block data has the following structure:

```
block data [ <block data name> ]
  [<variable type declarations>]
  [<variable attribute statements>]
  [<use statements>]
  [<common block statements>]
  [<include statements>]
end [ block data [<block data name>] ]
```

Type declarations

The definition of the `<argument/variable type declaration>` part is

```
<typespec> [ [<attrspec>] :: ] <entitydecl>
```

where

```
<typespec> := byte | character [<charselector>]
            | complex [<kindselector>] | real [<kindselector>]
            | double complex | double precision
```

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```
           | integer [<kindselector>] | logical [<kindselector>]

<charselector> := * <charlen>
                | ( [len=] <len> [ , [kind=] <kind>] )
                | ( kind= <kind> [ , len= <len> ] )
<kindselector> := * <intlen> | ( [kind=] <kind> )

<entitydecl> := <name> [ [ * <charlen> ] [ ( <arrayspec> ) ]
                       | [ ( <arrayspec> ) ] * <charlen> ]
                      | [ / <init_expr> / | = <init_expr> ] \
                        [ , <entitydecl> ]
```

and

- `<attrspec>` is a comma separated list of *attributes*;
- `<arrayspec>` is a comma separated list of dimension bounds;
- `<init_expr>` is a *C expression*;
- `<intlen>` may be negative integer for `integer` type specifications. In such cases `integer*<negintlen>` represents unsigned C integers;

If an argument has no `<argument type declaration>`, its type is determined by applying `implicit` rules to its name.

Statements

Attribute statements

The `<argument/variable attribute statement>` is similar to the `<argument/variable type declaration>`, but without `<typespec>`.

An attribute statement cannot contain other attributes, and `<entitydecl>` can be only a list of names. See *Attributes* for more details on the attributes that can be used by F2PY.

Use statements

- The definition of the `<use statement>` part is

  ```
  use <modulename> [ , <rename_list> | , ONLY : <only_list> ]
  ```

  where

  ```
  <rename_list> := <local_name> => <use_name> [ , <rename_list> ]
  ```

- Currently F2PY uses `use` statements only for linking call-back modules and `external` arguments (call-back functions). See *Call-back arguments*.

Common block statements

- The definition of the <common block statement> part is

```
common / <common name> / <shortentitydecl>
```

  where

```
<shortentitydecl> := <name> [ ( <arrayspec> ) ] [ , <shortentitydecl> ]
```

- If a python module block contains two or more common blocks with the same name, the variables from the additional declarations are appended. The types of variables in <shortentitydecl> are defined using <argument type declarations>. Note that the corresponding <argument type declarations> may contain array specifications; then these need not be specified in <shortentitydecl>.

Other statements

- The <other statement> part refers to any other Fortran language constructs that are not described above. F2PY ignores most of them except the following:
  - call statements and function calls of external arguments (see *more details on external arguments*);
  - **include statements**

```
include '<filename>'
include "<filename>"
```

    If a file <filename> does not exist, the include statement is ignored. Otherwise, the file <filename> is included to a signature file. include statements can be used in any part of a signature file, also outside the Fortran/C routine signature blocks.

  - **implicit statements**

```
implicit none
implicit <list of implicit maps>
```

    where

```
<implicit map> := <typespec> ( <list of letters or range of letters> )
```

    Implicit rules are used to determine the type specification of a variable (from the first-letter of its name) if the variable is not defined using <variable type declaration>. Default implicit rules are given by:

```
implicit real (a-h,o-z,$_), integer (i-m)
```

  - **entry statements**

```
entry <entry name> [([<arguments>])]
```

    F2PY generates wrappers for all entry names using the signature of the routine block.

    Note: The entry statement can be used to describe the signature of an arbitrary subroutine or function allowing F2PY to generate a number of wrappers from only one routine block signature. There are

few restrictions while doing this: `fortranname` cannot be used, `callstatement` and `callprotoargument` can be used only if they are valid for all entry routines, etc.

F2PY statements

In addition, F2PY introduces the following statements:

threadsafe
Uses a `Py_BEGIN_ALLOW_THREADS .. Py_END_ALLOW_THREADS` block around the call to Fortran/C function.

callstatement <C-expr|multi-line block>
Replaces the F2PY generated call statement to Fortran/C function with `<C-expr|multi-line block>`. The wrapped Fortran/C function is available as `(*f2py_func)`.

To raise an exception, set `f2py_success = 0` in `<C-expr|multi-line block>`.

callprotoargument <C-typespecs>
When the `callstatement` statement is used, F2PY may not generate proper prototypes for Fortran/C functions (because `<C-expr>` may contain function calls, and F2PY has no way to determine what should be the proper prototype).

With this statement you can explicitly specify the arguments of the corresponding prototype:

```
extern <return type> FUNC_F(<routine name>,<ROUTINE NAME>)(<callprotoargument>);
```

fortranname [<actual Fortran/C routine name>]
F2PY allows for the use of an arbitrary `<routine name>` for a given Fortran/C function. Then this statement is used for the `<actual Fortran/C routine name>`.

If `fortranname` statement is used without `<actual Fortran/C routine name>` then a dummy wrapper is generated.

usercode <multi-line block>
When this is used inside a `python module` block, the given C code will be inserted to generated C/API source just before wrapper function definitions.

Here you can define arbitrary C functions to be used for the initialization of optional arguments.

For example, if `usercode` is used twice inside `python module` block then the second multi-line block is inserted after the definition of the external routines.

When used inside `<routine signature>`, then the given C code will be inserted into the corresponding wrapper function just after the declaration of variables but before any C statements. So, the `usercode` follow-up can contain both declarations and C statements.

When used inside the first `interface` block, then the given C code will be inserted at the end of the initialization function of the extension module. This is how the extension modules dictionary can be modified and has many use-cases; for example, to define additional variables.

pymethoddef <multiline block>
This is a multi-line block which will be inserted into the definition of a module methods `PyMethodDef`-array. It must be a comma-separated list of C arrays (see Extending and Embedding Python documentation for details). `pymethoddef` statement can be used only inside `python module` block.

Attributes

The following attributes can be used by F2PY.

optional
The corresponding argument is moved to the end of `<optional arguments>` list. A default value for an optional argument can be specified via `<init_expr>` (see the `entitydecl` *definition*)

Note:

- The default value must be given as a valid C expression.
- Whenever `<init_expr>` is used, the `optional` attribute is set automatically by F2PY.
- For an optional array argument, all its dimensions must be bounded.

---

required
The corresponding argument with this attribute is considered mandatory. This is the default. `required` should only be specified if there is a need to disable the automatic `optional` setting when `<init_expr>` is used.

If a Python `None` object is used as a required argument, the argument is treated as optional. That is, in the case of array arguments, the memory is allocated. If `<init_expr>` is given, then the corresponding initialization is carried out.

dimension(<arrayspec>)
The corresponding variable is considered as an array with dimensions given in `<arrayspec>`.

intent(<intentspec>)
This specifies the "intention" of the corresponding argument. `<intentspec>` is a comma separated list of the following keys:

- **in**
  The corresponding argument is considered to be input-only. This means that the value of the argument is passed to a Fortran/C function and that the function is expected to not change the value of this argument.
- **inout**
  The corresponding argument is marked for input/output or as an *in situ* output argument. `intent(inout)` arguments can be only contiguous NumPy arrays (in either the Fortran or C sense) with proper type and size. The latter coincides with the default contiguous concept used in NumPy and is effective only if `intent(c)` is used. F2PY assumes Fortran contiguous arguments by default.

  Note: Using `intent(inout)` is generally not recommended, as it can cause unexpected results. For example, scalar arguments using `intent(inout)` are assumed to be array objects in order to have *in situ* changes be effective. Use `intent(in,out)` instead.

  See also the `intent(inplace)` attribute.
- **inplace**
  The corresponding argument is considered to be an input/output or *in situ* output argument. `intent(inplace)` arguments must be NumPy arrays of a proper size. If the type of an array is not "proper" or the array is non-contiguous then the array will be modified in-place to fix the type and make it contiguous.

  Note: Using `intent(inplace)` is generally not recommended either.

For example, when slices have been taken from an `intent(inplace)` argument then after in-place changes, the data pointers for the slices may point to an unallocated memory area.

- **out**

  The corresponding argument is considered to be a return variable. It is appended to the `<returned variables>` list. Using `intent(out)` sets `intent(hide)` automatically, unless `intent(in)` or `intent(inout)` are specified as well.

  By default, returned multidimensional arrays are Fortran-contiguous. If `intent(c)` attribute is used, then the returned multidimensional arrays are C-contiguous.

- **hide**

  The corresponding argument is removed from the list of required or optional arguments. Typically `intent(hide)` is used with `intent(out)` or when `<init_expr>` completely determines the value of the argument like in the following example:

  ```
  integer intent(hide),depend(a) :: n = len(a)
  real intent(in),dimension(n) :: a
  ```

- **c**

  The corresponding argument is treated as a C scalar or C array argument. For the case of a scalar argument, its value is passed to a C function as a C scalar argument (recall that Fortran scalar arguments are actually C pointer arguments). For array arguments, the wrapper function is assumed to treat multidimensional arrays as C-contiguous arrays.

  There is no need to use `intent(c)` for one-dimensional arrays, irrespective of whether the wrapped function is in Fortran or C. This is because the concepts of Fortran- and C contiguity overlap in one-dimensional cases.

  If `intent(c)` is used as a statement but without an entity declaration list, then F2PY adds the `intent(c)` attribute to all arguments.

  Also, when wrapping C functions, one must use `intent(c)` attribute for `<routine name>` in order to disable Fortran specific `F_FUNC(..,..)` macros.

- **cache**

  The corresponding argument is treated as junk memory. No Fortran nor C contiguity checks are carried out. Using `intent(cache)` makes sense only for array arguments, also in conjunction with `intent(hide)` or `optional` attributes.

- **copy**

  Ensures that the original contents of `intent(in)` argument is preserved. Typically used with the `intent(in,out)` attribute. F2PY creates an optional argument `overwrite_<argument name>` with the default value `0`.

- **overwrite**

  This indicates that the original contents of the `intent(in)` argument may be altered by the Fortran/C function. F2PY creates an optional argument `overwrite_<argument name>` with the default value `1`.

- **out=<new name>**

  Replaces the returned name with `<new name>` in the `__doc__` string of the wrapper function.

- **callback**

  Constructs an external function suitable for calling Python functions from Fortran. `intent(callback)` must be specified before the corresponding `external` statement. If the 'argument' is not in the argument list then it will be added to Python wrapper but only by initializing an external function.

Note: Use `intent(callback)` in situations where the Fortran/C code assumes that the user implemented a function with a given prototype and linked it to an executable. Don't use `intent(callback)` if the function appears in the argument list of a Fortran routine.

With `intent(hide)` or `optional` attributes specified and using a wrapper function without specifying the callback argument in the argument list; then the call-back function is assumed to be found in the namespace of the F2PY generated extension module where it can be set as a module attribute by a user.

- **aux**
  Defines an auxiliary C variable in the F2PY generated wrapper function. Useful to save parameter values so that they can be accessed in initialization expressions for other variables.

  Note: `intent(aux)` silently implies `intent(c)`.

The following rules apply:

- If none of `intent(in | inout | out | hide)` are specified, `intent(in)` is assumed.
  - `intent(in,inout)` is `intent(in)`;
  - `intent(in,hide)` or `intent(inout,hide)` is `intent(hide)`;
  - `intent(out)` is `intent(out,hide)` unless `intent(in)` or `intent(inout)` is specified.
- If `intent(copy)` or `intent(overwrite)` is used, then an additional optional argument is introduced with a name `overwrite_<argument name>` and a default value 0 or 1, respectively.
  - `intent(inout,inplace)` is `intent(inplace)`;
  - `intent(in,inplace)` is `intent(inplace)`;
  - `intent(hide)` disables `optional` and `required`.

check([<C-booleanexpr>])
Performs a consistency check on the arguments by evaluating `<C-booleanexpr>`; if `<C-booleanexpr>` returns 0, an exception is raised.

Note: If `check(..)` is not used then F2PY automatically generates a few standard checks (e.g. in a case of an array argument, it checks for the proper shape and size). Use `check()` to disable checks generated by F2PY.

depend([<names>])
This declares that the corresponding argument depends on the values of variables in the `<names>` list. For example, `<init_expr>` may use the values of other arguments. Using information given by `depend(..)` attributes, F2PY ensures that arguments are initialized in a proper order. If the `depend(..)` attribute is not used then F2PY determines dependence relations automatically. Use `depend()` to disable the dependence relations generated by F2PY.

When you edit dependence relations that were initially generated by F2PY, be careful not to break the dependence relations of other relevant variables. Another thing to watch out for is cyclic dependencies. F2PY is able to detect cyclic dependencies when constructing wrappers and it complains if any are found.

allocatable
The corresponding variable is a Fortran 90 allocatable array defined as Fortran 90 module data.

external
The corresponding argument is a function provided by user. The signature of this call-back function can be defined

- in `__user__` module block,
- or by demonstrative (or real, if the signature file is a real Fortran code) call in the `<other statements>` block.

For example, F2PY generates from:

```
external cb_sub, cb_fun
integer n
real a(n),r
call cb_sub(a,n)
r = cb_fun(4)
```

the following call-back signatures:

```
subroutine cb_sub(a,n)
    real dimension(n) :: a
    integer optional,check(len(a)>=n),depend(a) :: n=len(a)
end subroutine cb_sub
function cb_fun(e_4_e) result (r)
    integer :: e_4_e
    real :: r
end function cb_fun
```

The corresponding user-provided Python function are then:

```
def cb_sub(a,[n]):
    ...
    return
def cb_fun(e_4_e):
    ...
    return r
```

See also the `intent(callback)` attribute.

parameter
: This indicates that the corresponding variable is a parameter and it must have a fixed value. F2PY replaces all parameter occurrences by their corresponding values.

Extensions

F2PY directives

The F2PY directives allow using F2PY signature file constructs in Fortran 77/90 source codes. With this feature one can (almost) completely skip the intermediate signature file generation and apply F2PY directly to Fortran source codes.

F2PY directives have the following form:

```
<comment char>f2py ...
```

where allowed comment characters for fixed and free format Fortran codes are `cC*!#` and `!`, respectively. Everything that follows `<comment char>f2py` is ignored by a compiler but read by F2PY as a normal non-comment Fortran line:

Note: When F2PY finds a line with F2PY directive, the directive is first replaced by 5 spaces and then the line is reread.

For fixed format Fortran codes, `<comment char>` must be at the first column of a file, of course. For free format Fortran codes, the F2PY directives can appear anywhere in a file.

C expressions

C expressions are used in the following parts of signature files:

- `<init_expr>` for variable initialization;
- `<C-booleanexpr>` of the `check` attribute;
- `<arrayspec>` of the `dimension` attribute;
- `callstatement` statement, here also a C multi-line block can be used.

A C expression may contain:

- standard C constructs;
- functions from `math.h` and `Python.h`;
- variables from the argument list, presumably initialized before according to given dependence relations;
- the following CPP macros:

  `f2py_rank(<name>)`
  Returns the rank of an array `<name>`.

  `f2py_shape(<name>, <n>)`
  Returns the `<n>`-th dimension of an array `<name>`.

  `f2py_len(<name>)`
  Returns the length of an array `<name>`.

  `f2py_size(<name>)`
  Returns the size of an array `<name>`.

  `f2py_itemsize(<name>)`
  Returns the itemsize of an array `<name>`.

  `f2py_slen(<name>)`
  Returns the length of a string `<name>`.

For initializing an array `<array name>`, F2PY generates a loop over all indices and dimensions that executes the following pseudo-statement:

```
<array name>(_i[0],_i[1],...) = <init_expr>;
```

where `_i[<i>]` refers to the `<i>`-th index value and that runs from `0` to `shape(<array name>,<i>)-1`.

For example, a function `myrange(n)` generated from the following signature

```
subroutine myrange(a,n)
  fortranname        ! myrange is a dummy wrapper
  integer intent(in) :: n
  real*8 intent(c,out),dimension(n),depend(n) :: a = _i[0]
end subroutine myrange
```

is equivalent to `numpy.arange(n,dtype=float)`.

Warning: F2PY may lower cases also in C expressions when scanning Fortran codes (see `--[no]-lower` option).

Multi-line blocks

A multi-line block starts with `'''` (triple single-quotes) and ends with `'''` in some *strictly* subsequent line. Multi-line blocks can be used only within .pyf files. The contents of a multi-line block can be arbitrary (except that it cannot contain `'''`) and no transformations (e.g. lowering cases) are applied to it.

Currently, multi-line blocks can be used in the following constructs:

- as a C expression of the `callstatement` statement;
- as a C type specification of the `callprotoargument` statement;
- as a C code block of the `usercode` statement;
- as a list of C arrays of the `pymethoddef` statement;
- as documentation string.

Extended char-selector

F2PY extends char-selector specification, usable within a signature file or a F2PY directive, as follows:

```
<extended-charselector> := <charselector>
                         | (f2py_len= <len>)
```

See *Character strings* for usage.

Using F2PY bindings in Python

In this page, you can find a full description and a few examples of common usage patterns for F2PY with Python and different argument types. For more examples and use cases, see *F2PY examples*.

Fortran type objects

All wrappers for Fortran/C routines, common blocks, or Fortran 90 module data generated by F2PY are exposed to Python as `fortran` type objects. Routine wrappers are callable `fortran` type objects while wrappers to Fortran data have attributes referring to data objects.

All `fortran` type objects have an attribute `_cpointer` that contains a `PyCapsule` referring to the C pointer of the corresponding Fortran/C function or variable at the C level. Such `PyCapsule` objects can be used as callback arguments for F2PY generated functions to bypass the Python C/API layer for calling Python functions from Fortran or C. This can be useful when the computational aspects of such functions are implemented in C or Fortran and wrapped with F2PY (or any other tool capable of providing the `PyCapsule` containing a function).

Consider a Fortran 77 file `` `ftype.f ``:

```
C FILE: FTYPE.F
      SUBROUTINE FOO(N)
      INTEGER N
Cf2py integer optional,intent(in) :: n = 13
```

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```
      REAL A,X
      COMMON /DATA/ A,X(3)
C     PRINT*, "IN FOO: N=",N," A=",A," X=[",X(1),X(2),X(3),"]"
      END
C END OF FTYPE.F
```

and a wrapper built using `f2py -c ftype.f -m ftype`.

In Python, you can observe the types of `foo` and `data`, and how to access individual objects of the wrapped Fortran code.

```
>>> import ftype
>>> print(ftype.__doc__)
This module 'ftype' is auto-generated with f2py (version:2).
Functions:
  foo(n=13)
COMMON blocks:
  /data/ a,x(3)
.
>>> type(ftype.foo), type(ftype.data)
(<class 'fortran'>, <class 'fortran'>)
>>> ftype.foo()
 IN FOO: N= 13 A=  0. X=[  0.  0.  0.]
>>> ftype.data.a = 3
>>> ftype.data.x = [1,2,3]
>>> ftype.foo()
 IN FOO: N= 13 A=  3. X=[  1.  2.  3.]
>>> ftype.data.x[1] = 45
>>> ftype.foo(24)
 IN FOO: N= 24 A=  3. X=[  1.  45.  3.]
>>> ftype.data.x
array([  1.,  45.,   3.], dtype=float32)
```

Scalar arguments

In general, a scalar argument for a F2PY generated wrapper function can be an ordinary Python scalar (integer, float, complex number) as well as an arbitrary sequence object (list, tuple, array, string) of scalars. In the latter case, the first element of the sequence object is passed to the Fortran routine as a scalar argument.

Note:

- When type-casting is required and there is possible loss of information via narrowing e.g. when type-casting float to integer or complex to float, F2PY *does not* raise an exception.
  - For complex to real type-casting only the real part of a complex number is used.
- `intent(inout)` scalar arguments are assumed to be array objects in order to have *in situ* changes be effective. It is recommended to use arrays with proper type but also other types work. *Read more about the intent attribute*.

Consider the following Fortran 77 code:

```
C FILE: SCALAR.F
      SUBROUTINE FOO(A,B)
      REAL*8 A, B
```

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```
Cf2py intent(in) a
Cf2py intent(inout) b
      PRINT*, "    A=",A," B=",B
      PRINT*, "INCREMENT A AND B"
      A = A + 1D0
      B = B + 1D0
      PRINT*, "NEW A=",A," B=",B
      END
C END OF FILE SCALAR.F
```

and wrap it using `f2py -c -m scalar scalar.f`.

In Python:

```
>>> import scalar
>>> print(scalar.foo.__doc__)
foo(a,b)

Wrapper for ``foo``.

Parameters
----------
a : input float
b : in/output rank-0 array(float,'d')

>>> scalar.foo(2, 3)
     A=  2. B=  3.
 INCREMENT A AND B
 NEW A=  3. B=  4.
>>> import numpy
>>> a = numpy.array(2)    # these are integer rank-0 arrays
>>> b = numpy.array(3)
>>> scalar.foo(a, b)
     A=  2. B=  3.
 INCREMENT A AND B
 NEW A=  3. B=  4.
>>> print(a, b)           # note that only b is changed in situ
2 4
```

String arguments

F2PY generated wrapper functions accept almost any Python object as a string argument, since `str` is applied for non-string objects. Exceptions are NumPy arrays that must have type code `'S1'` or `'b'` (corresponding to the outdated `'c'` or `'1'` typecodes, respectively) when used as string arguments. See *Scalars* for more information on these typecodes.

A string can have an arbitrary length when used as a string argument for an F2PY generated wrapper function. If the length is greater than expected, the string is truncated silently. If the length is smaller than expected, additional memory is allocated and filled with `\0`.

Because Python strings are immutable, an `intent(inout)` argument expects an array version of a string in order to have *in situ* changes be effective.

Consider the following Fortran 77 code:

```
C FILE: STRING.F
      SUBROUTINE FOO(A,B,C,D)
```

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```
      CHARACTER*5 A, B
      CHARACTER*(*) C,D
Cf2py intent(in) a,c
Cf2py intent(inout) b,d
      PRINT*, "A=",A
      PRINT*, "B=",B
      PRINT*, "C=",C
      PRINT*, "D=",D
      PRINT*, "CHANGE A,B,C,D"
      A(1:1) = 'A'
      B(1:1) = 'B'
      C(1:1) = 'C'
      D(1:1) = 'D'
      PRINT*, "A=",A
      PRINT*, "B=",B
      PRINT*, "C=",C
      PRINT*, "D=",D
      END
C END OF FILE STRING.F
```

and wrap it using `f2py -c -m mystring string.f`.

Python session:

```
>>> import mystring
>>> print(mystring.foo.__doc__)
foo(a,b,c,d)

Wrapper for ``foo``.

Parameters
----------
a : input string(len=5)
b : in/output rank-0 array(string(len=5),'c')
c : input string(len=-1)
d : in/output rank-0 array(string(len=-1),'c')

>>> from numpy import array
>>> a = array(b'123\0\0')
>>> b = array(b'123\0\0')
>>> c = array(b'123')
>>> d = array(b'123')
>>> mystring.foo(a, b, c, d)
 A=123
 B=123
 C=123
 D=123
 CHANGE A,B,C,D
 A=A23
 B=B23
 C=C23
 D=D23
>>> a[()], b[()], c[()], d[()]
(b'123', b'B23', b'123', b'D2')
```

Array arguments

In general, array arguments for F2PY generated wrapper functions accept arbitrary sequences that can be transformed to NumPy array objects. There are two notable exceptions:

- `intent(inout)` array arguments must always be proper-contiguous and have a compatible `dtype`, otherwise an exception is raised.
- `intent(inplace)` array arguments will be changed *in situ* if the argument has a different type than expected (see the `intent(inplace)` *attribute* for more information).

In general, if a NumPy array is proper-contiguous and has a proper type then it is directly passed to the wrapped Fortran/C function. Otherwise, an element-wise copy of the input array is made and the copy, being proper-contiguous and with proper type, is used as the array argument.

Usually there is no need to worry about how the arrays are stored in memory and whether the wrapped functions, being either Fortran or C functions, assume one or another storage order. F2PY automatically ensures that wrapped functions get arguments with the proper storage order; the underlying algorithm is designed to make copies of arrays only when absolutely necessary. However, when dealing with very large multidimensional input arrays with sizes close to the size of the physical memory in your computer, then care must be taken to ensure the usage of proper-contiguous and proper type arguments.

To transform input arrays to column major storage order before passing them to Fortran routines, use the function *numpy.asfortranarray*.

Consider the following Fortran 77 code:

```
C FILE: ARRAY.F
      SUBROUTINE FOO(A,N,M)
C
C     INCREMENT THE FIRST ROW AND DECREMENT THE FIRST COLUMN OF A
C
      INTEGER N,M,I,J
      REAL*8 A(N,M)
Cf2py intent(in,out,copy) a
Cf2py integer intent(hide),depend(a) :: n=shape(a,0), m=shape(a,1)
      DO J=1,M
         A(1,J) = A(1,J) + 1D0
      ENDDO
      DO I=1,N
         A(I,1) = A(I,1) - 1D0
      ENDDO
      END
C END OF FILE ARRAY.F
```

and wrap it using `f2py -c -m arr array.f -DF2PY_REPORT_ON_ARRAY_COPY=1`.

In Python:

```
>>> import arr
>>> from numpy import asfortranarray
>>> print(arr.foo.__doc__)
a = foo(a,[overwrite_a])

Wrapper for ``foo``.

Parameters
----------
a : input rank-2 array('d') with bounds (n,m)
```

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```
Other Parameters
----------------
overwrite_a : input int, optional
    Default: 0

Returns
-------
a : rank-2 array('d') with bounds (n,m)

>>> a = arr.foo([[1, 2, 3],
...              [4, 5, 6]])
created an array from object
>>> print(a)
[[ 1.  3.  4.]
 [ 3.  5.  6.]]
>>> a.flags.c_contiguous
False
>>> a.flags.f_contiguous
True
# even if a is proper-contiguous and has proper type,
# a copy is made forced by intent(copy) attribute
# to preserve its original contents
>>> b = arr.foo(a)
copied an array: size=6, elsize=8
>>> print(a)
[[ 1.  3.  4.]
 [ 3.  5.  6.]]
>>> print(b)
[[ 1.  4.  5.]
 [ 2.  5.  6.]]
>>> b = arr.foo(a, overwrite_a = 1) # a is passed directly to Fortran
...                                 # routine and its contents is discarded
...
>>> print(a)
[[ 1.  4.  5.]
 [ 2.  5.  6.]]
>>> print(b)
[[ 1.  4.  5.]
 [ 2.  5.  6.]]
>>> a is b                          # a and b are actually the same objects
True
>>> print(arr.foo([1, 2, 3]))       # different rank arrays are allowed
created an array from object
[ 1.  1.  2.]
>>> print(arr.foo([[[1], [2], [3]]]))
created an array from object
[[[ 1.]
  [ 1.]
  [ 2.]]]
>>>
>>> # Creating arrays with column major data storage order:
 ...
>>> s = asfortranarray([[1, 2, 3], [4, 5, 6]])
>>> s.flags.f_contiguous
True
>>> print(s)
```

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```
[[1 2 3]
 [4 5 6]]
>>> print(arr.foo(s))
>>> s2 = asfortranarray(s)
>>> s2 is s    # an array with column major storage order
               # is returned immediately
True
>>> # Note that arr.foo returns a column major data storage order array:
 ...
>>> s3 = ascontiguousarray(s)
>>> s3.flags.f_contiguous
False
>>> s3.flags.c_contiguous
True
>>> s3 = arr.foo(s3)
copied an array: size=6, elsize=8
>>> s3.flags.f_contiguous
True
>>> s3.flags.c_contiguous
False
```

Call-back arguments

F2PY supports calling Python functions from Fortran or C codes.

Consider the following Fortran 77 code:

```
C FILE: CALLBACK.F
      SUBROUTINE FOO(FUN,R)
      EXTERNAL FUN
      INTEGER I
      REAL*8 R, FUN
Cf2py intent(out) r
      R = 0D0
      DO I=-5,5
         R = R + FUN(I)
      ENDDO
      END
C END OF FILE CALLBACK.F
```

and wrap it using `f2py -c -m callback callback.f`.

In Python:

```
>>> import callback
>>> print(callback.foo.__doc__)
r = foo(fun,[fun_extra_args])

Wrapper for ``foo``.

Parameters
----------
fun : call-back function

Other Parameters
```

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```
----------------
fun_extra_args : input tuple, optional
    Default: ()

Returns
-------
r : float

Notes
-----
Call-back functions::

  def fun(i): return r
  Required arguments:
    i : input int
  Return objects:
    r : float

>>> def f(i): return i*i
...
>>> print(callback.foo(f))
110.0
>>> print(callback.foo(lambda i:1))
11.0
```

In the above example F2PY was able to guess accurately the signature of the call-back function. However, sometimes F2PY cannot establish the appropriate signature; in these cases the signature of the call-back function must be explicitly defined in the signature file.

To facilitate this, signature files may contain special modules (the names of these modules contain the special `__user__` sub-string) that define the various signatures for call-back functions. Callback arguments in routine signatures have the `external` attribute (see also the `intent(callback)` *attribute*). To relate a callback argument with its signature in a `__user__` module block, a `use` statement can be utilized as illustrated below. The same signature for a callback argument can be referred to in different routine signatures.

We use the same Fortran 77 code as in the previous example but now we will pretend that F2PY was not able to guess the signatures of call-back arguments correctly. First, we create an initial signature file `callback2.pyf` using F2PY:

```
f2py -m callback2 -h callback2.pyf callback.f
```

Then modify it as follows

```
!    -*- f90 -*-
python module __user__routines
    interface
        function fun(i) result (r)
            integer :: i
            real*8 :: r
        end function fun
    end interface
end python module __user__routines

python module callback2
    interface
        subroutine foo(f,r)
            use __user__routines, f=>fun
            external f
```

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```
            real*8 intent(out) :: r
        end subroutine foo
    end interface
end python module callback2
```

Finally, we build the extension module using `f2py -c callback2.pyf callback.f`.

An example Python session for this snippet would be identical to the previous example except that the argument names would differ.

Sometimes a Fortran package may require that users provide routines that the package will use. F2PY can construct an interface to such routines so that Python functions can be called from Fortran.

Consider the following Fortran 77 subroutine that takes an array as its input and applies a function `func` to its elements.

```
      subroutine calculate(x,n)
cf2py intent(callback) func
      external func
c     The following lines define the signature of func for F2PY:
cf2py real*8 y
cf2py y = func(y)
c
cf2py intent(in,out,copy) x
      integer n,i
      real*8 x(n), func
      do i=1,n
         x(i) = func(x(i))
      end do
      end
```

The Fortran code expects that the function `func` has been defined externally. In order to use a Python function for `func`, it must have an attribute `intent(callback)` and it must be specified before the `external` statement.

Finally, build an extension module using `f2py -c -m foo calculate.f`

In Python:

```
>>> import foo
>>> foo.calculate(range(5), lambda x: x*x)
array([  0.,   1.,   4.,   9.,  16.])
>>> import math
>>> foo.calculate(range(5), math.exp)
array([  1.        ,   2.71828183,   7.3890561,  20.08553692,  54.59815003])
```

The function is included as an argument to the python function call to the Fortran subroutine even though it was *not* in the Fortran subroutine argument list. The "external" keyword refers to the C function generated by f2py, not the Python function itself. The python function is essentially being supplied to the C function.

The callback function may also be explicitly set in the module. Then it is not necessary to pass the function in the argument list to the Fortran function. This may be desired if the Fortran function calling the Python callback function is itself called by another Fortran function.

Consider the following Fortran 77 subroutine:

```
      subroutine f1()
         print *, "in f1, calling f2 twice.."
         call f2()
         call f2()
```

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```
         return
      end

      subroutine f2()
cf2py    intent(callback, hide) fpy
         external fpy
         print *, "in f2, calling f2py.."
         call fpy()
         return
      end
```

and wrap it using `f2py -c -m pfromf extcallback.f`.

In Python:

```
>>> import pfromf
>>> pfromf.f2()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
pfromf.error: Callback fpy not defined (as an argument or module pfromf attribute).

>>> def f(): print("python f")
...
>>> pfromf.fpy = f
>>> pfromf.f2()
 in f2, calling f2py..
python f
>>> pfromf.f1()
 in f1, calling f2 twice..
 in f2, calling f2py..
python f
 in f2, calling f2py..
python f
>>>
```

Note: When using modified Fortran code via `callstatement` or other directives, the wrapped Python function must be called as a callback, otherwise only the bare Fortran routine will be used. For more details, see https://github.com/numpy/numpy/issues/26681#issuecomment-2466460943

Resolving arguments to call-back functions

F2PY generated interfaces are very flexible with respect to call-back arguments. For each call-back argument an additional optional argument `<name>_extra_args` is introduced by F2PY. This argument can be used to pass extra arguments to user provided call-back functions.

If a F2PY generated wrapper function expects the following call-back argument:

```
def fun(a_1,...,a_n):
   ...
   return x_1,...,x_k
```

but the following Python function

```
def gun(b_1,...,b_m):
    ...
    return y_1,...,y_l
```

is provided by a user, and in addition,

```
fun_extra_args = (e_1,...,e_p)
```

is used, then the following rules are applied when a Fortran or C function evaluates the call-back argument `gun`:

- If `p == 0` then `gun(a_1, ..., a_q)` is called, here `q = min(m, n)`.
- If `n + p <= m` then `gun(a_1, ..., a_n, e_1, ..., e_p)` is called.
- If `p <= m < n + p` then `gun(a_1, ..., a_q, e_1, ..., e_p)` is called, and here `q=m-p`.
- If `p > m` then `gun(e_1, ..., e_m)` is called.
- If `n + p` is less than the number of required arguments to `gun` then an exception is raised.

If the function `gun` may return any number of objects as a tuple; then the following rules are applied:

- If `k < l`, then `y_{k + 1}, ..., y_l` are ignored.
- If `k > l`, then only `x_1, ..., x_l` are set.

Common blocks

F2PY generates wrappers to `common` blocks defined in a routine signature block. Common blocks are visible to all Fortran codes linked to the current extension module, but not to other extension modules (this restriction is due to the way Python imports shared libraries). In Python, the F2PY wrappers to `common` blocks are `fortran` type objects that have (dynamic) attributes related to the data members of the common blocks. When accessed, these attributes return as NumPy array objects (multidimensional arrays are Fortran-contiguous) which directly link to data members in common blocks. Data members can be changed by direct assignment or by in-place changes to the corresponding array objects.

Consider the following Fortran 77 code:

```
C FILE: COMMON.F
      SUBROUTINE FOO
      INTEGER I,X
      REAL A
      COMMON /DATA/ I,X(4),A(2,3)
      PRINT*, "I=",I
      PRINT*, "X=[",X,"]"
      PRINT*, "A=["
      PRINT*, "[",A(1,1),",",A(1,2),",",A(1,3),"]"
      PRINT*, "[",A(2,1),",",A(2,2),",",A(2,3),"]"
      PRINT*, "]"
      END
C END OF COMMON.F
```

and wrap it using `f2py -c -m common common.f`.

In Python:

```
>>> import common
>>> print(common.data.__doc__)
i : 'i'-scalar
x : 'i'-array(4)
```

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```
a : 'f'-array(2,3)

>>> common.data.i = 5
>>> common.data.x[1] = 2
>>> common.data.a = [[1,2,3],[4,5,6]]
>>> common.foo()
>>> common.foo()
 I=           5
 X=[           0           2           0           0 ]
 A=[
 [   1.00000000     ,   2.00000000     ,   3.00000000     ]
 [   4.00000000     ,   5.00000000     ,   6.00000000     ]
 ]
>>> common.data.a[1] = 45
>>> common.foo()
 I=           5
 X=[           0           2           0           0 ]
 A=[
 [   1.00000000     ,   2.00000000     ,   3.00000000     ]
 [   45.0000000     ,   45.0000000     ,   45.0000000     ]
 ]
>>> common.data.a                  # a is Fortran-contiguous
array([[  1.,   2.,   3.],
       [ 45.,  45.,  45.]], dtype=float32)
>>> common.data.a.flags.f_contiguous
True
```

Fortran 90 module data

The F2PY interface to Fortran 90 module data is similar to the handling of Fortran 77 common blocks.

Consider the following Fortran 90 code:

```
module mod
  integer i
  integer :: x(4)
  real, dimension(2,3) :: a
  real, allocatable, dimension(:,:) :: b
contains
  subroutine foo
    integer k
    print*, "i=",i
    print*, "x=[",x,"]"
    print*, "a=["
    print*, "[",a(1,1),",",a(1,2),",",a(1,3),"]"
    print*, "[",a(2,1),",",a(2,2),",",a(2,3),"]"
    print*, "]"
    print*, "Setting a(1,2)=a(1,2)+3"
    a(1,2) = a(1,2)+3
  end subroutine foo
end module mod
```

and wrap it using `f2py -c -m moddata moddata.f90`.

In Python:

```
>>> import moddata
>>> print(moddata.mod.__doc__)
i : 'i'-scalar
x : 'i'-array(4)
a : 'f'-array(2,3)
b : 'f'-array(-1,-1), not allocated
foo()

Wrapper for ``foo``.



>>> moddata.mod.i = 5
>>> moddata.mod.x[:2] = [1,2]
>>> moddata.mod.a = [[1,2,3],[4,5,6]]
>>> moddata.mod.foo()
 i=           5
 x=[           1           2           0           0 ]
 a=[
 [   1.000000     ,   2.000000     ,   3.000000     ]
 [   4.000000     ,   5.000000     ,   6.000000     ]
 ]
 Setting a(1,2)=a(1,2)+3
>>> moddata.mod.a               # a is Fortran-contiguous
array([[ 1.,  5.,  3.],
       [ 4.,  5.,  6.]], dtype=float32)
>>> moddata.mod.a.flags.f_contiguous
True
```

Allocatable arrays

F2PY has basic support for Fortran 90 module allocatable arrays.

Consider the following Fortran 90 code:

```
module mod
  real, allocatable, dimension(:,:) :: b
contains
  subroutine foo
    integer k
    if (allocated(b)) then
       print*, "b=["
       do k = 1,size(b,1)
          print*, b(k,1:size(b,2))
       enddo
       print*, "]"
    else
       print*, "b is not allocated"
    endif
  end subroutine foo
end module mod
```

and wrap it using `f2py -c -m allocarr allocarr.f90`.

In Python:

```
>>> import allocarr
>>> print(allocarr.mod.__doc__)
b : 'f'-array(-1,-1), not allocated
foo()

Wrapper for ``foo``.



>>> allocarr.mod.foo()
 b is not allocated
>>> allocarr.mod.b = [[1, 2, 3], [4, 5, 6]]             # allocate/initialize b
>>> allocarr.mod.foo()
 b=[
   1.000000       2.000000       3.000000
   4.000000       5.000000       6.000000
 ]
>>> allocarr.mod.b                                      # b is Fortran-contiguous
array([[ 1.,  2.,  3.],
       [ 4.,  5.,  6.]], dtype=float32)
>>> allocarr.mod.b.flags.f_contiguous
True
>>> allocarr.mod.b = [[1, 2, 3], [4, 5, 6], [7, 8, 9]]  # reallocate/initialize b
>>> allocarr.mod.foo()
 b=[
   1.000000       2.000000       3.000000
   4.000000       5.000000       6.000000
   7.000000       8.000000       9.000000
 ]
>>> allocarr.mod.b = None                               # deallocate array
>>> allocarr.mod.foo()
 b is not allocated
```

F2PY and build systems

In this section we will cover the various popular build systems and their usage with `f2py`.

Changed in version NumPy: 1.26.x

The default build system for `f2py` has traditionally been through the enhanced `numpy.distutils` module. This module is based on `distutils` which was removed in `Python 3.12.0` in **October 2023**. Like the rest of NumPy and SciPy, `f2py` uses `meson` now, see *Status of numpy.distutils and migration advice* for some more details.

> All changes to `f2py` are tested on SciPy, so their CI configuration is always supported.

Note: See *1 Migrating to meson* for migration information.

Basic concepts

Building an extension module which includes Python and Fortran consists of:

- Fortran source(s)
- One or more generated files from `f2py`
  - A `C` wrapper file is always created
  - Code with modules require an additional `.f90` wrapper
  - Code with functions generate an additional `.f` wrapper
- `fortranobject.{c,h}`
  - Distributed with `numpy`
  - Can be queried via `python -c "import numpy.f2py; print(numpy.f2py.get_include())"`
- NumPy headers
  - Can be queried via `python -c "import numpy; print(numpy.get_include())"`
- Python libraries and development headers

Broadly speaking there are three cases which arise when considering the outputs of `f2py`:

Fortran 77 programs

- Input file `blah.f`
- Generates
  - `blahmodule.c`
  - `blah-f2pywrappers.f`

When no `COMMON` blocks are present only a `C` wrapper file is generated. Wrappers are also generated to rewrite assumed shape arrays as automatic arrays.

Fortran 90 programs

- Input file `blah.f90`
- Generates:
  - `blahmodule.c`
  - `blah-f2pywrappers.f`
  - `blah-f2pywrappers2.f90`

The `f90` wrapper is used to handle code which is subdivided into modules. The `f` wrapper makes `subroutines` for `functions`. It rewrites assumed shape arrays as automatic arrays.

Signature files

- Input file `blah.pyf`
- Generates:
  - `blahmodule.c`
  - `blah-f2pywrappers2.f90` (occasionally)
  - `blah-f2pywrappers.f` (occasionally)

Signature files `.pyf` do not signal their language standard via the file extension, they may generate the F90 and F77 specific wrappers depending on their contents; which shifts the burden of checking for generated files onto the build system.

Changed in version NumPy: `1.22.4`

`f2py` will deterministically generate wrapper files based on the input file Fortran standard (F77 or greater). `--skip-empty-wrappers` can be passed to `f2py` to restore the previous behaviour of only generating wrappers when needed by the input .

In theory keeping the above requirements in hand, any build system can be adapted to generate `f2py` extension modules. Here we will cover a subset of the more popular systems.

Note: `make` has no place in a modern multi-language setup, and so is not discussed further.

Build systems

Using via `numpy.distutils`

Legacy

This submodule is considered legacy and will no longer receive updates. This could also mean it will be removed in future NumPy versions. `distutils` has been removed in favor of `meson` see *Status of numpy.distutils and migration advice*.

`numpy.distutils` is part of NumPy, and extends the standard Python `distutils` module to deal with Fortran sources and F2PY signature files, e.g. compile Fortran sources, call F2PY to construct extension modules, etc.

Example

Consider the following `setup_file.py` for the `fib` and `scalar` examples from *Three ways to wrap - getting started* section:

```
from numpy.distutils.core import Extension

ext1 = Extension(name = 'scalar',
                 sources = ['scalar.f'])
ext2 = Extension(name = 'fib2',
                 sources = ['fib2.pyf', 'fib1.f'])

if __name__ == "__main__":
    from numpy.distutils.core import setup
    setup(name = 'f2py_example',
          description       = "F2PY Users Guide examples",
          author            = "Pearu Peterson",
          author_email      = "pearu@cens.ioc.ee",
          ext_modules = [ext1, ext2]
          )
# End of setup_example.py
```

Running

```
python setup_example.py build
```

will build two extension modules `scalar` and `fib2` to the build directory.

Extensions to `distutils`

numpy.distutils extends `distutils` with the following features:

- *Extension* class argument `sources` may contain Fortran source files. In addition, the list `sources` may contain at most one F2PY signature file, and in this case, the name of an Extension module must match with the `<modulename>` used in signature file. It is assumed that an F2PY signature file contains exactly one `python module` block.

  If `sources` do not contain a signature file, then F2PY is used to scan Fortran source files to construct wrappers to the Fortran codes.

  Additional options to the F2PY executable can be given using the *Extension* class argument `f2py_options`.

- The following new `distutils` commands are defined:

  `build_src`
  : to construct Fortran wrapper extension modules, among many other things.

  `config_fc`
  : to change Fortran compiler options.

  Additionally, the `build_ext` and `build_clib` commands are also enhanced to support Fortran sources.

  Run

  ```
  python <setup.py file> config_fc build_src build_ext --help
  ```

  to see available options for these commands.

- When building Python packages containing Fortran sources, one can choose different Fortran compilers by using the `build_ext` command option `--fcompiler=<Vendor>`. Here `<Vendor>` can be one of the following names (on `linux` systems):

  ```
  absoft compaq fujitsu g95 gnu gnu95 intel intele intelem lahey nag nagfor nv␣
  ↪pathf95 pg vast
  ```

  See `numpy_distutils/fcompiler.py` for an up-to-date list of supported compilers for different platforms, or run

  ```
  python -m numpy.f2py -c --backend distutils --help-fcompiler
  ```

Using via `meson`

Note: Much of this document is now obsoleted, one can run `f2py` with `--build-dir` to get a skeleton `meson` project with basic dependencies setup.

Changed in version 1.26.x: The default build system for `f2py` is now `meson`, see *Status of numpy.distutils and migration advice* for some more details..

The key advantage gained by leveraging `meson` over the techniques described in *Using via numpy.distutils* is that this feeds into existing systems and larger projects with ease. `meson` has a rather pythonic syntax which makes it more comfortable and amenable to extension for `python` users.

Fibonacci walkthrough (F77)

We will need the generated `C` wrapper before we can use a general purpose build system like `meson`. We will acquire this by:

```
python -m numpy.f2py fib1.f -m fib2
```

Now, consider the following `meson.build` file for the `fib` and `scalar` examples from *Three ways to wrap - getting started* section:

```
project('f2py_examples', 'c',
  version : '0.1',
  license: 'BSD-3',
  meson_version: '>=0.64.0',
  default_options : ['warning_level=2'],
)

add_languages('fortran')

py_mod = import('python')
py = py_mod.find_installation(pure: false)
py_dep = py.dependency()

incdir_numpy = run_command(py,
  ['-c', 'import os; os.chdir(".."); import numpy; print(numpy.get_include())'],
  check : true
).stdout().strip()

incdir_f2py = run_command(py,
    ['-c', 'import os; os.chdir(".."); import numpy.f2py; print(numpy.f2py.get_
↪include())'],
    check : true
).stdout().strip()

inc_np = include_directories(incdir_numpy, incdir_f2py)

py.extension_module('fib2',
  [
    'fib1.f',
    'fib2module.c',  # note: this assumes f2py was manually run before!
  ],
  incdir_f2py / 'fortranobject.c',
  include_directories: inc_np,
  dependencies : py_dep,
  install : true
)
```

At this point the build will complete, but the import will fail:

```
meson setup builddir
meson compile -C builddir
cd builddir
python -c 'import fib2'
Traceback (most recent call last):
File "<string>", line 1, in <module>
ImportError: fib2.cpython-39-x86_64-linux-gnu.so: undefined symbol: FIB_
# Check this isn't a false positive
```

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```
nm -A fib2.cpython-39-x86_64-linux-gnu.so | grep FIB_
fib2.cpython-39-x86_64-linux-gnu.so: U FIB_
```

Recall that the original example, as reproduced below, was in SCREAMCASE:

```
C FILE: FIB1.F
      SUBROUTINE FIB(A,N)
C
C     CALCULATE FIRST N FIBONACCI NUMBERS
C
      INTEGER N
      REAL*8 A(N)
      DO I=1,N
         IF (I.EQ.1) THEN
            A(I) = 0.0D0
         ELSEIF (I.EQ.2) THEN
            A(I) = 1.0D0
         ELSE
            A(I) = A(I-1) + A(I-2)
         ENDIF
      ENDDO
      END
C END FILE FIB1.F
```

With the standard approach, the subroutine exposed to `python` is `fib` and not `FIB`. This means we have a few options. One approach (where possible) is to lowercase the original Fortran file with say:

```
tr "[:upper:]" "[:lower:]" < fib1.f > fib1.f
python -m numpy.f2py fib1.f -m fib2
meson --wipe builddir
meson compile -C builddir
cd builddir
python -c 'import fib2'
```

However this requires the ability to modify the source which is not always possible. The easiest way to solve this is to let `f2py` deal with it:

```
python -m numpy.f2py fib1.f -m fib2 --lower
meson --wipe builddir
meson compile -C builddir
cd builddir
python -c 'import fib2'
```

Automating wrapper generation

A major pain point in the workflow defined above, is the manual tracking of inputs. Although it would require more effort to figure out the actual outputs for reasons discussed in *F2PY and build systems*.

Note: From NumPy `1.22.4` onwards, `f2py` will deterministically generate wrapper files based on the input file Fortran standard (F77 or greater). `--skip-empty-wrappers` can be passed to `f2py` to restore the previous behaviour of only generating wrappers when needed by the input .

However, we can augment our workflow in a straightforward to take into account files for which the outputs are known when the build system is set up.

```
project('f2py_examples', 'c',
  version : '0.1',
  license: 'BSD-3',
  meson_version: '>=0.64.0',
  default_options : ['warning_level=2'],
)

add_languages('fortran')

py_mod = import('python')
py = py_mod.find_installation(pure: false)
py_dep = py.dependency()

incdir_numpy = run_command(py,
  ['-c', 'import os; os.chdir(".."); import numpy; print(numpy.get_include())'],
  check : true
).stdout().strip()

incdir_f2py = run_command(py,
    ['-c', 'import os; os.chdir(".."); import numpy.f2py; print(numpy.f2py.get_
↪include())'],
    check : true
).stdout().strip()

fibby_source = custom_target('fibbymodule.c',
  input : ['fib1.f'],  # .f so no F90 wrappers
  output : ['fibbymodule.c', 'fibby-f2pywrappers.f'],
  command : [py, '-m', 'numpy.f2py', '@INPUT@', '-m', 'fibby', '--lower']
)

inc_np = include_directories(incdir_numpy, incdir_f2py)

py.extension_module('fibby',
  ['fib1.f', fibby_source],
  incdir_f2py / 'fortranobject.c',
  include_directories: inc_np,
  dependencies : py_dep,
  install : true
)
```

This can be compiled and run as before.

```
rm -rf builddir
meson setup builddir
meson compile -C builddir
cd builddir
python -c "import numpy as np; import fibby; a = np.zeros(9); fibby.fib(a); print (a)"
# [ 0.  1.  1.  2.  3.  5.  8. 13. 21.]
```

Salient points

It is worth keeping in mind the following:

- It is not possible to use SCREAMCASE in this context, so either the contents of the `.f` file or the generated wrapper `.c` needs to be lowered to regular letters; which can be facilitated by the `--lower` option of `F2PY`

Using via `cmake`

In terms of complexity, `cmake` falls between `make` and `meson`. The learning curve is steeper since CMake syntax is not pythonic and is closer to `make` with environment variables.

However, the trade-off is enhanced flexibility and support for most architectures and compilers. An introduction to the syntax is out of scope for this document, but this extensive CMake collection of resources is great.

Note: `cmake` is very popular for mixed-language systems, however support for `f2py` is not particularly native or pleasant; and a more natural approach is to consider *Using via scikit-build*

Fibonacci walkthrough (F77)

Returning to the `fib` example from *Three ways to wrap - getting started* section.

```
C FILE: FIB1.F
      SUBROUTINE FIB(A,N)
C
C     CALCULATE FIRST N FIBONACCI NUMBERS
C
      INTEGER N
      REAL*8 A(N)
      DO I=1,N
         IF (I.EQ.1) THEN
            A(I) = 0.0D0
         ELSEIF (I.EQ.2) THEN
            A(I) = 1.0D0
         ELSE
            A(I) = A(I-1) + A(I-2)
         ENDIF
      ENDDO
      END
C END FILE FIB1.F
```

We do not need to explicitly generate the `python -m numpy.f2py fib1.f` output, which is `fib1module.c`, which is beneficial. With this; we can now initialize a `CMakeLists.txt` file as follows:

```
cmake_minimum_required(VERSION 3.18) # Needed to avoid requiring embedded Python libs␣
↪too

project(fibby
  VERSION 1.0
  DESCRIPTION "FIB module"
  LANGUAGES C Fortran
)
```

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```
# Safety net
if(PROJECT_SOURCE_DIR STREQUAL PROJECT_BINARY_DIR)
  message(
    FATAL_ERROR
      "In-source builds not allowed. Please make a new directory (called a build␣
↪directory) and run CMake from there.\n"
  )
endif()

# Grab Python, 3.8 or newer
find_package(Python 3.8 REQUIRED
  COMPONENTS Interpreter Development.Module NumPy)

# Grab the variables from a local Python installation
# F2PY headers
execute_process(
  COMMAND "${Python_EXECUTABLE}"
  -c "import numpy.f2py; print(numpy.f2py.get_include())"
  OUTPUT_VARIABLE F2PY_INCLUDE_DIR
  OUTPUT_STRIP_TRAILING_WHITESPACE
)

# Print out the discovered paths
include(CMakePrintHelpers)
cmake_print_variables(Python_INCLUDE_DIRS)
cmake_print_variables(F2PY_INCLUDE_DIR)
cmake_print_variables(Python_NumPy_INCLUDE_DIRS)

# Common variables
set(f2py_module_name "fibby")
set(fortran_src_file "${CMAKE_SOURCE_DIR}/fib1.f")
set(f2py_module_c "${f2py_module_name}module.c")

# Generate sources
add_custom_target(
  genpyf
  DEPENDS "${CMAKE_CURRENT_BINARY_DIR}/${f2py_module_c}"
)
add_custom_command(
  OUTPUT "${CMAKE_CURRENT_BINARY_DIR}/${f2py_module_c}"
  COMMAND ${Python_EXECUTABLE}  -m "numpy.f2py"
                  "${fortran_src_file}"
                  -m "fibby"
                  --lower # Important
  DEPENDS fib1.f # Fortran source
)

# Set up target
Python_add_library(${CMAKE_PROJECT_NAME} MODULE WITH_SOABI
  "${CMAKE_CURRENT_BINARY_DIR}/${f2py_module_c}" # Generated
  "${F2PY_INCLUDE_DIR}/fortranobject.c" # From NumPy
  "${fortran_src_file}" # Fortran source(s)
)

# Depend on sources
target_link_libraries(${CMAKE_PROJECT_NAME} PRIVATE Python::NumPy)
add_dependencies(${CMAKE_PROJECT_NAME} genpyf)
```

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```
target_include_directories(${CMAKE_PROJECT_NAME} PRIVATE "${F2PY_INCLUDE_DIR}")
```

A key element of the `CMakeLists.txt` file defined above is that the `add_custom_command` is used to generate the wrapper `C` files and then added as a dependency of the actual shared library target via a `add_custom_target` directive which prevents the command from running every time. Additionally, the method used for obtaining the `fortranobject.c` file can also be used to grab the `numpy` headers on older `cmake` versions.

This then works in the same manner as the other modules, although the naming conventions are different and the output library is not automatically prefixed with the `cython` information.

```
ls .
# CMakeLists.txt fib1.f
cmake -S . -B build
cmake --build build
cd build
python -c "import numpy as np; import fibby; a = np.zeros(9); fibby.fib(a); print (a)"
# [ 0.  1.  1.  2.  3.  5.  8. 13. 21.]
```

This is particularly useful where an existing toolchain already exists and `scikit-build` or other additional `python` dependencies are discouraged.

Using via `scikit-build`

`scikit-build` provides two separate concepts geared towards the users of Python extension modules.

1. A `setuptools` replacement (legacy behaviour)
2. A series of `cmake` modules with definitions which help building Python extensions

---

Note: It is possible to use `scikit-build`'s `cmake` modules to bypass the cmake setup mechanism completely, and to write targets which call `f2py -c`. This usage is **not recommended** since the point of these build system documents are to move away from the internal `numpy.distutils` methods.

For situations where no `setuptools` replacements are required or wanted (i.e. if `wheels` are not needed), it is recommended to instead use the vanilla `cmake` setup described in *Using via cmake*.

Fibonacci walkthrough (F77)

We will consider the `fib` example from *Three ways to wrap - getting started* section.

```
C FILE: FIB1.F
      SUBROUTINE FIB(A,N)
C
C     CALCULATE FIRST N FIBONACCI NUMBERS
C
      INTEGER N
      REAL*8 A(N)
      DO I=1,N
         IF (I.EQ.1) THEN
            A(I) = 0.0D0
         ELSEIF (I.EQ.2) THEN
            A(I) = 1.0D0
```

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```
         ELSE
            A(I) = A(I-1) + A(I-2)
         ENDIF
      ENDDO
      END
C END FILE FIB1.F
```

`CMake` modules only

Consider using the following `CMakeLists.txt`.

```
### setup project ###
cmake_minimum_required(VERSION 3.9)

project(fibby
  VERSION 1.0
  DESCRIPTION "FIB module"
  LANGUAGES C Fortran
  )

# Safety net
if(PROJECT_SOURCE_DIR STREQUAL PROJECT_BINARY_DIR)
  message(
    FATAL_ERROR
      "In-source builds not allowed. Please make a new directory (called a build␣
↪directory) and run CMake from there.\n"
  )
endif()

# Ensure scikit-build modules
if (NOT SKBUILD)
  find_package(PythonInterp 3.8 REQUIRED)
  # Kanged --> https://github.com/Kitware/torch_liberator/blob/master/CMakeLists.txt
  # If skbuild is not the driver; include its utilities in CMAKE_MODULE_PATH
  execute_process(
    COMMAND "${PYTHON_EXECUTABLE}"
    -c "import os, skbuild; print(os.path.dirname(skbuild.__file__))"
    OUTPUT_VARIABLE SKBLD_DIR
    OUTPUT_STRIP_TRAILING_WHITESPACE
  )
  list(APPEND CMAKE_MODULE_PATH "${SKBLD_DIR}/resources/cmake")
  message(STATUS "Looking in ${SKBLD_DIR}/resources/cmake for CMake modules")
endif()

# scikit-build style includes
find_package(PythonExtensions REQUIRED) # for ${PYTHON_EXTENSION_MODULE_SUFFIX}

# Grab the variables from a local Python installation
# NumPy headers
execute_process(
  COMMAND "${PYTHON_EXECUTABLE}"
  -c "import numpy; print(numpy.get_include())"
  OUTPUT_VARIABLE NumPy_INCLUDE_DIRS
  OUTPUT_STRIP_TRAILING_WHITESPACE
)
```

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```
# F2PY headers
execute_process(
  COMMAND "${PYTHON_EXECUTABLE}"
  -c "import numpy.f2py; print(numpy.f2py.get_include())"
  OUTPUT_VARIABLE F2PY_INCLUDE_DIR
  OUTPUT_STRIP_TRAILING_WHITESPACE
)

# Prepping the module
set(f2py_module_name "fibby")
set(fortran_src_file "${CMAKE_SOURCE_DIR}/fib1.f")
set(f2py_module_c "${f2py_module_name}module.c")

# Target for enforcing dependencies
add_custom_target(genpyf
  DEPENDS "${fortran_src_file}"
)
add_custom_command(
  OUTPUT "${CMAKE_CURRENT_BINARY_DIR}/${f2py_module_c}"
  COMMAND ${PYTHON_EXECUTABLE}  -m "numpy.f2py"
                  "${fortran_src_file}"
                  -m "fibby"
                  --lower # Important
  DEPENDS fib1.f # Fortran source
)

add_library(${CMAKE_PROJECT_NAME} MODULE
            "${f2py_module_name}module.c"
            "${F2PY_INCLUDE_DIR}/fortranobject.c"
            "${fortran_src_file}")

target_include_directories(${CMAKE_PROJECT_NAME} PUBLIC
                           ${F2PY_INCLUDE_DIR}
                           ${NumPy_INCLUDE_DIRS}
                           ${PYTHON_INCLUDE_DIRS})
set_target_properties(${CMAKE_PROJECT_NAME} PROPERTIES SUFFIX "${PYTHON_EXTENSION_
↪MODULE_SUFFIX}")
set_target_properties(${CMAKE_PROJECT_NAME} PROPERTIES PREFIX "")

# Linker fixes
if (UNIX)
  if (APPLE)
    set_target_properties(${CMAKE_PROJECT_NAME} PROPERTIES
    LINK_FLAGS  '-Wl,-dylib,-undefined,dynamic_lookup')
  else()
    set_target_properties(${CMAKE_PROJECT_NAME} PROPERTIES
  LINK_FLAGS  '-Wl,--allow-shlib-undefined')
  endif()
endif()

add_dependencies(${CMAKE_PROJECT_NAME} genpyf)

install(TARGETS ${CMAKE_PROJECT_NAME} DESTINATION fibby)
```

Much of the logic is the same as in *Using via cmake*, however notably here the appropriate module suffix is generated via `sysconfig.get_config_var("SO")`. The resulting extension can be built and loaded in the standard workflow.

```
ls .
# CMakeLists.txt fib1.f
cmake -S . -B build
cmake --build build
cd build
python -c "import numpy as np; import fibby; a = np.zeros(9); fibby.fib(a); print (a)"
# [ 0.  1.  1.  2.  3.  5.  8. 13. 21.]
```

`setuptools` replacement

Note: As of November 2021

The behavior described here of driving the `cmake` build of a module is considered to be legacy behaviour and should not be depended on.

The utility of `scikit-build` lies in being able to drive the generation of more than extension modules, in particular a common usage pattern is the generation of Python distributables (for example for PyPI).

The workflow with `scikit-build` straightforwardly supports such packaging requirements. Consider augmenting the project with a `setup.py` as defined:

```
from skbuild import setup

setup(
    name="fibby",
    version="0.0.1",
    description="a minimal example package (fortran version)",
    license="MIT",
    packages=['fibby'],
    python_requires=">=3.7",
)
```

Along with a commensurate `pyproject.toml`

```
[build-system]
requires = ["setuptools>=42", "wheel", "scikit-build", "cmake>=3.9", "numpy>=1.21"]
build-backend = "setuptools.build_meta"
```

Together these can build the extension using `cmake` in tandem with other standard `setuptools` outputs. Running `cmake` through `setup.py` is mostly used when it is necessary to integrate with extension modules not built with `cmake`.

```
ls .
# CMakeLists.txt fib1.f pyproject.toml setup.py
python setup.py build_ext --inplace
python -c "import numpy as np; import fibby.fibby; a = np.zeros(9); fibby.fibby.
↪fib(a); print (a)"
# [ 0.  1.  1.  2.  3.  5.  8. 13. 21.]
```

Where we have modified the path to the module as `--inplace` places the extension module in a subfolder.

1 Migrating to `meson`

As per the timeline laid out in *Status of numpy.distutils and migration advice*, `distutils` has ceased to be the default build backend for `f2py`. This page collects common workflows in both formats.

Note: This is a ****living**** document, pull requests are very welcome!

1.1 Baseline

We will start out with a slightly modern variation of the classic Fibonnaci series generator.

```
! fib.f90
subroutine fib(a, n)
  use iso_c_binding
   integer(c_int), intent(in) :: n
   integer(c_int), intent(out) :: a(n)
   do i = 1, n
      if (i .eq. 1) then
         a(i) = 0.0d0
      elseif (i .eq. 2) then
         a(i) = 1.0d0
      else
         a(i) = a(i - 1) + a(i - 2)
      end if
   end do
end
```

This will not win any awards, but can be a reasonable starting point.

1.2 Compilation options

1.2.1 Basic Usage

This is unchanged:

```
python -m numpy.f2py -c fib.f90 -m fib
❯ python -c "import fib; print(fib.fib(30))"
[     0      1      1      2      3      5      8     13     21     34
     55     89    144    233    377    610    987   1597   2584   4181
   6765  10946  17711  28657  46368  75025 121393 196418 317811 514229]
```

1.2.2 Specify the backend

Distutils

```
python -m numpy.f2py -c fib.f90 -m fib --backend distutils
```

This is the default for Python versions before 3.12.

Meson

```
python -m numpy.f2py -c fib.f90 -m fib --backend meson
```

This is the only option for Python versions after 3.12.

1.2.3 Pass a compiler name

Distutils

```
python -m numpy.f2py -c fib.f90 -m fib --backend distutils --fcompiler=gfortran
```

Meson

```
FC="gfortran" python -m numpy.f2py -c fib.f90 -m fib --backend meson
```

Native files can also be used.

Similarly, `CC` can be used in both cases to set the `C` compiler. Since the environment variables are generally pretty common across both, so a small sample is included below.

Name	What
FC	Fortran compiler
CC	C compiler
CFLAGS	C compiler options
FFLAGS	Fortran compiler options
LDFLAGS	Linker options
$LD_{LIBRARYPATH}$	Library file locations (Unix)
LIBS	Libraries to link against
PATH	Search path for executables
LDFLAGS	Linker flags
CXX	C++ compiler
CXXFLAGS	C++ compiler options

Note: For Windows, these may not work very reliably, so native files are likely the best bet, or by direct *1.3 Customizing builds*.

1.2.4 Dependencies

Here, `meson` can actually be used to set dependencies more robustly.

Distutils

```
python -m numpy.f2py -c fib.f90 -m fib --backend distutils -llapack
```

Note that this approach in practice is error prone.

Meson

```
python -m numpy.f2py -c fib.f90 -m fib --backend meson --dep lapack
```

This maps to `dependency("lapack")` and so can be used for a wide variety of dependencies. They can be customized further to use CMake or other systems to resolve dependencies.

1.2.5 Libraries

Both `meson` and `distutils` are capable of linking against libraries.

Distutils

```
python -m numpy.f2py -c fib.f90 -m fib --backend distutils -lmylib -L/path/to/mylib
```

Meson

```
python -m numpy.f2py -c fib.f90 -m fib --backend meson -lmylib -L/path/to/mylib
```

1.3 Customizing builds

Distutils

```
python -m numpy.f2py -c fib.f90 -m fib --backend distutils --build-dir blah
```

This can be technically integrated with other codes, see *Using via numpy.distutils*.

Meson

```
python -m numpy.f2py -c fib.f90 -m fib --backend meson --build-dir blah
```

The resulting build can be customized via the Meson Build How-To Guide. In fact, the resulting set of files can even be committed directly and used as a meson subproject in a separate codebase.

Advanced F2PY use cases

Adding user-defined functions to F2PY generated modules

User-defined Python C/API functions can be defined inside signature files using `usercode` and `pymethoddef` statements (they must be used inside the `python module` block). For example, the following signature file `spam.pyf`

```
!    -*- f90 -*-
python module spam
    usercode '''
  static char doc_spam_system[] = "Execute a shell command.";
  static PyObject *spam_system(PyObject *self, PyObject *args)
  {
    char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = system(command);
    return Py_BuildValue("i", sts);
  }
    '''
    pymethoddef '''
    {"system",  spam_system, METH_VARARGS, doc_spam_system},
    '''
end python module spam
```

wraps the C library function `system()`:

```
f2py -c spam.pyf
```

In Python this can then be used as:

```
>>> import spam
>>> status = spam.system('whoami')
pearu
>>> status = spam.system('blah')
sh: line 1: blah: command not found
```

Adding user-defined variables

The following example illustrates how to add user-defined variables to a F2PY generated extension module by modifying the dictionary of a F2PY generated module. Consider the following signature file (compiled with `f2py -c var.pyf`):

```
!    -*- f90 -*-
python module var
  usercode '''
    int BAR = 5;
  '''
  interface
    usercode '''
      PyDict_SetItemString(d,"BAR",PyLong_FromLong(BAR));
    '''
  end interface
end python module
```

Notice that the second `usercode` statement must be defined inside an `interface` block and the module dictionary is available through the variable `d` (see `varmodule.c` generated by `f2py var.pyf` for additional details).

Usage in Python:

```
>>> import var
>>> var.BAR
5
```

Dealing with KIND specifiers

Currently, F2PY can handle only `<type spec>(kind=<kindselector>)` declarations where `<kindselector>` is a numeric integer (e.g. 1, 2, 4,...), but not a function call `KIND(..)` or any other expression. F2PY needs to know what would be the corresponding C type and a general solution for that would be too complicated to implement.

However, F2PY provides a hook to overcome this difficulty, namely, users can define their own <Fortran type> to <C type> maps. For example, if Fortran 90 code contains:

```
REAL(kind=KIND(0.0D0)) ...
```

then create a mapping file containing a Python dictionary:

```
{'real': {'KIND(0.0D0)': 'double'}}
```

for instance.

Use the `--f2cmap` command-line option to pass the file name to F2PY. By default, F2PY assumes file name is `.f2py_f2cmap` in the current working directory.

More generally, the f2cmap file must contain a dictionary with items:

```
&lt;Fortran typespec&gt; : {&lt;selector_expr&gt;:&lt;C type&gt;}
```

that defines mapping between Fortran type:

```
&lt;Fortran typespec&gt;([kind=]&lt;selector_expr&gt;)
```

and the corresponding <C type>. The <C type> can be one of the following:

```
double
float
long_double
char
signed_char
unsigned_char
short
unsigned_short
int
long
long_long
unsigned
complex_float
complex_double
complex_long_double
string
```

For example, for a Fortran file `func1.f` containing:

```
      subroutine func1(n, x, res)
        use, intrinsic :: iso_fortran_env, only: int64, real64
        implicit none
        integer(int64), intent(in) :: n
        real(real64), intent(in) :: x(n)
        real(real64), intent(out) :: res
Cf2py   intent(hide) :: n
        res = sum(x)
      end
```

In order to convert `int64` and `real64` to valid `C` data types, a `.f2py_f2cmap` file with the following content can be created in the current directory:

```
dict(real=dict(real64='double'), integer=dict(int64='long long'))
```

and create the module as usual. F2PY checks if a `.f2py_f2cmap` file is present in the current directory and will use it to map `KIND` specifiers to `C` data types.

```
f2py -c func1.f -m func1
```

Alternatively, the mapping file can be saved with any other name, for example `mapfile.txt`, and this information can be passed to F2PY by using the `--f2cmap` option.

```
f2py -c func1.f -m func1 --f2cmap mapfile.txt
```

For more information, see F2Py source code `numpy/f2py/capi_maps.py`.

Character strings

Assumed length character strings

In Fortran, assumed length character string arguments are declared as `character*(*)` or `character(len=*)`, that is, the length of such arguments are determined by the actual string arguments at runtime. For `intent(in)` arguments, this lack of length information poses no problems for f2py to construct functional wrapper functions. However, for `intent(out)` arguments, the lack of length information is problematic for f2py generated wrappers because there is no size information available for creating memory buffers for such arguments and F2PY assumes the length is 0.

Depending on how the length of assumed length character strings are specified, there exist ways to workaround this problem, as exemplified below.

If the length of the `character*(*)` output argument is determined by the state of other input arguments, the required connection can be established in a signature file or within a f2py-comment by adding an extra declaration for the corresponding argument that specifies the length in character selector part. For example, consider a Fortran file `asterisk1.f90`:

```
subroutine foo1(s)
  character*(*), intent(out) :: s
  !f2py character(f2py_len=12) s
  s = "123456789A12"
end subroutine foo1
```

Compile it with `f2py -c asterisk1.f90 -m asterisk1` and then in Python:

```
>>> import asterisk1
>>> asterisk1.foo1()
b'123456789A12'
```

Notice that the extra declaration `character(f2py_len=12) s` is interpreted only by f2py and in the `f2py_len=` specification one can use C-expressions as a length value.

In the following example:

```
subroutine foo2(s, n)
  character(len=*), intent(out) :: s
  integer, intent(in) :: n
  !f2py character(f2py_len=n), depend(n) :: s
  s = "123456789A123456789B"(1:n)
end subroutine foo2
```

the length of the output assumed length string depends on an input argument `n`, after wrapping with F2PY, in Python:

```
>>> import asterisk
>>> asterisk.foo2(2)
b'12'
>>> asterisk.foo2(12)
b'123456789A12'
>>>
```

Boilerplate reduction and templating

Using FYPP for binding generic interfaces

`f2py` doesn't currently support binding interface blocks. However, there are workarounds in use. Perhaps the best known is the usage of `tempita` for using `.pyf.src` files as is done in the bindings which are part of scipy. *tempita* support has been removed and is no longer recommended in any case.

Note: The reason interfaces cannot be supported within `f2py` itself is because they don't correspond to exported symbols in compiled libraries.

```
❯ nm gen.o
 0000000000000078 T __add_mod_MOD_add_complex
 0000000000000000 T __add_mod_MOD_add_complex_dp
```

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```
0000000000000150 T __add_mod_MOD_add_integer
0000000000000124 T __add_mod_MOD_add_real
00000000000000ee T __add_mod_MOD_add_real_dp
```

Here we will discuss a few techniques to leverage `f2py` in conjunction with fypp to emulate generic interfaces and to ease the binding of multiple (similar) functions.

Basic example: Addition module

Let us build on the example (from the user guide, *F2PY examples*) of a subroutine which takes in two arrays and returns its sum.

```
C
      SUBROUTINE ZADD(A,B,C,N)
C
      DOUBLE COMPLEX A(*)
      DOUBLE COMPLEX B(*)
      DOUBLE COMPLEX C(*)
      INTEGER N
      DO 20 J = 1, N
         C(J) = A(J)+B(J)
 20   CONTINUE
      END
```

We will recast this into modern fortran:

```
module adder
    implicit none
contains

    subroutine zadd(a, b, c, n)
        integer, intent(in) :: n
        double complex, intent(in) :: a(n), b(n)
        double complex, intent(out) :: c(n)
        integer :: j
        do j = 1, n
            c(j) = a(j) + b(j)
        end do
    end subroutine zadd

end module adder
```

We could go on as in the original example, adding intents by hand among other things, however in production often there are other concerns. For one, we can template via FYPP the construction of similar functions:

```
module adder
    implicit none
contains

#:def add_subroutine(dtype_prefix, dtype)
    subroutine ${dtype_prefix}$add(a, b, c, n)
        integer, intent(in) :: n
        ${dtype}$, intent(in) :: a(n), b(n)
        ${dtype}$ :: c(n)
```

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```
        integer :: j
        do j = 1, n
            c(j) = a(j) + b(j)
        end do
    end subroutine ${dtype_prefix}$add

#:enddef

#:for dtype_prefix, dtype in [('i', 'integer'), ('s', 'real'), ('d', 'real(kind=8)'),␣
↪('c', 'complex'), ('z', 'double complex')]
    @:add_subroutine(${dtype_prefix}$, ${dtype}$)
#:endfor

end module adder
```

This can be pre-processed to generate the full fortran code:

```
 fypp gen_adder.f90.fypp > adder.f90
```

As to be expected, this can be wrapped by `f2py` subsequently.

Now we will consider maintaining the bindings in a separate file. Note the following basic `.pyf` which can be generated for a single subroutine via `f2py -m adder adder_base.f90 -h adder.pyf`:

```
!    -*- f90 -*-
! Note: the context of this file is case sensitive.

python module adder ! in
    interface  ! in :adder
        module adder ! in :adder:adder_base.f90
            subroutine zadd(a,b,c,n) ! in :adder:adder_base.f90:adder
                double complex dimension(n),intent(in) :: a
                double complex dimension(n),intent(in),depend(n) :: b
                double complex dimension(n),intent(out),depend(n) :: c
                integer, optional,intent(in),check(shape(a, 0) == n),depend(a) ::␣
↪n=shape(a, 0)
            end subroutine zadd
        end module adder
    end interface
end python module adder

! This file was auto-generated with f2py (version:2.0.0.dev0+git20240101.bab7280).
! See:
! https://web.archive.org/web/20140822061353/http://cens.ioc.ee/projects/f2py2e
```

With the docstring:

```
c = zadd(a,b,[n])

Wrapper for ``zadd``.

Parameters
----------
a : input rank-1 array('D') with bounds (n)
b : input rank-1 array('D') with bounds (n)

Other Parameters
```

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```
----------------
n : input int, optional
    Default: shape(a, 0)

Returns
-------
c : rank-1 array('D') with bounds (n)
```

Which is already pretty good. However, `n` should never be passed in the first place so we will make some minor adjustments.

```
!    -*- f90 -*-
! Note: the context of this file is case sensitive.

python module adder ! in
    interface  ! in :adder
        module adder ! in :adder:adder_base.f90
            subroutine zadd(a,b,c,n) ! in :adder:adder_base.f90:adder
                integer intent(hide),depend(a) :: n=len(a)
                double complex dimension(n),intent(in) :: a
                double complex dimension(n),intent(in),depend(n) :: b
                double complex dimension(n),intent(out),depend(n) :: c
            end subroutine zadd
        end module adder
    end interface
end python module adder

! This file was auto-generated with f2py (version:2.0.0.dev0+git20240101.bab7280).
! See:
! https://numpy.org/doc/stable/f2py/
```

Which corresponds to:

```
In [3]: ?adder.adder.zadd
Call signature: adder.adder.zadd(*args, **kwargs)
Type:           fortran
String form:    <fortran function zadd>
Docstring:
c = zadd(a,b)

Wrapper for ``zadd``.

Parameters
----------
a : input rank-1 array('D') with bounds (n)
b : input rank-1 array('D') with bounds (n)

Returns
-------
c : rank-1 array('D') with bounds (n)
```

Finally, we can template over this in a similar manner, to attain the original goal of having bindings which make use of `f2py` directives and have minimal spurious repetition.

```
!    -*- f90 -*-
! Note: the context of this file is case sensitive.
```

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```
python module adder ! in
    interface  ! in :adder
        module adder ! in :adder:adder_base.f90
#:def add_subroutine(dtype_prefix, dtype)
            subroutine ${dtype_prefix}$add(a,b,c,n) ! in :adder:adder_base.f90:adder
                integer intent(hide),depend(a) :: n=len(a)
                ${dtype}$ dimension(n),intent(in) :: a
                ${dtype}$ dimension(n),intent(in),depend(n) :: b
                ${dtype}$ dimension(n),intent(out),depend(n) :: c
            end subroutine ${dtype_prefix}$add

#:enddef

#:for dtype_prefix, dtype in [('i', 'integer'), ('s', 'real'), ('d', 'real(kind=8)'),␣
↪('c', 'complex'), ('z', 'complex(kind=8)')]
    @:add_subroutine(${dtype_prefix}$, ${dtype}$)
#:endfor
        end module adder
    end interface
end python module adder

! This file was auto-generated with f2py (version:2.0.0.dev0+git20240101.bab7280).
! See:
! https://numpy.org/doc/stable/f2py/
```

Usage boils down to:

```
fypp gen_adder.f90.fypp > adder.f90
fypp adder.pyf.fypp > adder.pyf
f2py -m adder -c adder.pyf adder.f90 --backend meson
```

F2PY test suite

F2PY's test suite is present in the directory `numpy/f2py/tests`. Its aim is to ensure that Fortran language features are correctly translated to Python. For example, the user can specify starting and ending indices of arrays in Fortran. This behaviour is translated to the generated CPython library where the arrays strictly start from 0 index.

The directory of the test suite looks like the following:

```
./tests/
├── __init__.py
├── src
│   ├── abstract_interface
│   ├── array_from_pyobj
│   ├── // ... several test folders
│   └── string
├── test_abstract_interface.py
├── test_array_from_pyobj.py
├── // ... several test files
├── test_symbolic.py
└── util.py
```

Files starting with `test_` contain tests for various aspects of f2py from parsing Fortran files to checking modules' documentation. `src` directory contains the Fortran source files upon which we do the testing. `util.py` contains utility functions for building and importing Fortran modules during test time using a temporary location.

Adding a test

F2PY's current test suite predates `pytest` and therefore does not use fixtures. Instead, the test files contain test classes that inherit from `F2PyTest` class present in `util.py`.

```
    backend = SimplifiedMesonBackend(
        modulename=module_name,
        sources=source_files,
        extra_objects=kwargs.get("extra_objects", []),
        build_dir=build_dir,
        include_dirs=kwargs.get("include_dirs", []),
        library_dirs=kwargs.get("library_dirs", []),
        libraries=kwargs.get("libraries", []),
        define_macros=kwargs.get("define_macros", []),
        undef_macros=kwargs.get("undef_macros", []),
```

This class many helper functions for parsing and compiling test source files. Its child classes can override its `sources` data member to provide their own source files. This superclass will then compile the added source files upon object creation and their functions will be appended to `self.module` data member. Thus, the child classes will be able to access the fortran functions specified in source file by calling `self.module.[fortran_function_name]`.

New in version v2.0.0b1.

Each of the `f2py` tests should run without failure if no Fortran compilers are present on the host machine. To facilitate this, the `CompilerChecker` is used, essentially providing a `meson` dependent set of utilities namely `has_{c,f77,f90,fortran}_compiler()`.

For the CLI tests in `test_f2py2e`, flags which are expected to call `meson` or otherwise depend on a compiler need to call `compiler_check_f2pycli()` instead of `f2pycli()`.

Example

Consider the following subroutines, contained in a file named `add-test.f`

```
        subroutine addb(k)
          real(8), intent(inout) :: k(:)
          k=k+1
        endsubroutine

        subroutine addc(w,k)
          real(8), intent(in) :: w(:)
          real(8), intent(out) :: k(size(w))
          k=w+1
        endsubroutine
```

The first routine *addb* simply takes an array and increases its elements by 1. The second subroutine *addc* assigns a new array *k* with elements greater that the elements of the input array *w* by 1.

A test can be implemented as follows:

```
class TestAdd(util.F2PyTest):
    sources = [util.getpath("add-test.f")]

    def test_module(self):
        k = np.array([1, 2, 3], dtype=np.float64)
        w = np.array([1, 2, 3], dtype=np.float64)
        self.module.addb(k)
```

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```
        assert np.allclose(k, w + 1)
        self.module.addc([w, k])
        assert np.allclose(k, w + 1)
```

We override the `sources` data member to provide the source file. The source files are compiled and subroutines are attached to module data member when the class object is created. The `test_module` function calls the subroutines and tests their results.

F2PY and Windows

Warning: F2PY support for Windows is not always at par with Linux support

Note: ScPy's documentation has some information on system-level dependencies which are well tested for Fortran as well.

Broadly speaking, there are two issues working with F2PY on Windows:

- the lack of actively developed FOSS Fortran compilers, and,
- the linking issues related to the C runtime library for building Python-C extensions.

The focus of this section is to establish a guideline for developing and extending Fortran modules for Python natively, via F2PY on Windows.

Currently supported toolchains are:

- Mingw-w64 C/C++/Fortran compilers
- Intel compilers
- Clang-cl + Flang
- MSVC + Flang

Overview

From a user perspective, the most UNIX compatible Windows development environment is through emulation, either via the Windows Subsystem on Linux, or facilitated by Docker. In a similar vein, traditional virtualization methods like VirtualBox are also reasonable methods to develop UNIX tools on Windows.

Native Windows support is typically stunted beyond the usage of commercial compilers. However, as of 2022, most commercial compilers have free plans which are sufficient for general use. Additionally, the Fortran language features supported by `f2py` (partial coverage of Fortran 2003), means that newer toolchains are often not required. Briefly, then, for an end user, in order of use:

Classic Intel Compilers (commercial)
: These are maintained actively, though licensing restrictions may apply as further detailed in *F2PY and Windows Intel Fortran*.

  Suitable for general use for those building native Windows programs by building off of MSVC.

MSYS2 (FOSS)
: In conjunction with the `mingw-w64` project, `gfortran` and `gcc` toolchains can be used to natively build Windows programs.

Windows Subsystem for Linux
: Assuming the usage of `gfortran`, this can be used for cross-compiling Windows applications, but is significantly more complicated.

Conda
: Windows support for compilers in `conda` is facilitated by pulling MSYS2 binaries, however these are outdated, and therefore not recommended (as of 30-01-2022).

PGI Compilers (commercial)
: Unmaintained but sufficient if an existing license is present. Works natively, but has been superseded by the Nvidia HPC SDK, with no native Windows support.

Cygwin (FOSS)
: Can also be used for `gfortran`. However, the POSIX API compatibility layer provided by Cygwin is meant to compile UNIX software on Windows, instead of building native Windows programs. This means cross compilation is required.

The compilation suites described so far are compatible with the now deprecated `np.distutils` build backend which is exposed by the F2PY CLI. Additional build system usage (`meson`, `cmake`) as described in *F2PY and build systems* allows for a more flexible set of compiler backends including:

Intel oneAPI
: The newer Intel compilers (`ifx`, `icx`) are based on LLVM and can be used for native compilation. Licensing requirements can be onerous.

Classic Flang (FOSS)
: The backbone of the PGI compilers were cannibalized to form the "classic" or legacy version of Flang. This may be compiled from source and used natively. LLVM Flang does not support Windows yet (30-01-2022).

LFortran (FOSS)
: One of two LLVM based compilers. Not all of F2PY supported Fortran can be compiled yet (30-01-2022) but uses MSVC for native linking.

Baseline

For this document we will assume the following basic tools:

- The IDE being considered is the community supported Microsoft Visual Studio Code
- The terminal being used is the Windows Terminal
- The shell environment is assumed to be Powershell 7.x
- **Python 3.10 from the Microsoft Store and this can be tested with** `Get-Command python.exe` resolving to `C:\Users\$USERNAME\AppData\Local\Microsoft\WindowsApps\python.exe`
- The Microsoft Visual C++ (MSVC) toolset

With this baseline configuration, we will further consider a configuration matrix as follows:

Table 5: Support matrix, exe implies a Windows installer

Fortran Compiler	C/C++ Compiler	Source
Intel Fortran	MSVC / ICC	exe
GFortran	MSVC	MSYS2/exe
GFortran	GCC	WSL
Classic Flang	MSVC	Source / Conda
Anaconda GFortran	Anaconda GCC	exe

For an understanding of the key issues motivating the need for such a matrix Pauli Virtanen's in-depth post on wheels with Fortran for Windows is an excellent resource. An entertaining explanation of an application binary interface (ABI) can be found in this post by JeanHeyd Meneide.

PowerShell and MSVC

MSVC is installed either via the Visual Studio Bundle or the lighter (preferred) Build Tools for Visual Studio with the `Desktop development with C++` setting.

Note: This can take a significant amount of time as it includes a download of around 2GB and requires a restart.

It is possible to use the resulting environment from a standard command prompt. However, it is more pleasant to use a developer powershell, with a profile in Windows Terminal. This can be achieved by adding the following block to the `profiles->list` section of the JSON file used to configure Windows Terminal (see `Settings->Open JSON file`):

```
{
"name": "Developer PowerShell for VS 2019",
"commandline": "powershell.exe -noe -c \"$vsPath = (Join-Path ${env:ProgramFiles(x86)}
↪ -ChildPath 'Microsoft Visual Studio\\2019\\BuildTools'); Import-Module (Join-Path
↪$vsPath 'Common7\\Tools\\Microsoft.VisualStudio.DevShell.dll'); Enter-VsDevShell -
↪VsInstallPath $vsPath -SkipAutomaticLocation\"",
"icon": "ms-appx:///ProfileIcons/{61c54bbd-c2c6-5271-96e7-009a87ff44bf}.png"
}
```

Now, testing the compiler toolchain could look like:

```
 # New Windows Developer Powershell instance / tab
 # or
 $vsPath = (Join-Path ${env:ProgramFiles(x86)} -ChildPath 'Microsoft Visual Studio\\
↪2019\\BuildTools');
 Import-Module (Join-Path $vsPath 'Common7\\Tools\\Microsoft.VisualStudio.DevShell.dll
↪');
 Enter-VsDevShell -VsInstallPath $vsPath -SkipAutomaticLocation
 **********************************************************************
 ** Visual Studio 2019 Developer PowerShell v16.11.9
 ** Copyright (c) 2021 Microsoft Corporation
 **********************************************************************
 cd $HOME
 echo "#include<stdio.h>" > blah.cpp; echo 'int main(){printf("Hi");return 1;}' >>␣
↪blah.cpp
 cl blah.cpp
.\blah.exe
 # Hi
 rm blah.cpp
```

It is also possible to check that the environment has been updated correctly with `$ENV:PATH`.

Microsoft Store Python paths

The MS Windows version of Python discussed here installs to a non-deterministic path using a hash. This needs to be added to the `PATH` variable.

```
$Env:Path += ";$env:LOCALAPPDATA\packages\pythonsoftwarefoundation.python.3.10_
↪qbz5n2kfra8p0\localcache\local-packages\python310\scripts"
```

F2PY and Windows Intel Fortran

As of NumPy 1.23, only the classic Intel compilers (`ifort`) are supported.

Note: The licensing restrictions for beta software have been relaxed during the transition to the LLVM backed `ifx/icc` family of compilers. However this document does not endorse the usage of Intel in downstream projects due to the issues pertaining to disassembly of components and liability.

Neither the Python Intel installation nor the *Classic Intel C/C++ Compiler* are required.

- The Intel Fortran Compilers come in a combined installer providing both Classic and Beta versions; these also take around a gigabyte and a half or so.

We will consider the classic example of the generation of Fibonnaci numbers, `fib1.f`, given by:

```
C FILE: FIB1.F
      SUBROUTINE FIB(A,N)
C
C     CALCULATE FIRST N FIBONACCI NUMBERS
C
      INTEGER N
      REAL*8 A(N)
      DO I=1,N
         IF (I.EQ.1) THEN
            A(I) = 0.0D0
         ELSEIF (I.EQ.2) THEN
            A(I) = 1.0D0
         ELSE
            A(I) = A(I-1) + A(I-2)
         ENDIF
      ENDDO
      END
C END FILE FIB1.F
```

For `cmd.exe` fans, using the Intel oneAPI command prompt is the easiest approach, as it loads the required environment for both `ifort` and `msvc`. Helper batch scripts are also provided.

```
# cmd.exe
"C:\Program Files (x86)\Intel\oneAPI\setvars.bat"
python -m numpy.f2py -c fib1.f -m fib1
python -c "import fib1; import numpy as np; a=np.zeros(8); fib1.fib(a); print(a)"
```

Powershell usage is a little less pleasant, and this configuration now works with MSVC as:

```
# Powershell
python -m numpy.f2py -c fib1.f -m fib1 --f77exec='C:\Program Files (x86)\Intel\oneAPI\
```

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```
↪compiler\latest\windows\bin\intel64\ifort.exe' --f90exec='C:\Program Files (x86)\
↪Intel\oneAPI\compiler\latest\windows\bin\intel64\ifort.exe' -L'C:\Program Files␣
↪(x86)\Intel\oneAPI\compiler\latest\windows\compiler\lib\ia32'
python -c "import fib1; import numpy as np; a=np.zeros(8); fib1.fib(a); print(a)"
# Alternatively, set environment and reload Powershell in one line
cmd.exe /k '"C:\Program Files (x86)\Intel\oneAPI\setvars.bat" && powershell'
python -m numpy.f2py -c fib1.f -m fib1
python -c "import fib1; import numpy as np; a=np.zeros(8); fib1.fib(a); print(a)"
```

Note that the actual path to your local installation of *ifort* may vary, and the command above will need to be updated accordingly.

F2PY and Windows with MSYS2

Follow the standard installation instructions. Then, to grab the requisite Fortran compiler with `MVSC`:

```
# Assuming a fresh install
pacman -Syu # Restart the terminal
pacman -Su  # Update packages
# Get the toolchains
pacman -S --needed base-devel gcc-fortran
pacman -S mingw-w64-x86_64-toolchain
```

F2PY and Conda on Windows

As a convenience measure, we will additionally assume the existence of `scoop`, which can be used to install tools without administrative access.

```
Invoke-Expression (New-Object System.Net.WebClient).DownloadString('https://get.scoop.
↪sh')
```

Now we will setup a `conda` environment.

```
scoop install miniconda3
# For conda activate / deactivate in powershell
conda install -n root -c pscondaenvs pscondaenvs
Powershell -c Set-ExecutionPolicy -ExecutionPolicy RemoteSigned -Scope CurrentUser
conda init powershell
# Open a new shell for the rest
```

`conda` pulls packages from `msys2`, however, the UX is sufficiently different enough to warrant a separate discussion.

Warning: As of 30-01-2022, the MSYS2 binaries shipped with `conda` are **outdated** and this approach is **not preferred**.

F2PY and PGI Fortran on Windows

A variant of these are part of the so called "classic" Flang, however, as classic Flang requires a custom LLVM and compilation from sources.

Warning: Since the proprietary compilers are no longer available for usage they are not recommended and will not be ported to the new `f2py` CLI.

Note: As of November 2021

As of 29-01-2022, PGI compiler toolchains have been superseded by the Nvidia HPC SDK, with no native Windows support.

Masked array operations

Constants

ma.MaskType	alias of *bool*

numpy.ma.**MaskType**
alias of *bool*

Creation

From existing data

ma.masked_array	alias of *MaskedArray*
ma.array(data[, dtype, copy, order, mask, ...])	An array class with possibly masked values.
ma.copy(self, *args, **params) a.copy(order=)	Return a copy of the array.
ma.frombuffer(buffer[, dtype, count, ...])	Interpret a buffer as a 1-dimensional array.
ma.fromfunction(function, shape, **dtype)	Construct an array by executing a function over each coordinate.
ma.MaskedArray.copy([order])	Return a copy of the array.
ma.diagflat	Create a two-dimensional array with the flattened input as a diagonal.

numpy.ma.**masked_array**
alias of *MaskedArray*

ma.**array**(*data*, *dtype=None*, *copy=False*, *order=None*, *mask=np.False_*, *fill_value=None*, *keep_mask=True*, *hard_mask=False*, *shrink=True*, *subok=True*, *ndmin=0*)

An array class with possibly masked values.

Masked values of True exclude the corresponding element from any computation.

Construction:

```
x = MaskedArray(data, mask=nomask, dtype=None, copy=False, subok=True,
                ndmin=0, fill_value=None, keep_mask=True, hard_mask=None,
                shrink=True, order=None)
```

Parameters

data
[array_like] Input data.

mask
[sequence, optional] Mask. Must be convertible to an array of booleans with the same shape as *data*. True indicates a masked (i.e. invalid) data.

dtype
[dtype, optional] Data type of the output. If *dtype* is None, the type of the data argument (`data.dtype`) is used. If *dtype* is not None and different from `data.dtype`, a copy is performed.

copy
[bool, optional] Whether to copy the input data (True), or to use a reference instead. Default is False.

subok
[bool, optional] Whether to return a subclass of *MaskedArray* if possible (True) or a plain *MaskedArray*. Default is True.

ndmin
[int, optional] Minimum number of dimensions. Default is 0.

fill_value
[scalar, optional] Value used to fill in the masked values when necessary. If None, a default based on the data-type is used.

keep_mask
[bool, optional] Whether to combine *mask* with the mask of the input data, if any (True), or to use only *mask* for the output (False). Default is True.

hard_mask
[bool, optional] Whether to use a hard mask or not. With a hard mask, masked values cannot be unmasked. Default is False.

shrink
[bool, optional] Whether to force compression of an empty mask. Default is True.

order
[{'C', 'F', 'A'}, optional] Specify the order of the array. If order is 'C', then the array will be in C-contiguous order (last-index varies the fastest). If order is 'F', then the returned array will be in Fortran-contiguous order (first-index varies the fastest). If order is 'A' (default), then the returned array may be in any order (either C-, Fortran-contiguous, or even discontiguous), unless a copy is required, in which case it will be C-contiguous.

Examples

```
>>> import numpy as np
```

The `mask` can be initialized with an array of boolean values with the same shape as `data`.

```
>>> data = np.arange(6).reshape((2, 3))
>>> np.ma.MaskedArray(data, mask=[[False, True, False],
...                               [False, False, True]])
masked_array(
  data=[[0, --, 2],
        [3, 4, --]],
  mask=[[False,  True, False],
        [False, False,  True]],
  fill_value=999999)
```

Alternatively, the `mask` can be initialized to homogeneous boolean array with the same shape as `data` by passing in a scalar boolean value:

```
>>> np.ma.MaskedArray(data, mask=False)
masked_array(
  data=[[0, 1, 2],
        [3, 4, 5]],
  mask=[[False, False, False],
        [False, False, False]],
  fill_value=999999)
```

```
>>> np.ma.MaskedArray(data, mask=True)
masked_array(
  data=[[--, --, --],
        [--, --, --]],
  mask=[[ True,  True,  True],
        [ True,  True,  True]],
  fill_value=999999,
  dtype=int64)
```

Note: The recommended practice for initializing `mask` with a scalar boolean value is to use `True`/`False` rather than `np.True_`/`np.False_`. The reason is *`nomask`* is represented internally as `np.False_`.

```
>>> np.False_ is np.ma.nomask
True
```

---

ma.**copy**(*self*, **args*, ***params*) *a.copy(order='C')* **= <numpy.ma.core._frommethod object>**

Return a copy of the array.

Parameters

order
: [{'C', 'F', 'A', 'K'}, optional] Controls the memory layout of the copy. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible. (Note that this function and *`numpy.copy`* are very similar but have different default values for their order= arguments, and this function always passes sub-classes through.)

See also:

numpy.copy
Similar function with different default behavior

numpy.copyto

Notes

This function is the preferred method for creating an array copy. The function *numpy.copy* is similar, but it defaults to using order 'K', and will not pass sub-classes through by default.

Examples

```
>>> import numpy as np
>>> x = np.array([[1,2,3],[4,5,6]], order='F')
```

```
>>> y = x.copy()
```

```
>>> x.fill(0)
```

```
>>> x
array([[0, 0, 0],
       [0, 0, 0]])
```

```
>>> y
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> y.flags['C_CONTIGUOUS']
True
```

For arrays containing Python objects (e.g. dtype=object), the copy is a shallow one. The new array will contain the same object which may lead to surprises if that object can be modified (is mutable):

```
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> b = a.copy()
>>> b[2][0] = 10
>>> a
array([1, 'm', list([10, 3, 4])], dtype=object)
```

To ensure all elements within an `object` array are copied, use `copy.deepcopy`:

```
>>> import copy
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> c = copy.deepcopy(a)
>>> c[2][0] = 10
>>> c
array([1, 'm', list([10, 3, 4])], dtype=object)
>>> a
array([1, 'm', list([2, 3, 4])], dtype=object)
```

ma.**frombuffer**(*buffer*, *dtype=float*, *count=-1*, *offset=0*, *, *like=None*) **= <numpy.ma.core._convert2ma object>**

Interpret a buffer as a 1-dimensional array.

Parameters

buffer
[buffer_like] An object that exposes the buffer interface.

dtype
[data-type, optional] Data-type of the returned array; default: float.

count
[int, optional] Number of items to read. `-1` means all data in the buffer.

offset
[int, optional] Start reading the buffer from this offset (in bytes); default: 0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out: MaskedArray

See also:

ndarray.tobytes
Inverse of this operation, construct Python bytes from the raw data bytes in the array.

Notes

If the buffer has data that is not in machine byte-order, this should be specified as part of the data-type, e.g.:

```
>>> dt = np.dtype(int)
>>> dt = dt.newbyteorder('>')
>>> np.frombuffer(buf, dtype=dt)
```

The data of the resulting array will not be byteswapped, but will be interpreted correctly.

This function creates a view into the original object. This should be safe in general, but it may make sense to copy the result when the original object is mutable or untrusted.

Examples

```
>>> import numpy as np
>>> s = b'hello world'
>>> np.frombuffer(s, dtype='S1', count=5, offset=6)
array([b'w', b'o', b'r', b'l', b'd'], dtype='|S1')
```

```
>>> np.frombuffer(b'\x01\x02', dtype=np.uint8)
array([1, 2], dtype=uint8)
>>> np.frombuffer(b'\x01\x02\x03\x04\x05', dtype=np.uint8, count=3)
array([1, 2, 3], dtype=uint8)
```

ma.**fromfunction**(*function*, *shape*, ***dtype*) **= <numpy.ma.core._convert2ma object>**

Construct an array by executing a function over each coordinate.

The resulting array therefore has a value `fn(x, y, z)` at coordinate `(x, y, z)`.

Parameters

function
[callable] The function is called with N parameters, where N is the rank of *shape*. Each parameter represents the coordinates of the array varying along a specific axis. For example, if *shape* were `(2, 2)`, then the parameters would be `array([[0, 0], [1, 1]])` and `array([[0, 1], [0, 1]])`

shape
[(N,) tuple of ints] Shape of the output array, which also determines the shape of the coordinate arrays passed to *function*.

dtype
[data-type, optional] Data-type of the coordinate arrays passed to *function*. By default, *dtype* is float.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

fromfunction: MaskedArray
The result of the call to *function* is passed back directly. Therefore the shape of *fromfunction* is completely determined by *function*. If *function* returns a scalar value, the shape of *fromfunction* would not match the *shape* parameter.

See also:

indices*, *meshgrid

Notes

Keywords other than *dtype* and *like* are passed to *function*.

Examples

```
>>> import numpy as np
>>> np.fromfunction(lambda i, j: i, (2, 2), dtype=float)
array([[0., 0.],
       [1., 1.]])
```

```
>>> np.fromfunction(lambda i, j: j, (2, 2), dtype=float)
array([[0., 1.],
       [0., 1.]])
```

```
>>> np.fromfunction(lambda i, j: i == j, (3, 3), dtype=int)
array([[ True, False, False],
       [False,  True, False],
       [False, False,  True]])
```

```
>>> np.fromfunction(lambda i, j: i + j, (3, 3), dtype=int)
array([[0, 1, 2],
       [1, 2, 3],
       [2, 3, 4]])
```

method

ma.MaskedArray.**copy**(*order='C'*)

Return a copy of the array.

Parameters

order

[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout of the copy. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible. (Note that this function and *numpy.copy* are very similar but have different default values for their order= arguments, and this function always passes sub-classes through.)

See also:

numpy.copy

Similar function with different default behavior

numpy.copyto

Notes

This function is the preferred method for creating an array copy. The function *numpy.copy* is similar, but it defaults to using order 'K', and will not pass sub-classes through by default.

Examples

```
>>> import numpy as np
>>> x = np.array([[1,2,3],[4,5,6]], order='F')
```

```
>>> y = x.copy()
```

```
>>> x.fill(0)
```

```
>>> x
array([[0, 0, 0],
       [0, 0, 0]])
```

```
>>> y
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> y.flags['C_CONTIGUOUS']
True
```

For arrays containing Python objects (e.g. dtype=object), the copy is a shallow one. The new array will contain the same object which may lead to surprises if that object can be modified (is mutable):

```
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> b = a.copy()
>>> b[2][0] = 10
>>> a
array([1, 'm', list([10, 3, 4])], dtype=object)
```

To ensure all elements within an `object` array are copied, use `copy.deepcopy`:

```
>>> import copy
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> c = copy.deepcopy(a)
>>> c[2][0] = 10
>>> c
array([1, 'm', list([10, 3, 4])], dtype=object)
>>> a
array([1, 'm', list([2, 3, 4])], dtype=object)
```

ma.**diagflat = <numpy.ma.extras._fromnxfunction_single object>**

Create a two-dimensional array with the flattened input as a diagonal.

Parameters

v

[array_like] Input data, which is flattened and set as the *k*-th diagonal of the output.

k

[int, optional] Diagonal to set; 0, the default, corresponds to the "main" diagonal, a positive (negative) *k* giving the number of the diagonal above (below) the main.

Returns

out

[ndarray] The 2-D output array.

See also:

diag
MATLAB work-alike for 1-D and 2-D arrays.

diagonal
Return specified diagonals.

trace
Sum along diagonals.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> np.diagflat([[1,2], [3,4]])
array([[1, 0, 0, 0],
       [0, 2, 0, 0],
       [0, 0, 3, 0],
       [0, 0, 0, 4]])
```

```
>>> np.diagflat([1,2], 1)
array([[0, 1, 0],
       [0, 0, 2],
       [0, 0, 0]])
```

Ones and zeros

ma.empty(shape[, dtype, order, device, like])	Return a new array of given shape and type, without initializing entries.
ma.empty_like(prototype[, dtype, order, ...])	Return a new array with the same shape and type as a given array.
ma.masked_all(shape[, dtype])	Empty masked array with all elements masked.
ma.masked_all_like(arr)	Empty masked array with the properties of an existing array.
ma.ones(shape[, dtype, order])	Return a new array of given shape and type, filled with ones.
ma.ones_like	Return an array of ones with the same shape and type as a given array.
ma.zeros(shape[, dtype, order, like])	Return a new array of given shape and type, filled with zeros.
ma.zeros_like	Return an array of zeros with the same shape and type as a given array.

ma.**empty**(*shape*, *dtype=float*, *order='C'*, ***, *device=None*, *like=None*) **= <numpy.ma.core._convert2ma object>**

Return a new array of given shape and type, without initializing entries.

Parameters

shape
[int or tuple of int] Shape of the empty array, e.g., `(2, 3)` or `2`.

dtype
[data-type, optional] Desired output data-type for the array, e.g, *numpy.int8*. Default is *numpy.float64*.

order
[{'C', 'F'}, optional, default: 'C'] Whether to store multi-dimensional data in row-major (C-style) or column-major (Fortran-style) order in memory.

device
[str, optional] The device on which to place the created array. Default: `None`. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[MaskedArray] Array of uninitialized (arbitrary) data of the given shape, dtype, and order. Object arrays will be initialized to None.

See also:

empty_like
Return an empty array with shape and type of input.

ones
Return a new array setting values to one.

zeros
Return a new array setting values to zero.

full
Return a new array of given shape filled with value.

Notes

Unlike other array creation functions (e.g. *zeros*, *ones*, *full*), *empty* does not initialize the values of the array, and may therefore be marginally faster. However, the values stored in the newly allocated array are arbitrary. For reproducible behavior, be sure to set each element of the array before reading.

Examples

```
>>> import numpy as np
>>> np.empty([2, 2])
array([[ -9.74499359e+001,   6.69583040e-309],
       [  2.13182611e-314,   3.06959433e-309]])         #uninitialized
```

```
>>> np.empty([2, 2], dtype=int)
array([[-1073741821, -1067949133],
       [  496041986,    19249760]])                     #uninitialized
```

ma.**empty_like**(*prototype*, *dtype=None*, *order='K'*, *subok=True*, *shape=None*, ***, *device=None*) = **<numpy.ma.core._convert2ma object>**

Return a new array with the same shape and type as a given array.

Parameters

prototype
[array_like] The shape and data-type of *prototype* define these same attributes of the returned array.

dtype
[data-type, optional] Overrides the data type of the result.

order
[{'C', 'F', 'A', or 'K'}, optional] Overrides the memory layout of the result. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *prototype* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *prototype* as closely as possible.

subok
[bool, optional.] If True, then the newly created array will use the sub-class type of *prototype*, otherwise it will be a base-class array. Defaults to True.

shape
[int or sequence of ints, optional.] Overrides the shape of the result. If order='K' and the number of dimensions is unchanged, will try to keep order, otherwise, order='C' is implied.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

Returns

out
[MaskedArray] Array of uninitialized (arbitrary) data with the same shape and type as *prototype*.

See also:

ones_like
Return an array of ones with shape and type of input.

zeros_like
Return an array of zeros with shape and type of input.

full_like
Return a new array with shape of input filled with value.

empty
Return a new uninitialized array.

Notes

Unlike other array creation functions (e.g. *zeros_like*, *ones_like*, *full_like*), *empty_like* does not initialize the values of the array, and may therefore be marginally faster. However, the values stored in the newly allocated array are arbitrary. For reproducible behavior, be sure to set each element of the array before reading.

Examples

```
>>> import numpy as np
>>> a = ([1,2,3], [4,5,6])                         # a is array-like
>>> np.empty_like(a)
array([[-1073741821, -1073741821,           3],    # uninitialized
       [          0,           0, -1073741821]])
>>> a = np.array([[1., 2., 3.],[4.,5.,6.]])
>>> np.empty_like(a)
array([[ -2.00000715e+000,   1.48219694e-323,  -2.00000572e+000], # uninitialized
       [  4.38791518e-305,  -2.00000715e+000,   4.17269252e-309]])
```

ma.**masked_all**(*shape*, *dtype=<class 'float'>*)
Empty masked array with all elements masked.

Return an empty masked array of the given shape and dtype, where all the data are masked.

Parameters

shape
[int or tuple of ints] Shape of the required MaskedArray, e.g., `(2, 3)` or `2`.

dtype
[dtype, optional] Data type of the output.

Returns

a
[MaskedArray] A masked array with all data masked.

See also:

masked_all_like
Empty masked array modelled on an existing array.

Notes

Unlike other masked array creation functions (e.g. *numpy.ma.zeros*, *numpy.ma.ones*, *numpy.ma.full*), *masked_all* does not initialize the values of the array, and may therefore be marginally faster. However, the values stored in the newly allocated array are arbitrary. For reproducible behavior, be sure to set each element of the array before reading.

Examples

```
>>> import numpy as np
>>> np.ma.masked_all((3, 3))
masked_array(
  data=[[--, --, --],
        [--, --, --],
        [--, --, --]],
  mask=[[ True,  True,  True],
        [ True,  True,  True],
        [ True,  True,  True]],
  fill_value=1e+20,
  dtype=float64)
```

The *dtype* parameter defines the underlying data type.

```
>>> a = np.ma.masked_all((3, 3))
>>> a.dtype
dtype('float64')
>>> a = np.ma.masked_all((3, 3), dtype=np.int32)
>>> a.dtype
dtype('int32')
```

ma.**masked_all_like**(*arr*)

Empty masked array with the properties of an existing array.

Return an empty masked array of the same shape and dtype as the array *arr*, where all the data are masked.

Parameters

arr
[ndarray] An array describing the shape and dtype of the required MaskedArray.

Returns

a
[MaskedArray] A masked array with all data masked.

Raises

AttributeError
If *arr* doesn't have a shape attribute (i.e. not an ndarray)

See also:

masked_all
Empty masked array with all elements masked.

Notes

Unlike other masked array creation functions (e.g. *numpy.ma.zeros_like*, *numpy.ma.ones_like*, *numpy.ma.full_like*), *masked_all_like* does not initialize the values of the array, and may therefore be marginally faster. However, the values stored in the newly allocated array are arbitrary. For reproducible behavior, be sure to set each element of the array before reading.

Examples

```
>>> import numpy as np
>>> arr = np.zeros((2, 3), dtype=np.float32)
>>> arr
array([[0., 0., 0.],
       [0., 0., 0.]], dtype=float32)
>>> np.ma.masked_all_like(arr)
masked_array(
  data=[[--, --, --],
        [--, --, --]],
  mask=[[ True,  True,  True],
        [ True,  True,  True]],
  fill_value=np.float64(1e+20),
  dtype=float32)
```

The dtype of the masked array matches the dtype of *arr*.

```
>>> arr.dtype
dtype('float32')
>>> np.ma.masked_all_like(arr).dtype
dtype('float32')
```

ma.**ones**(*shape*, *dtype=None*, *order='C'*) **= <numpy.ma.core._convert2ma object>**

Return a new array of given shape and type, filled with ones.

Parameters

shape
[int or sequence of ints] Shape of the new array, e.g., `(2, 3)` or `2`.

dtype
[data-type, optional] The desired data-type for the array, e.g., *numpy.int8*. Default is *numpy.float64*.

order
[{'C', 'F'}, optional, default: C] Whether to store multi-dimensional data in row-major (C-style) or column-major (Fortran-style) order in memory.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[MaskedArray] Array of ones with the given shape, dtype, and order.

See also:

ones_like
Return an array of ones with shape and type of input.

empty
Return a new uninitialized array.

zeros
Return a new array setting values to zero.

full
Return a new array of given shape filled with value.

Examples

```
>>> import numpy as np
>>> np.ones(5)
array([1., 1., 1., 1., 1.])
```

```
>>> np.ones((5,), dtype=int)
array([1, 1, 1, 1, 1])
```

```
>>> np.ones((2, 1))
array([[1.],
       [1.]])
```

```
>>> s = (2,2)
>>> np.ones(s)
array([[1.,  1.],
       [1.,  1.]])
```

ma.**ones_like = <numpy.ma.core._convert2ma object>**
Return an array of ones with the same shape and type as a given array.

Parameters

a
[array_like] The shape and data-type of *a* define these same attributes of the returned array.

dtype
[data-type, optional] Overrides the data type of the result.

order
[{'C', 'F', 'A', or 'K'}, optional] Overrides the memory layout of the result. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible.

subok
[bool, optional.] If True, then the newly created array will use the sub-class type of *a*, otherwise it will be a base-class array. Defaults to True.

shape
[int or sequence of ints, optional.] Overrides the shape of the result. If order='K' and the number of dimensions is unchanged, will try to keep order, otherwise, order='C' is implied.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

Returns

out
[MaskedArray] Array of ones with the same shape and type as *a*.

See also:

empty_like
Return an empty array with shape and type of input.

zeros_like
Return an array of zeros with shape and type of input.

full_like
Return a new array with shape of input filled with value.

ones
Return a new array setting values to one.

Examples

```
>>> import numpy as np
>>> x = np.arange(6)
>>> x = x.reshape((2, 3))
>>> x
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.ones_like(x)
array([[1, 1, 1],
       [1, 1, 1]])
```

```
>>> y = np.arange(3, dtype=float)
>>> y
array([0., 1., 2.])
>>> np.ones_like(y)
array([1.,  1.,  1.])
```

ma.**zeros**(*shape*, *dtype=float*, *order='C'*, ***, *like=None*) **= <numpy.ma.core._convert2ma object>**

Return a new array of given shape and type, filled with zeros.

Parameters

shape
[int or tuple of ints] Shape of the new array, e.g., `(2, 3)` or `2`.

dtype
[data-type, optional] The desired data-type for the array, e.g., *numpy.int8*. Default is *numpy.float64*.

order
[{'C', 'F'}, optional, default: 'C'] Whether to store multi-dimensional data in row-major (C-style) or column-major (Fortran-style) order in memory.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol,

the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[MaskedArray] Array of zeros with the given shape, dtype, and order.

See also:

zeros_like
Return an array of zeros with shape and type of input.

empty
Return a new uninitialized array.

ones
Return a new array setting values to one.

full
Return a new array of given shape filled with value.

Examples

```
>>> import numpy as np
>>> np.zeros(5)
array([ 0.,  0.,  0.,  0.,  0.])
```

```
>>> np.zeros((5,), dtype=int)
array([0, 0, 0, 0, 0])
```

```
>>> np.zeros((2, 1))
array([[ 0.],
       [ 0.]])
```

```
>>> s = (2,2)
>>> np.zeros(s)
array([[ 0.,  0.],
       [ 0.,  0.]])
```

```
>>> np.zeros((2,), dtype=[('x', 'i4'), ('y', 'i4')]) # custom dtype
array([(0, 0), (0, 0)],
      dtype=[('x', '<i4'), ('y', '<i4')])
```

ma.**zeros_like = <numpy.ma.core._convert2ma object>**

Return an array of zeros with the same shape and type as a given array.

Parameters

a
[array_like] The shape and data-type of *a* define these same attributes of the returned array.

dtype
[data-type, optional] Overrides the data type of the result.

order
[{'C', 'F', 'A', or 'K'}, optional] Overrides the memory layout of the result. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible.

subok
[bool, optional.] If True, then the newly created array will use the sub-class type of *a*, otherwise it will be a base-class array. Defaults to True.

shape
[int or sequence of ints, optional.] Overrides the shape of the result. If order='K' and the number of dimensions is unchanged, will try to keep order, otherwise, order='C' is implied.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

Returns

out
[MaskedArray] Array of zeros with the same shape and type as *a*.

See also:

empty_like
Return an empty array with shape and type of input.

ones_like
Return an array of ones with shape and type of input.

full_like
Return a new array with shape of input filled with value.

zeros
Return a new array setting values to zero.

Examples

```
>>> import numpy as np
>>> x = np.arange(6)
>>> x = x.reshape((2, 3))
>>> x
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.zeros_like(x)
array([[0, 0, 0],
       [0, 0, 0]])
```

```
>>> y = np.arange(3, dtype=float)
>>> y
array([0., 1., 2.])
>>> np.zeros_like(y)
array([0.,  0.,  0.])
```

Inspecting the array

ma.all(self[, axis, out, keepdims])	Returns True if all elements evaluate to True.
ma.any(self[, axis, out, keepdims])	Returns True if any of the elements of *a* evaluate to True.
ma.count(self[, axis, keepdims])	Count the non-masked elements of the array along the given axis.
ma.count_masked(arr[, axis])	Count the number of masked elements along the given axis.
ma.getmask(a)	Return the mask of a masked array, or nomask.
ma.getmaskarray(arr)	Return the mask of a masked array, or full boolean array of False.
ma.getdata(a[, subok])	Return the data of a masked array as an ndarray.
ma.nonzero(self)	Return the indices of unmasked elements that are not zero.
ma.shape(obj)	Return the shape of an array.
ma.size(obj[, axis])	Return the number of elements along a given axis.
ma.is_masked(x)	Determine whether input has masked values.
ma.is_mask(m)	Return True if m is a valid, standard mask.
ma.isMaskedArray(x)	Test whether input is an instance of MaskedArray.
ma.isMA(x)	Test whether input is an instance of MaskedArray.
ma.isarray(x)	Test whether input is an instance of MaskedArray.
ma.isin(element, test_elements[, ...])	Calculates *element in test_elements*, broadcasting over *element* only.
ma.in1d(ar1, ar2[, assume_unique, invert])	Test whether each element of an array is also present in a second array.
ma.unique(ar1[, return_index, return_inverse])	Finds the unique elements of an array.
ma.MaskedArray.all([axis, out, keepdims])	Returns True if all elements evaluate to True.
ma.MaskedArray.any([axis, out, keepdims])	Returns True if any of the elements of *a* evaluate to True.
ma.MaskedArray.count([axis, keepdims])	Count the non-masked elements of the array along the given axis.
ma.MaskedArray.nonzero()	Return the indices of unmasked elements that are not zero.
ma.shape(obj)	Return the shape of an array.
ma.size(obj[, axis])	Return the number of elements along a given axis.

ma.**all**(*self*, *axis=None*, *out=None*, *keepdims=<no value>*) **= <numpy.ma.core._frommethod object>**

Returns True if all elements evaluate to True.

The output array is masked where all the values along the given axis are masked: if the output would have been a scalar and that all the values are masked, then the output is *masked*.

Refer to *numpy.all* for full documentation.

See also:

numpy.ndarray.all
corresponding function for ndarrays

numpy.all
equivalent function

Examples

```
>>> import numpy as np
>>> np.ma.array([1,2,3]).all()
True
>>> a = np.ma.array([1,2,3], mask=True)
>>> (a.all() is np.ma.masked)
True
```

ma.**any**(*self*, *axis=None*, *out=None*, *keepdims=<no value>*) **= <numpy.ma.core._frommethod object>**

Returns True if any of the elements of *a* evaluate to True.

Masked values are considered as False during computation.

Refer to *numpy.any* for full documentation.

See also:

numpy.ndarray.any
corresponding function for ndarrays

numpy.any
equivalent function

ma.**count**(*self*, *axis=None*, *keepdims=<no value>*) **= <numpy.ma.core._frommethod object>**

Count the non-masked elements of the array along the given axis.

Parameters

axis
[None or int or tuple of ints, optional] Axis or axes along which the count is performed. The default, None, performs the count over all the dimensions of the input array. *axis* may be negative, in which case it counts from the last to the first axis. If this is a tuple of ints, the count is performed on multiple axes, instead of a single axis or all the axes as before.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

Returns

result
[ndarray or scalar] An array with the same shape as the input array, with the specified axis removed. If the array is a 0-d array, or if *axis* is None, a scalar is returned.

See also:

ma.count_masked
Count masked elements in array or along a given axis.

Examples

```
>>> import numpy.ma as ma
>>> a = ma.arange(6).reshape((2, 3))
>>> a[1, :] = ma.masked
>>> a
masked_array(
  data=[[0, 1, 2],
        [--, --, --]],
  mask=[[False, False, False],
        [ True,  True,  True]],
  fill_value=999999)
>>> a.count()
3
```

When the *axis* keyword is specified an array of appropriate size is returned.

```
>>> a.count(axis=0)
array([1, 1, 1])
>>> a.count(axis=1)
array([3, 0])
```

ma.**count_masked**(*arr*, *axis=None*)

Count the number of masked elements along the given axis.

Parameters

arr
[array_like] An array with (possibly) masked elements.

axis
[int, optional] Axis along which to count. If None (default), a flattened version of the array is used.

Returns

count
[int, ndarray] The total number of masked elements (axis=None) or the number of masked elements along each slice of the given axis.

See also:

MaskedArray.count
Count non-masked elements.

Examples

```
>>> import numpy as np
>>> a = np.arange(9).reshape((3,3))
>>> a = np.ma.array(a)
>>> a[1, 0] = np.ma.masked
>>> a[1, 2] = np.ma.masked
>>> a[2, 1] = np.ma.masked
>>> a
masked_array(
  data=[[0, 1, 2],
        [--, 4, --],
```

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```
       [6, --, 8]],
  mask=[[False, False, False],
       [ True, False,  True],
       [False,  True, False]],
  fill_value=999999)
>>> np.ma.count_masked(a)
3
```

When the *axis* keyword is used an array is returned.

```
>>> np.ma.count_masked(a, axis=0)
array([1, 1, 1])
>>> np.ma.count_masked(a, axis=1)
array([0, 2, 1])
```

ma.**getmask**(*a*)

Return the mask of a masked array, or nomask.

Return the mask of *a* as an ndarray if *a* is a *MaskedArray* and the mask is not *nomask*, else return *nomask*. To guarantee a full array of booleans of the same shape as a, use *getmaskarray*.

Parameters

a
[array_like] Input *MaskedArray* for which the mask is required.

See also:

getdata
Return the data of a masked array as an ndarray.

getmaskarray
Return the mask of a masked array, or full array of False.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1,2],[3,4]], 2)
>>> a
masked_array(
  data=[[1, --],
       [3, 4]],
  mask=[[False,  True],
       [False, False]],
  fill_value=2)
>>> ma.getmask(a)
array([[False,  True],
       [False, False]])
```

Equivalently use the *MaskedArray* *mask* attribute.

```
>>> a.mask
array([[False,  True],
       [False, False]])
```

Result when mask == *nomask*

```
>>> b = ma.masked_array([[1,2],[3,4]])
>>> b
masked_array(
  data=[[1, 2],
        [3, 4]],
  mask=False,
  fill_value=999999)
>>> ma.nomask
False
>>> ma.getmask(b) == ma.nomask
True
>>> b.mask == ma.nomask
True
```

ma.**getmaskarray**(*arr*)

Return the mask of a masked array, or full boolean array of False.

Return the mask of *arr* as an ndarray if *arr* is a *MaskedArray* and the mask is not *nomask*, else return a full boolean array of False of the same shape as *arr*.

Parameters

arr
[array_like] Input *MaskedArray* for which the mask is required.

See also:

getmask
Return the mask of a masked array, or nomask.

getdata
Return the data of a masked array as an ndarray.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1,2],[3,4]], 2)
>>> a
masked_array(
  data=[[1, --],
        [3, 4]],
  mask=[[False,  True],
        [False, False]],
  fill_value=2)
>>> ma.getmaskarray(a)
array([[False,  True],
       [False, False]])
```

Result when mask == `nomask`

```
>>> b = ma.masked_array([[1,2],[3,4]])
>>> b
masked_array(
  data=[[1, 2],
        [3, 4]],
  mask=False,
```

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```
  fill_value=999999)
>>> ma.getmaskarray(b)
array([[False, False],
       [False, False]])
```

ma.**getdata**(*a*, *subok=True*)

Return the data of a masked array as an ndarray.

Return the data of *a* (if any) as an ndarray if *a* is a `MaskedArray`, else return *a* as a ndarray or subclass (depending on *subok*) if not.

Parameters

a
[array_like] Input `MaskedArray`, alternatively a ndarray or a subclass thereof.

subok
[bool] Whether to force the output to be a *pure* ndarray (False) or to return a subclass of ndarray if appropriate (True, default).

See also:

getmask
Return the mask of a masked array, or nomask.

getmaskarray
Return the mask of a masked array, or full array of False.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = ma.masked_equal([[1,2],[3,4]], 2)
>>> a
masked_array(
  data=[[1, --],
        [3, 4]],
  mask=[[False,  True],
        [False, False]],
  fill_value=2)
>>> ma.getdata(a)
array([[1, 2],
       [3, 4]])
```

Equivalently use the `MaskedArray` *data* attribute.

```
>>> a.data
array([[1, 2],
       [3, 4]])
```

ma.**nonzero**(*self*) **= <numpy.ma.core._frommethod object>**

Return the indices of unmasked elements that are not zero.

Returns a tuple of arrays, one for each dimension, containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

```
a[a.nonzero()]
```

To group the indices by element, rather than dimension, use instead:

```
np.transpose(a.nonzero())
```

The result of this is always a 2d array, with a row for each non-zero element.

Parameters

None

Returns

tuple_of_arrays
[tuple] Indices of elements that are non-zero.

See also:

numpy.nonzero
Function operating on ndarrays.

flatnonzero
Return indices that are non-zero in the flattened version of the input array.

numpy.ndarray.nonzero
Equivalent ndarray method.

count_nonzero
Counts the number of non-zero elements in the input array.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = ma.array(np.eye(3))
>>> x
masked_array(
  data=[[1., 0., 0.],
        [0., 1., 0.],
        [0., 0., 1.]],
  mask=False,
  fill_value=1e+20)
>>> x.nonzero()
(array([0, 1, 2]), array([0, 1, 2]))
```

Masked elements are ignored.

```
>>> x[1, 1] = ma.masked
>>> x
masked_array(
  data=[[1.0, 0.0, 0.0],
        [0.0, --, 0.0],
        [0.0, 0.0, 1.0]],
  mask=[[False, False, False],
        [False,  True, False],
        [False, False, False]],
  fill_value=1e+20)
```

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```
>>> x.nonzero()
(array([0, 2]), array([0, 2]))
```

Indices can also be grouped by element.

```
>>> np.transpose(x.nonzero())
array([[0, 0],
       [2, 2]])
```

A common use for `nonzero` is to find the indices of an array, where a condition is True. Given an array *a*, the condition *a* > 3 is a boolean array and since False is interpreted as 0, ma.nonzero(a > 3) yields the indices of the *a* where the condition is true.

```
>>> a = ma.array([[1,2,3],[4,5,6],[7,8,9]])
>>> a > 3
masked_array(
  data=[[False, False, False],
        [ True,  True,  True],
        [ True,  True,  True]],
  mask=False,
  fill_value=True)
>>> ma.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

The `nonzero` method of the condition array can also be called.

```
>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

`ma.`**`shape`**(*obj*)

Return the shape of an array.

Parameters

a
: [array_like] Input array.

Returns

shape
: [tuple of ints] The elements of the shape tuple give the lengths of the corresponding array dimensions.

See also:

`len`
: `len(a)` is equivalent to `np.shape(a)[0]` for N-D arrays with `N>=1`.

`ndarray.shape`
: Equivalent array method.

Examples

```
>>> import numpy as np
>>> np.shape(np.eye(3))
(3, 3)
>>> np.shape([[1, 3]])
(1, 2)
>>> np.shape([0])
(1,)
>>> np.shape(0)
()
```

```
>>> a = np.array([(1, 2), (3, 4), (5, 6)],
...              dtype=[('x', 'i4'), ('y', 'i4')])
>>> np.shape(a)
(3,)
>>> a.shape
(3,)
```

ma.**size**(*obj*, *axis=None*)

Return the number of elements along a given axis.

Parameters

a
[array_like] Input data.

axis
[int, optional] Axis along which the elements are counted. By default, give the total number of elements.

Returns

element_count
[int] Number of elements along the specified axis.

See also:

shape
dimensions of array

ndarray.shape
dimensions of array

ndarray.size
number of elements in array

Examples

```
>>> import numpy as np
>>> a = np.array([[1,2,3],[4,5,6]])
>>> np.size(a)
6
>>> np.size(a,1)
3
>>> np.size(a,0)
2
```

ma.**is_masked**(*x*)

Determine whether input has masked values.

Accepts any object as input, but always returns False unless the input is a MaskedArray containing masked values.

Parameters

x
[array_like] Array to check for masked values.

Returns

result
[bool] True if *x* is a MaskedArray with masked values, False otherwise.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = ma.masked_equal([0, 1, 0, 2, 3], 0)
>>> x
masked_array(data=[--, 1, --, 2, 3],
             mask=[ True, False,  True, False, False],
       fill_value=0)
>>> ma.is_masked(x)
True
>>> x = ma.masked_equal([0, 1, 0, 2, 3], 42)
>>> x
masked_array(data=[0, 1, 0, 2, 3],
             mask=False,
       fill_value=42)
>>> ma.is_masked(x)
False
```

Always returns False if *x* isn't a MaskedArray.

```
>>> x = [False, True, False]
>>> ma.is_masked(x)
False
>>> x = 'a string'
>>> ma.is_masked(x)
False
```

ma.**is_mask**(*m*)

Return True if m is a valid, standard mask.

This function does not check the contents of the input, only that the type is MaskType. In particular, this function returns False if the mask has a flexible dtype.

Parameters

m
[array_like] Array to test.

Returns

result
[bool] True if *m.dtype.type* is MaskType, False otherwise.

See also:

ma.isMaskedArray
Test whether input is an instance of MaskedArray.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> m = ma.masked_equal([0, 1, 0, 2, 3], 0)
>>> m
masked_array(data=[--, 1, --, 2, 3],
             mask=[ True, False,  True, False, False],
       fill_value=0)
>>> ma.is_mask(m)
False
>>> ma.is_mask(m.mask)
True
```

Input must be an ndarray (or have similar attributes) for it to be considered a valid mask.

```
>>> m = [False, True, False]
>>> ma.is_mask(m)
False
>>> m = np.array([False, True, False])
>>> m
array([False,  True, False])
>>> ma.is_mask(m)
True
```

Arrays with complex dtypes don't return True.

```
>>> dtype = np.dtype({'names':['monty', 'pithon'],
...                   'formats':[bool, bool]})
>>> dtype
dtype([('monty', '|b1'), ('pithon', '|b1')])
>>> m = np.array([(True, False), (False, True), (True, False)],
...              dtype=dtype)
>>> m
array([( True, False), (False,  True), ( True, False)],
      dtype=[('monty', '?'), ('pithon', '?')])
>>> ma.is_mask(m)
False
```

ma.**isMaskedArray**(*x*)
Test whether input is an instance of MaskedArray.

This function returns True if *x* is an instance of MaskedArray and returns False otherwise. Any object is accepted as input.

Parameters

x
[object] Object to test.

Returns

result
[bool] True if *x* is a MaskedArray.

See also:

isMA
Alias to isMaskedArray.

isarray
Alias to isMaskedArray.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.eye(3, 3)
>>> a
array([[ 1.,  0.,  0.],
       [ 0.,  1.,  0.],
       [ 0.,  0.,  1.]])
>>> m = ma.masked_values(a, 0)
>>> m
masked_array(
  data=[[1.0, --, --],
        [--, 1.0, --],
        [--, --, 1.0]],
  mask=[[False,  True,  True],
        [ True, False,  True],
        [ True,  True, False]],
  fill_value=0.0)
>>> ma.isMaskedArray(a)
False
>>> ma.isMaskedArray(m)
True
>>> ma.isMaskedArray([0, 1, 2])
False
```

ma.**isMA**(*x*)

Test whether input is an instance of MaskedArray.

This function returns True if *x* is an instance of MaskedArray and returns False otherwise. Any object is accepted as input.

Parameters

x
[object] Object to test.

Returns

result
[bool] True if *x* is a MaskedArray.

See also:

isMA
Alias to isMaskedArray.

isarray
Alias to isMaskedArray.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.eye(3, 3)
>>> a
array([[ 1.,  0.,  0.],
       [ 0.,  1.,  0.],
       [ 0.,  0.,  1.]])
>>> m = ma.masked_values(a, 0)
>>> m
masked_array(
  data=[[1.0, --, --],
        [--, 1.0, --],
        [--, --, 1.0]],
  mask=[[False,  True,  True],
        [ True, False,  True],
        [ True,  True, False]],
  fill_value=0.0)
>>> ma.isMaskedArray(a)
False
>>> ma.isMaskedArray(m)
True
>>> ma.isMaskedArray([0, 1, 2])
False
```

ma.**isarray**(*x*)

Test whether input is an instance of MaskedArray.

This function returns True if *x* is an instance of MaskedArray and returns False otherwise. Any object is accepted as input.

Parameters

x
[object] Object to test.

Returns

result
[bool] True if *x* is a MaskedArray.

See also:

isMA
Alias to isMaskedArray.

isarray
Alias to isMaskedArray.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.eye(3, 3)
>>> a
array([[ 1.,  0.,  0.],
       [ 0.,  1.,  0.],
       [ 0.,  0.,  1.]])
>>> m = ma.masked_values(a, 0)
>>> m
masked_array(
  data=[[1.0, --, --],
        [--, 1.0, --],
        [--, --, 1.0]],
  mask=[[False,  True,  True],
        [ True, False,  True],
        [ True,  True, False]],
  fill_value=0.0)
>>> ma.isMaskedArray(a)
False
>>> ma.isMaskedArray(m)
True
>>> ma.isMaskedArray([0, 1, 2])
False
```

ma.**isin**(*element*, *test_elements*, *assume_unique=False*, *invert=False*)

Calculates *element in test_elements*, broadcasting over *element* only.

The output is always a masked array of the same shape as *element*. See *numpy.isin* for more details.

See also:

in1d
: Flattened version of this function.

numpy.isin
: Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
>>> element = np.ma.array([1, 2, 3, 4, 5, 6])
>>> test_elements = [0, 2]
>>> np.ma.isin(element, test_elements)
masked_array(data=[False,  True, False, False, False, False],
             mask=False,
       fill_value=True)
```

ma.**in1d**(*ar1*, *ar2*, *assume_unique=False*, *invert=False*)

Test whether each element of an array is also present in a second array.

The output is always a masked array. See *numpy.in1d* for more details.

We recommend using *isin* instead of *in1d* for new code.

See also:

isin
: Version of this function that preserves the shape of ar1.

numpy.in1d
: Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
>>> ar1 = np.ma.array([0, 1, 2, 5, 0])
>>> ar2 = [0, 2]
>>> np.ma.in1d(ar1, ar2)
masked_array(data=[ True, False,  True, False,  True],
             mask=False,
       fill_value=True)
```

ma.**unique**(*ar1*, *return_index=False*, *return_inverse=False*)

Finds the unique elements of an array.

Masked values are considered the same element (masked). The output array is always a masked array. See *numpy.unique* for more details.

See also:

numpy.unique
: Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
>>> a = [1, 2, 1000, 2, 3]
>>> mask = [0, 0, 1, 0, 0]
>>> masked_a = np.ma.masked_array(a, mask)
>>> masked_a
masked_array(data=[1, 2, --, 2, 3],
             mask=[False, False,  True, False, False],
    fill_value=999999)
>>> np.ma.unique(masked_a)
masked_array(data=[1, 2, 3, --],
             mask=[False, False, False,  True],
    fill_value=999999)
>>> np.ma.unique(masked_a, return_index=True)
(masked_array(data=[1, 2, 3, --],
             mask=[False, False, False,  True],
    fill_value=999999), array([0, 1, 4, 2]))
>>> np.ma.unique(masked_a, return_inverse=True)
(masked_array(data=[1, 2, 3, --],
             mask=[False, False, False,  True],
    fill_value=999999), array([0, 1, 3, 1, 2]))
>>> np.ma.unique(masked_a, return_index=True, return_inverse=True)
(masked_array(data=[1, 2, 3, --],
             mask=[False, False, False,  True],
    fill_value=999999), array([0, 1, 4, 2]), array([0, 1, 3, 1, 2]))
```

method

ma.MaskedArray.**all**(*axis=None*, *out=None*, *keepdims=<no value>*)

Returns True if all elements evaluate to True.

The output array is masked where all the values along the given axis are masked: if the output would have been a scalar and that all the values are masked, then the output is *masked*.

Refer to *numpy.all* for full documentation.

See also:

numpy.ndarray.all
corresponding function for ndarrays

numpy.all
equivalent function

Examples

```
>>> import numpy as np
>>> np.ma.array([1,2,3]).all()
True
>>> a = np.ma.array([1,2,3], mask=True)
>>> (a.all() is np.ma.masked)
True
```

method

ma.MaskedArray.**any**(*axis=None*, *out=None*, *keepdims=<no value>*)

Returns True if any of the elements of *a* evaluate to True.

Masked values are considered as False during computation.

Refer to *numpy.any* for full documentation.

See also:

numpy.ndarray.any
corresponding function for ndarrays

numpy.any
equivalent function

method

ma.MaskedArray.**count**(*axis=None*, *keepdims=<no value>*)

Count the non-masked elements of the array along the given axis.

Parameters

axis
[None or int or tuple of ints, optional] Axis or axes along which the count is performed. The default, None, performs the count over all the dimensions of the input array. *axis* may be negative, in which case it counts from the last to the first axis. If this is a tuple of ints, the count is performed on multiple axes, instead of a single axis or all the axes as before.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

Returns

result
[ndarray or scalar] An array with the same shape as the input array, with the specified axis removed. If the array is a 0-d array, or if *axis* is None, a scalar is returned.

See also:

ma.count_masked
Count masked elements in array or along a given axis.

Examples

```
>>> import numpy.ma as ma
>>> a = ma.arange(6).reshape((2, 3))
>>> a[1, :] = ma.masked
>>> a
masked_array(
  data=[[0, 1, 2],
        [--, --, --]],
  mask=[[False, False, False],
        [ True,  True,  True]],
  fill_value=999999)
>>> a.count()
3
```

When the *axis* keyword is specified an array of appropriate size is returned.

```
>>> a.count(axis=0)
array([1, 1, 1])
>>> a.count(axis=1)
array([3, 0])
```

method

ma.MaskedArray.**nonzero**()

Return the indices of unmasked elements that are not zero.

Returns a tuple of arrays, one for each dimension, containing the indices of the non-zero elements in that dimension. The corresponding non-zero values can be obtained with:

```
a[a.nonzero()]
```

To group the indices by element, rather than dimension, use instead:

```
np.transpose(a.nonzero())
```

The result of this is always a 2d array, with a row for each non-zero element.

Parameters

None

Returns

tuple_of_arrays
[tuple] Indices of elements that are non-zero.

See also:

numpy.nonzero
Function operating on ndarrays.

flatnonzero
Return indices that are non-zero in the flattened version of the input array.

numpy.ndarray.nonzero
Equivalent ndarray method.

count_nonzero
Counts the number of non-zero elements in the input array.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = ma.array(np.eye(3))
>>> x
masked_array(
  data=[[1., 0., 0.],
        [0., 1., 0.],
        [0., 0., 1.]],
  mask=False,
  fill_value=1e+20)
>>> x.nonzero()
(array([0, 1, 2]), array([0, 1, 2]))
```

Masked elements are ignored.

```
>>> x[1, 1] = ma.masked
>>> x
masked_array(
  data=[[1.0, 0.0, 0.0],
        [0.0, --, 0.0],
        [0.0, 0.0, 1.0]],
  mask=[[False, False, False],
        [False,  True, False],
        [False, False, False]],
  fill_value=1e+20)
>>> x.nonzero()
(array([0, 2]), array([0, 2]))
```

Indices can also be grouped by element.

```
>>> np.transpose(x.nonzero())
array([[0, 0],
       [2, 2]])
```

A common use for `nonzero` is to find the indices of an array, where a condition is True. Given an array a, the condition $a > 3$ is a boolean array and since False is interpreted as 0, ma.nonzero(a > 3) yields the indices of the a where the condition is true.

```
>>> a = ma.array([[1,2,3],[4,5,6],[7,8,9]])
>>> a > 3
masked_array(
  data=[[False, False, False],
        [ True,  True,  True],
```

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```
        [ True,  True,  True]],
  mask=False,
  fill_value=True)
>>> ma.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

The `nonzero` method of the condition array can also be called.

```
>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

ma.MaskedArray.data	Returns the underlying data, as a view of the masked array.
ma.MaskedArray.mask	Current mask.
ma.MaskedArray.recordmask	Get or set the mask of the array if it has no named fields.

Manipulating a MaskedArray

Changing the shape

ma.ravel(self[, order])	Returns a 1D version of self, as a view.
ma.reshape(a, new_shape[, order])	Returns an array containing the same data with a new shape.
ma.resize(x, new_shape)	Return a new masked array with the specified size and shape.
ma.MaskedArray.flatten([order])	Return a copy of the array collapsed into one dimension.
ma.MaskedArray.ravel([order])	Returns a 1D version of self, as a view.
ma.MaskedArray.reshape(*s, **kwargs)	Give a new shape to the array without changing its data.
ma.MaskedArray.resize(newshape[, refcheck, ...])	

ma.**ravel**(*self*, *order='C'*) **= <numpy.ma.core._frommethod object>**

Returns a 1D version of self, as a view.

Parameters

order

[{'C', 'F', 'A', 'K'}, optional] The elements of *a* are read using this index order. 'C' means to index the elements in C-like order, with the last axis index changing fastest, back to the first axis index changing slowest. 'F' means to index the elements in Fortran-like index order, with the first index changing fastest, and the last index changing slowest. Note that the 'C' and 'F' options take no account of the memory layout of the underlying array, and only refer to the order of axis indexing. 'A' means to read the elements in Fortran-like index order if *m* is Fortran *contiguous* in memory, C-like order otherwise. 'K' means to read the elements in the order they occur in memory, except for reversing the data when strides are negative. By default, 'C' index order is used. (Masked arrays currently use 'A' on the data when 'K' is passed.)

Returns

MaskedArray

Output view is of shape `(self.size,)` (or `(np.ma.product(self.shape),)`).

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> x
masked_array(
  data=[[1, --, 3],
        [--, 5, --],
        [7, --, 9]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
>>> x.ravel()
masked_array(data=[1, --, 3, --, 5, --, 7, --, 9],
             mask=[False,  True, False,  True, False,  True, False,  True,
                   False],
       fill_value=999999)
```

ma.**reshape**(*a*, *new_shape*, *order='C'*)

Returns an array containing the same data with a new shape.

Refer to *MaskedArray.reshape* for full documentation.

See also:

MaskedArray.reshape
equivalent function

Examples

Reshaping a 1-D array:

```
>>> a = np.ma.array([1, 2, 3, 4])
>>> np.ma.reshape(a, (2, 2))
masked_array(
  data=[[1, 2],
        [3, 4]],
  mask=False,
  fill_value=999999)
```

Reshaping a 2-D array:

```
>>> b = np.ma.array([[1, 2], [3, 4]])
>>> np.ma.reshape(b, (1, 4))
masked_array(data=[[1, 2, 3, 4]],
             mask=False,
       fill_value=999999)
```

Reshaping a 1-D array with a mask:

```
>>> c = np.ma.array([1, 2, 3, 4], mask=[False, True, False, False])
>>> np.ma.reshape(c, (2, 2))
masked_array(
  data=[[1, --],
        [3, 4]],
```

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```
  mask=[[False,  True],
        [False, False]],
  fill_value=999999)
```

ma.**resize**(*x*, *new_shape*)

Return a new masked array with the specified size and shape.

This is the masked equivalent of the *numpy.resize* function. The new array is filled with repeated copies of *x* (in the order that the data are stored in memory). If *x* is masked, the new array will be masked, and the new mask will be a repetition of the old one.

See also:

numpy.resize
Equivalent function in the top level NumPy module.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = ma.array([[1, 2] ,[3, 4]])
>>> a[0, 1] = ma.masked
>>> a
masked_array(
  data=[[1, --],
        [3, 4]],
  mask=[[False,  True],
        [False, False]],
  fill_value=999999)
>>> np.resize(a, (3, 3))
masked_array(
  data=[[1, 2, 3],
        [4, 1, 2],
        [3, 4, 1]],
  mask=False,
  fill_value=999999)
>>> ma.resize(a, (3, 3))
masked_array(
  data=[[1, --, 3],
        [4, 1, --],
        [3, 4, 1]],
  mask=[[False,  True, False],
        [False, False,  True],
        [False, False, False]],
  fill_value=999999)
```

A MaskedArray is always returned, regardless of the input type.

```
>>> a = np.array([[1, 2] ,[3, 4]])
>>> ma.resize(a, (3, 3))
masked_array(
  data=[[1, 2, 3],
        [4, 1, 2],
        [3, 4, 1]],
```

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```
  mask=False,
  fill_value=999999)
```

method

ma.MaskedArray.**flatten**(*order='C'*)

Return a copy of the array collapsed into one dimension.

Parameters

order

[{'C', 'F', 'A', 'K'}, optional] 'C' means to flatten in row-major (C-style) order. 'F' means to flatten in column-major (Fortran- style) order. 'A' means to flatten in column-major order if *a* is Fortran *contiguous* in memory, row-major order otherwise. 'K' means to flatten *a* in the order the elements occur in memory. The default is 'C'.

Returns

y

[ndarray] A copy of the input array, flattened to one dimension.

See also:

ravel

Return a flattened array.

flat

A 1-D flat iterator over the array.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,2], [3,4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

method

ma.MaskedArray.**ravel**(*order='C'*)

Returns a 1D version of self, as a view.

Parameters

order

[{'C', 'F', 'A', 'K'}, optional] The elements of *a* are read using this index order. 'C' means to index the elements in C-like order, with the last axis index changing fastest, back to the first axis index changing slowest. 'F' means to index the elements in Fortran-like index order, with the first index changing fastest, and the last index changing slowest. Note that the 'C' and 'F' options take no account of the memory layout of the underlying array, and only refer to the order of axis indexing. 'A' means to read the elements in Fortran-like index order if *m* is Fortran *contiguous* in memory, C-like order otherwise. 'K' means to read the elements in the order they occur in memory, except for reversing the data when strides are negative. By default, 'C' index order is used. (Masked arrays currently use 'A' on the data when 'K' is passed.)

Returns

MaskedArray
Output view is of shape `(self.size,)` (or `(np.ma.product(self.shape),)`).

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> x
masked_array(
  data=[[1, --, 3],
        [--, 5, --],
        [7, --, 9]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
>>> x.ravel()
masked_array(data=[1, --, 3, --, 5, --, 7, --, 9],
             mask=[False,  True, False,  True, False,  True, False,  True,
                   False],
       fill_value=999999)
```

method

`ma.MaskedArray.`**`reshape`**(**s*, ***kwargs*)

Give a new shape to the array without changing its data.

Returns a masked array containing the same data, but with a new shape. The result is a view on the original array; if this is not possible, a ValueError is raised.

Parameters

shape
[int or tuple of ints] The new shape should be compatible with the original shape. If an integer is supplied, then the result will be a 1-D array of that length.

order
[{'C', 'F'}, optional] Determines whether the array data should be viewed as in C (row-major) or FORTRAN (column-major) order.

Returns

reshaped_array
[array] A new view on the array.

See also:

reshape
Equivalent function in the masked array module.

numpy.ndarray.reshape
Equivalent method on ndarray object.

numpy.reshape
Equivalent function in the NumPy module.

Notes

The reshaping operation cannot guarantee that a copy will not be made, to modify the shape in place, use `a.shape = s`

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2],[3,4]], mask=[1,0,0,1])
>>> x
masked_array(
  data=[[--, 2],
        [3, --]],
  mask=[[ True, False],
        [False,  True]],
  fill_value=999999)
>>> x = x.reshape((4,1))
>>> x
masked_array(
  data=[[--],
        [2],
        [3],
        [--]],
  mask=[[ True],
        [False],
        [False],
        [ True]],
  fill_value=999999)
```

method

ma.MaskedArray.**resize**(*newshape*, *refcheck=True*, *order=False*)

> **Warning:** This method does nothing, except raise a ValueError exception. A masked array does not own its data and therefore cannot safely be resized in place. Use the *numpy.ma.resize* function instead.

This method is difficult to implement safely and may be deprecated in future releases of NumPy.

Modifying axes

ma.swapaxes(self, *args, ...)	Return a view of the array with *axis1* and *axis2* interchanged.
ma.transpose(a[, axes])	Permute the dimensions of an array.
ma.MaskedArray.swapaxes(axis1, axis2)	Return a view of the array with *axis1* and *axis2* interchanged.
ma.MaskedArray.transpose(*axes)	Returns a view of the array with axes transposed.

ma.**swapaxes**(*self*, **args*, ***params*) *a.swapaxes(axis1, axis2)* **= <numpy.ma.core._frommethod object>**

Return a view of the array with *axis1* and *axis2* interchanged.

Refer to *numpy.swapaxes* for full documentation.

See also:

numpy.swapaxes
equivalent function

ma.**transpose**(*a*, *axes=None*)

Permute the dimensions of an array.

This function is exactly equivalent to *numpy.transpose*.

See also:

numpy.transpose
Equivalent function in top-level NumPy module.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = ma.arange(4).reshape((2,2))
>>> x[1, 1] = ma.masked
>>> x
masked_array(
  data=[[0, 1],
        [2, --]],
  mask=[[False, False],
        [False,  True]],
  fill_value=999999)
```

```
>>> ma.transpose(x)
masked_array(
  data=[[0, 2],
        [1, --]],
  mask=[[False, False],
        [False,  True]],
  fill_value=999999)
```

method

ma.MaskedArray.**swapaxes**(*axis1*, *axis2*)

Return a view of the array with *axis1* and *axis2* interchanged.

Refer to *numpy.swapaxes* for full documentation.

See also:

numpy.swapaxes
equivalent function

method

ma.MaskedArray.**transpose**(**axes*)

Returns a view of the array with axes transposed.

Refer to *numpy.transpose* for full documentation.

Parameters

axes

[None, tuple of ints, or *n* ints]

- None or no argument: reverses the order of the axes.
- tuple of ints: *i* in the *j*-th place in the tuple means that the array's *i*-th axis becomes the transposed array's *j*-th axis.
- *n* ints: same as an n-tuple of the same ints (this form is intended simply as a "convenience" alternative to the tuple form).

Returns

p

[ndarray] View of the array with its axes suitably permuted.

See also:

transpose

Equivalent function.

ndarray.T

Array property returning the array transposed.

ndarray.reshape

Give a new shape to an array without changing its data.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

```
>>> a = np.array([1, 2, 3, 4])
>>> a
array([1, 2, 3, 4])
>>> a.transpose()
array([1, 2, 3, 4])
```

Changing the number of dimensions

ma.atleast_1d	Convert inputs to arrays with at least one dimension.
ma.atleast_2d	View inputs as arrays with at least two dimensions.
ma.atleast_3d	View inputs as arrays with at least three dimensions.
ma.expand_dims(a, axis)	Expand the shape of an array.
ma.squeeze	Remove axes of length one from *a*.
ma.MaskedArray.squeeze([axis])	Remove axes of length one from *a*.
ma.stack	Join a sequence of arrays along a new axis.
ma.column_stack	Stack 1-D arrays as columns into a 2-D array.
ma.concatenate(arrays[, axis])	Concatenate a sequence of arrays along the given axis.
ma.dstack	Stack arrays in sequence depth wise (along third axis).
ma.hstack	Stack arrays in sequence horizontally (column wise).
ma.hsplit	Split an array into multiple sub-arrays horizontally (column-wise).
*ma.mr_*	Translate slice objects to concatenation along the first axis.
ma.vstack	Stack arrays in sequence vertically (row wise).

ma.**atleast_1d = <numpy.ma.extras._fromnxfunction_allargs object>**

Convert inputs to arrays with at least one dimension.

Scalar inputs are converted to 1-dimensional arrays, whilst higher-dimensional inputs are preserved.

Parameters

arys1, arys2, …
[array_like] One or more input arrays.

Returns

ret
[ndarray] An array, or tuple of arrays, each with `a.ndim >= 1`. Copies are made only if necessary.

See also:

atleast_2d*, *atleast_3d

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> np.atleast_1d(1.0)
array([1.])
```

```
>>> x = np.arange(9.0).reshape(3,3)
>>> np.atleast_1d(x)
array([[0., 1., 2.],
       [3., 4., 5.],
       [6., 7., 8.]])
```

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```
>>> np.atleast_1d(x) is x
True
```

```
>>> np.atleast_1d(1, [3, 4])
(array([1]), array([3, 4]))
```

ma.**atleast_2d = <numpy.ma.extras._fromnxfunction_allargs object>**

View inputs as arrays with at least two dimensions.

Parameters

arys1, arys2, …
[array_like] One or more array-like sequences. Non-array inputs are converted to arrays. Arrays that already have two or more dimensions are preserved.

Returns

res, res2, …
[ndarray] An array, or tuple of arrays, each with `a.ndim >= 2`. Copies are avoided where possible, and views with two or more dimensions are returned.

See also:

atleast_1d, *atleast_3d*

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> np.atleast_2d(3.0)
array([[3.]])
```

```
>>> x = np.arange(3.0)
>>> np.atleast_2d(x)
array([[0., 1., 2.]])
>>> np.atleast_2d(x).base is x
True
```

```
>>> np.atleast_2d(1, [1, 2], [[1, 2]])
(array([[1]]), array([[1, 2]]), array([[1, 2]]))
```

ma.**atleast_3d = <numpy.ma.extras._fromnxfunction_allargs object>**

View inputs as arrays with at least three dimensions.

Parameters

arys1, arys2, …
[array_like] One or more array-like sequences. Non-array inputs are converted to arrays. Arrays that already have three or more dimensions are preserved.

Returns

res1, res2, …
[ndarray] An array, or tuple of arrays, each with `a.ndim >= 3`. Copies are avoided where possible, and views with three or more dimensions are returned. For example, a 1-D array of shape `(N,)` becomes a view of shape `(1, N, 1)`, and a 2-D array of shape `(M, N)` becomes a view of shape `(M, N, 1)`.

See also:

atleast_1d*, *atleast_2d

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> np.atleast_3d(3.0)
array([[[3.]]])
```

```
>>> x = np.arange(3.0)
>>> np.atleast_3d(x).shape
(1, 3, 1)
```

```
>>> x = np.arange(12.0).reshape(4,3)
>>> np.atleast_3d(x).shape
(4, 3, 1)
>>> np.atleast_3d(x).base is x.base  # x is a reshape, so not base itself
True
```

```
>>> for arr in np.atleast_3d([1, 2], [[1, 2]], [[[1, 2]]]):
...     print(arr, arr.shape)
...
[[[1]
  [2]]] (1, 2, 1)
[[[1]
  [2]]] (1, 2, 1)
[[[1 2]]] (1, 1, 2)
```

`ma.`**`expand_dims`**(*a*, *axis*)

Expand the shape of an array.

Insert a new axis that will appear at the *axis* position in the expanded array shape.

Parameters

a
[array_like] Input array.

axis
[int or tuple of ints] Position in the expanded axes where the new axis (or axes) is placed.

Deprecated since version 1.13.0: Passing an axis where `axis > a.ndim` will be treated as `axis == a.ndim`, and passing `axis < -a.ndim - 1` will be treated as `axis == 0`. This behavior is deprecated.

Returns

result
[ndarray] View of *a* with the number of dimensions increased.

See also:

squeeze
The inverse operation, removing singleton dimensions

reshape
Insert, remove, and combine dimensions, and resize existing ones

atleast_1d, ***atleast_2d***, ***atleast_3d***

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2])
>>> x.shape
(2,)
```

The following is equivalent to `x[np.newaxis, :]` or `x[np.newaxis]`:

```
>>> y = np.expand_dims(x, axis=0)
>>> y
array([[1, 2]])
>>> y.shape
(1, 2)
```

The following is equivalent to `x[:, np.newaxis]`:

```
>>> y = np.expand_dims(x, axis=1)
>>> y
array([[1],
       [2]])
>>> y.shape
(2, 1)
```

`axis` may also be a tuple:

```
>>> y = np.expand_dims(x, axis=(0, 1))
>>> y
array([[[1, 2]]])
```

```
>>> y = np.expand_dims(x, axis=(2, 0))
>>> y
array([[[1],
        [2]]])
```

Note that some examples may use `None` instead of `np.newaxis`. These are the same objects:

```
>>> np.newaxis is None
True
```

ma.squeeze = <numpy.ma.core._convert2ma object>

Remove axes of length one from *a*.

Parameters

a
[array_like] Input data.

axis
[None or int or tuple of ints, optional] Selects a subset of the entries of length one in the shape. If an axis is selected with shape entry greater than one, an error is raised.

Returns

squeezed
[MaskedArray] The input array, but with all or a subset of the dimensions of length 1 removed. This is always *a* itself or a view into *a*. Note that if all axes are squeezed, the result is a 0d array and not a scalar.

Raises

ValueError
If *axis* is not None, and an axis being squeezed is not of length 1

See also:

expand_dims
The inverse operation, adding entries of length one

reshape
Insert, remove, and combine dimensions, and resize existing ones

Examples

```
>>> import numpy as np
>>> x = np.array([[[0], [1], [2]]])
>>> x.shape
(1, 3, 1)
>>> np.squeeze(x).shape
(3,)
>>> np.squeeze(x, axis=0).shape
(3, 1)
>>> np.squeeze(x, axis=1).shape
Traceback (most recent call last):
...
ValueError: cannot select an axis to squeeze out which has size
not equal to one
>>> np.squeeze(x, axis=2).shape
(1, 3)
>>> x = np.array([[1234]])
>>> x.shape
(1, 1)
>>> np.squeeze(x)
array(1234)  # 0d array
>>> np.squeeze(x).shape
()
>>> np.squeeze(x)[()]
1234
```

method

ma.MaskedArray.**squeeze**(*axis=None*)

Remove axes of length one from *a*.

Refer to *numpy.squeeze* for full documentation.

See also:

numpy.squeeze
equivalent function

ma.**stack = <numpy.ma.extras._fromnxfunction_seq object>**

Join a sequence of arrays along a new axis.

The `axis` parameter specifies the index of the new axis in the dimensions of the result. For example, if `axis=0` it will be the first dimension and if `axis=-1` it will be the last dimension.

Parameters

arrays
[sequence of ndarrays] Each array must have the same shape. In the case of a single ndarray array_like input, it will be treated as a sequence of arrays; i.e., each element along the zeroth axis is treated as a separate array.

axis
[int, optional] The axis in the result array along which the input arrays are stacked.

out
[ndarray, optional] If provided, the destination to place the result. The shape must be correct, matching that of what stack would have returned if no out argument were specified.

dtype
[str or dtype] If provided, the destination array will have this dtype. Cannot be provided together with *out*.

New in version 1.24.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'same_kind'.

New in version 1.24.

Returns

stacked
[ndarray] The stacked array has one more dimension than the input arrays.

See also:

concatenate
Join a sequence of arrays along an existing axis.

block
Assemble an nd-array from nested lists of blocks.

split
Split array into a list of multiple sub-arrays of equal size.

unstack
Split an array into a tuple of sub-arrays along an axis.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> arrays = [rng.normal(size=(3,4)) for _ in range(10)]
>>> np.stack(arrays, axis=0).shape
(10, 3, 4)
```

```
>>> np.stack(arrays, axis=1).shape
(3, 10, 4)
```

```
>>> np.stack(arrays, axis=2).shape
(3, 4, 10)
```

```
>>> a = np.array([1, 2, 3])
>>> b = np.array([4, 5, 6])
>>> np.stack((a, b))
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> np.stack((a, b), axis=-1)
array([[1, 4],
       [2, 5],
       [3, 6]])
```

ma.**column_stack = <numpy.ma.extras._fromnxfunction_seq object>**

Stack 1-D arrays as columns into a 2-D array.

Take a sequence of 1-D arrays and stack them as columns to make a single 2-D array. 2-D arrays are stacked as-is, just like with *hstack*. 1-D arrays are turned into 2-D columns first.

Parameters

tup
[sequence of 1-D or 2-D arrays.] Arrays to stack. All of them must have the same first dimension.

Returns

stacked
[2-D array] The array formed by stacking the given arrays.

See also:

stack*, *hstack*, *vstack*, *concatenate

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.column_stack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

ma.**concatenate**(*arrays*, *axis=0*)

Concatenate a sequence of arrays along the given axis.

Parameters

arrays
[sequence of array_like] The arrays must have the same shape, except in the dimension corresponding to *axis* (the first, by default).

axis
[int, optional] The axis along which the arrays will be joined. Default is 0.

Returns

result
[MaskedArray] The concatenated array with any masked entries preserved.

See also:

numpy.concatenate
Equivalent function in the top-level NumPy module.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = ma.arange(3)
>>> a[1] = ma.masked
>>> b = ma.arange(2, 5)
>>> a
masked_array(data=[0, --, 2],
             mask=[False,  True, False],
       fill_value=999999)
>>> b
masked_array(data=[2, 3, 4],
             mask=False,
       fill_value=999999)
>>> ma.concatenate([a, b])
masked_array(data=[0, --, 2, 2, 3, 4],
             mask=[False,  True, False, False, False, False],
       fill_value=999999)
```

ma.**dstack = <numpy.ma.extras._fromnxfunction_seq object>**

Stack arrays in sequence depth wise (along third axis).

This is equivalent to concatenation along the third axis after 2-D arrays of shape *(M,N)* have been reshaped to *(M,N,1)* and 1-D arrays of shape *(N,)* have been reshaped to *(1,N,1)*. Rebuilds arrays divided by *dsplit*.

This function makes most sense for arrays with up to 3 dimensions. For instance, for pixel-data with a height (first axis), width (second axis), and r/g/b channels (third axis). The functions *concatenate*, *stack* and *block* provide more general stacking and concatenation operations.

Parameters

tup
[sequence of arrays] The arrays must have the same shape along all but the third axis. 1-D or 2-D arrays must have the same shape.

Returns

stacked
[ndarray] The array formed by stacking the given arrays, will be at least 3-D.

See also:

concatenate
Join a sequence of arrays along an existing axis.

stack
Join a sequence of arrays along a new axis.

block
Assemble an nd-array from nested lists of blocks.

vstack
Stack arrays in sequence vertically (row wise).

hstack
Stack arrays in sequence horizontally (column wise).

column_stack
Stack 1-D arrays as columns into a 2-D array.

dsplit
Split array along third axis.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.dstack((a,b))
array([[[1, 2],
        [2, 3],
        [3, 4]]])
```

```
>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[2],[3],[4]])
>>> np.dstack((a,b))
array([[[1, 2]],
       [[2, 3]],
       [[3, 4]]])
```

ma.**hstack = <numpy.ma.extras._fromnxfunction_seq object>**

Stack arrays in sequence horizontally (column wise).

This is equivalent to concatenation along the second axis, except for 1-D arrays where it concatenates along the first axis. Rebuilds arrays divided by *hsplit*.

This function makes most sense for arrays with up to 3 dimensions. For instance, for pixel-data with a height (first axis), width (second axis), and r/g/b channels (third axis). The functions *concatenate*, *stack* and *block* provide more general stacking and concatenation operations.

Parameters

tup
[sequence of ndarrays] The arrays must have the same shape along all but the second axis, except 1-D arrays which can be any length. In the case of a single array_like input, it will be treated as a sequence of arrays; i.e., each element along the zeroth axis is treated as a separate array.

dtype
[str or dtype] If provided, the destination array will have this dtype. Cannot be provided together with *out*.

New in version 1.24.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'same_kind'.

New in version 1.24.

Returns

stacked
[ndarray] The array formed by stacking the given arrays.

See also:

concatenate
Join a sequence of arrays along an existing axis.

stack
Join a sequence of arrays along a new axis.

block
Assemble an nd-array from nested lists of blocks.

vstack
Stack arrays in sequence vertically (row wise).

dstack
Stack arrays in sequence depth wise (along third axis).

column_stack
Stack 1-D arrays as columns into a 2-D array.

hsplit
: Split an array into multiple sub-arrays horizontally (column-wise).

unstack
: Split an array into a tuple of sub-arrays along an axis.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> a = np.array((1,2,3))
>>> b = np.array((4,5,6))
>>> np.hstack((a,b))
array([1, 2, 3, 4, 5, 6])
>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[4],[5],[6]])
>>> np.hstack((a,b))
array([[1, 4],
       [2, 5],
       [3, 6]])
```

ma.**hsplit = <numpy.ma.extras._fromnxfunction_single object>**

Split an array into multiple sub-arrays horizontally (column-wise).

Please refer to the *split* documentation. *hsplit* is equivalent to *split* with `axis=1`, the array is always split along the second axis except for 1-D arrays, where it is split at `axis=0`.

See also:

split
: Split an array into multiple sub-arrays of equal size.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> x = np.arange(16.0).reshape(4, 4)
>>> x
array([[ 0.,   1.,   2.,   3.],
       [ 4.,   5.,   6.,   7.],
       [ 8.,   9.,  10.,  11.],
       [12.,  13.,  14.,  15.]])
>>> np.hsplit(x, 2)
[array([[  0.,   1.],
       [  4.,   5.],
       [  8.,   9.],
       [12.,  13.]]),
```

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```
 array([[  2.,   3.],
        [  6.,   7.],
        [10.,  11.],
        [14.,  15.]])]
>>> np.hsplit(x, np.array([3, 6]))
[array([[ 0.,   1.,   2.],
        [ 4.,   5.,   6.],
        [ 8.,   9.,  10.],
        [12.,  13.,  14.]]),
 array([[ 3.],
        [ 7.],
        [11.],
        [15.]]),
 array([], shape=(4, 0), dtype=float64)]
```

With a higher dimensional array the split is still along the second axis.

```
>>> x = np.arange(8.0).reshape(2, 2, 2)
>>> x
array([[[0.,  1.],
        [2.,  3.]],
       [[4.,  5.],
        [6.,  7.]]])
>>> np.hsplit(x, 2)
[array([[[0.,  1.]],
        [[4.,  5.]]]),
 array([[[2.,  3.]],
        [[6.,  7.]]])]
```

With a 1-D array, the split is along axis 0.

```
>>> x = np.array([0, 1, 2, 3, 4, 5])
>>> np.hsplit(x, 2)
[array([0, 1, 2]), array([3, 4, 5])]
```

ma.**mr_ = <numpy.ma.extras.mr_class object>**

Translate slice objects to concatenation along the first axis.

This is the masked array version of *r_*.

See also:

r_

Examples

```
>>> import numpy as np
>>> np.ma.mr_[np.ma.array([1,2,3]), 0, 0, np.ma.array([4,5,6])]
masked_array(data=[1, 2, 3, ..., 4, 5, 6],
             mask=False,
       fill_value=999999)
```

ma.**vstack = <numpy.ma.extras._fromnxfunction_seq object>**

Stack arrays in sequence vertically (row wise).

This is equivalent to concatenation along the first axis after 1-D arrays of shape *(N,)* have been reshaped to *(1,N)*. Rebuilds arrays divided by `vsplit`.

This function makes most sense for arrays with up to 3 dimensions. For instance, for pixel-data with a height (first axis), width (second axis), and r/g/b channels (third axis). The functions `concatenate`, `stack` and `block` provide more general stacking and concatenation operations.

Parameters

tup
[sequence of ndarrays] The arrays must have the same shape along all but the first axis. 1-D arrays must have the same length. In the case of a single array_like input, it will be treated as a sequence of arrays; i.e., each element along the zeroth axis is treated as a separate array.

dtype
[str or dtype] If provided, the destination array will have this dtype. Cannot be provided together with *out*.

New in version 1.24.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'same_kind'.

New in version 1.24.

Returns

stacked
[ndarray] The array formed by stacking the given arrays, will be at least 2-D.

See also:

`concatenate`
Join a sequence of arrays along an existing axis.

`stack`
Join a sequence of arrays along a new axis.

`block`
Assemble an nd-array from nested lists of blocks.

`hstack`
Stack arrays in sequence horizontally (column wise).

`dstack`
Stack arrays in sequence depth wise (along third axis).

`column_stack`
Stack 1-D arrays as columns into a 2-D array.

`vsplit`
Split an array into multiple sub-arrays vertically (row-wise).

`unstack`
Split an array into a tuple of sub-arrays along an axis.

Notes

The function is applied to both the _data and the _mask, if any.

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2, 3])
>>> b = np.array([4, 5, 6])
>>> np.vstack((a,b))
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> a = np.array([[1], [2], [3]])
>>> b = np.array([[4], [5], [6]])
>>> np.vstack((a,b))
array([[1],
       [2],
       [3],
       [4],
       [5],
       [6]])
```

Joining arrays

ma.concatenate(arrays[, axis])	Concatenate a sequence of arrays along the given axis.
ma.stack	Join a sequence of arrays along a new axis.
ma.vstack	Stack arrays in sequence vertically (row wise).
ma.hstack	Stack arrays in sequence horizontally (column wise).
ma.dstack	Stack arrays in sequence depth wise (along third axis).
ma.column_stack	Stack 1-D arrays as columns into a 2-D array.
ma.append(a, b[, axis])	Append values to the end of an array.

ma.**append**(*a*, *b*, *axis=None*)

Append values to the end of an array.

Parameters

a
: [array_like] Values are appended to a copy of this array.

b
: [array_like] These values are appended to a copy of *a*. It must be of the correct shape (the same shape as *a*, excluding *axis*). If *axis* is not specified, *b* can be any shape and will be flattened before use.

axis
: [int, optional] The axis along which *v* are appended. If *axis* is not given, both *a* and *b* are flattened before use.

Returns

append
[MaskedArray] A copy of *a* with *b* appended to *axis*. Note that *append* does not occur in-place: a new array is allocated and filled. If *axis* is None, the result is a flattened array.

See also:

numpy.append
Equivalent function in the top-level NumPy module.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = ma.masked_values([1, 2, 3], 2)
>>> b = ma.masked_values([[4, 5, 6], [7, 8, 9]], 7)
>>> ma.append(a, b)
masked_array(data=[1, --, 3, 4, 5, 6, --, 8, 9],
             mask=[False,  True, False, False, False, False,  True, False,
                   False],
       fill_value=999999)
```

Operations on masks

Creating a mask

ma.make_mask(m[, copy, shrink, dtype])	Create a boolean mask from an array.
ma.make_mask_none(newshape[, dtype])	Return a boolean mask of the given shape, filled with False.
ma.mask_or(m1, m2[, copy, shrink])	Combine two masks with the `logical_or` operator.
ma.make_mask_descr(ndtype)	Construct a dtype description list from a given dtype.

ma.**make_mask**(*m*, *copy=False*, *shrink=True*, *dtype=<class 'numpy.bool'>*)

Create a boolean mask from an array.

Return *m* as a boolean mask, creating a copy if necessary or requested. The function can accept any sequence that is convertible to integers, or `nomask`. Does not require that contents must be 0s and 1s, values of 0 are interpreted as False, everything else as True.

Parameters

m
[array_like] Potential mask.

copy
[bool, optional] Whether to return a copy of *m* (True) or *m* itself (False).

shrink
[bool, optional] Whether to shrink *m* to `nomask` if all its values are False.

dtype
[dtype, optional] Data-type of the output mask. By default, the output mask has a dtype of MaskType (bool). If the dtype is flexible, each field has a boolean dtype. This is ignored when *m* is `nomask`, in which case `nomask` is always returned.

Returns

result
[ndarray] A boolean mask derived from *m*.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> m = [True, False, True, True]
>>> ma.make_mask(m)
array([ True, False,  True,  True])
>>> m = [1, 0, 1, 1]
>>> ma.make_mask(m)
array([ True, False,  True,  True])
>>> m = [1, 0, 2, -3]
>>> ma.make_mask(m)
array([ True, False,  True,  True])
```

Effect of the *shrink* parameter.

```
>>> m = np.zeros(4)
>>> m
array([0., 0., 0., 0.])
>>> ma.make_mask(m)
False
>>> ma.make_mask(m, shrink=False)
array([False, False, False, False])
```

Using a flexible *dtype*.

```
>>> m = [1, 0, 1, 1]
>>> n = [0, 1, 0, 0]
>>> arr = []
>>> for man, mouse in zip(m, n):
...     arr.append((man, mouse))
>>> arr
[(1, 0), (0, 1), (1, 0), (1, 0)]
>>> dtype = np.dtype({'names':['man', 'mouse'],
...                   'formats':[np.int64, np.int64]})
>>> arr = np.array(arr, dtype=dtype)
>>> arr
array([(1, 0), (0, 1), (1, 0), (1, 0)],
      dtype=[('man', '<i8'), ('mouse', '<i8')])
>>> ma.make_mask(arr, dtype=dtype)
array([(True, False), (False, True), (True, False), (True, False)],
      dtype=[('man', '|b1'), ('mouse', '|b1')])
```

ma.**make_mask_none**(*newshape*, *dtype=None*)

Return a boolean mask of the given shape, filled with False.

This function returns a boolean ndarray with all entries False, that can be used in common mask manipulations. If a complex dtype is specified, the type of each field is converted to a boolean type.

Parameters

newshape
[tuple] A tuple indicating the shape of the mask.

dtype
[{None, dtype}, optional] If None, use a MaskType instance. Otherwise, use a new datatype with the same fields as *dtype*, converted to boolean types.

Returns

result
[ndarray] An ndarray of appropriate shape and dtype, filled with False.

See also:

make_mask
Create a boolean mask from an array.

make_mask_descr
Construct a dtype description list from a given dtype.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> ma.make_mask_none((3,))
array([False, False, False])
```

Defining a more complex dtype.

```
>>> dtype = np.dtype({'names':['foo', 'bar'],
...                   'formats':[np.float32, np.int64]})
>>> dtype
dtype([('foo', '<f4'), ('bar', '<i8')])
>>> ma.make_mask_none((3,), dtype=dtype)
array([(False, False), (False, False), (False, False)],
      dtype=[('foo', '|b1'), ('bar', '|b1')])
```

ma.**mask_or**(*m1*, *m2*, *copy=False*, *shrink=True*)

Combine two masks with the `logical_or` operator.

The result may be a view on *m1* or *m2* if the other is *nomask* (i.e. False).

Parameters

m1, m2
[array_like] Input masks.

copy
[bool, optional] If copy is False and one of the inputs is *nomask*, return a view of the other input mask. Defaults to False.

shrink
[bool, optional] Whether to shrink the output to *nomask* if all its values are False. Defaults to True.

Returns

mask
[output mask] The result masks values that are masked in either *m1* or *m2*.

Raises

ValueError
If *m1* and *m2* have different flexible dtypes.

Examples

```
>>> import numpy as np
>>> m1 = np.ma.make_mask([0, 1, 1, 0])
>>> m2 = np.ma.make_mask([1, 0, 0, 0])
>>> np.ma.mask_or(m1, m2)
array([ True,  True,  True, False])
```

ma.**make_mask_descr**(*ndtype*)

Construct a dtype description list from a given dtype.

Returns a new dtype object, with the type of all fields in *ndtype* to a boolean type. Field names are not altered.

Parameters

ndtype
[dtype] The dtype to convert.

Returns

result
[dtype] A dtype that looks like *ndtype*, the type of all fields is boolean.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> dtype = np.dtype({'names':['foo', 'bar'],
...                   'formats':[np.float32, np.int64]})
>>> dtype
dtype([('foo', '<f4'), ('bar', '<i8')])
>>> ma.make_mask_descr(dtype)
dtype([('foo', '|b1'), ('bar', '|b1')])
>>> ma.make_mask_descr(np.float32)
dtype('bool')
```

Accessing a mask

ma.getmask(a)	Return the mask of a masked array, or nomask.
ma.getmaskarray(arr)	Return the mask of a masked array, or full boolean array of False.
ma.masked_array.mask	Current mask.

property

property ma.masked_array.**mask**

Current mask.

Finding masked data

ma.ndenumerate(a[, compressed])	Multidimensional index iterator.
ma.flatnotmasked_contiguous(a)	Find contiguous unmasked data in a masked array.
ma.flatnotmasked_edges(a)	Find the indices of the first and last unmasked values.
ma.notmasked_contiguous(a[, axis])	Find contiguous unmasked data in a masked array along the given axis.
ma.notmasked_edges(a[, axis])	Find the indices of the first and last unmasked values along an axis.
ma.clump_masked(a)	Returns a list of slices corresponding to the masked clumps of a 1-D array.
ma.clump_unmasked(a)	Return list of slices corresponding to the unmasked clumps of a 1-D array.

ma.**ndenumerate**(*a*, *compressed=True*)

Multidimensional index iterator.

Return an iterator yielding pairs of array coordinates and values, skipping elements that are masked. With *compressed=False*, *ma.masked* is yielded as the value of masked elements. This behavior differs from that of *numpy.ndenumerate*, which yields the value of the underlying data array.

Parameters

a
[array_like] An array with (possibly) masked elements.

compressed
[bool, optional] If True (default), masked elements are skipped.

See also:

numpy.ndenumerate
Equivalent function ignoring any mask.

Notes

New in version 1.23.0.

Examples

```
>>> import numpy as np
>>> a = np.ma.arange(9).reshape((3, 3))
>>> a[1, 0] = np.ma.masked
>>> a[1, 2] = np.ma.masked
>>> a[2, 1] = np.ma.masked
>>> a
masked_array(
  data=[[0, 1, 2],
        [--, 4, --],
        [6, --, 8]],
  mask=[[False, False, False],
        [ True, False,  True],
        [False,  True, False]],
```

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```
  fill_value=999999)
>>> for index, x in np.ma.ndenumerate(a):
...     print(index, x)
(0, 0) 0
(0, 1) 1
(0, 2) 2
(1, 1) 4
(2, 0) 6
(2, 2) 8
```

```
>>> for index, x in np.ma.ndenumerate(a, compressed=False):
...     print(index, x)
(0, 0) 0
(0, 1) 1
(0, 2) 2
(1, 0) --
(1, 1) 4
(1, 2) --
(2, 0) 6
(2, 1) --
(2, 2) 8
```

ma.**flatnotmasked_contiguous**(*a*)

Find contiguous unmasked data in a masked array.

Parameters

a
[array_like] The input array.

Returns

slice_list
[list] A sorted sequence of *slice* objects (start index, end index).

See also:

flatnotmasked_edges, ***notmasked_contiguous***, ***notmasked_edges***
clump_masked, ***clump_unmasked***

Notes

Only accepts 2-D arrays at most.

Examples

```
>>> import numpy as np
>>> a = np.ma.arange(10)
>>> np.ma.flatnotmasked_contiguous(a)
[slice(0, 10, None)]
```

```
>>> mask = (a < 3) | (a > 8) | (a == 5)
>>> a[mask] = np.ma.masked
>>> np.array(a[~a.mask])
array([3, 4, 6, 7, 8])
```

```
>>> np.ma.flatnotmasked_contiguous(a)
[slice(3, 5, None), slice(6, 9, None)]
>>> a[:] = np.ma.masked
>>> np.ma.flatnotmasked_contiguous(a)
[]
```

ma.**flatnotmasked_edges**(*a*)

Find the indices of the first and last unmasked values.

Expects a 1-D *MaskedArray*, returns None if all values are masked.

Parameters

a
[array_like] Input 1-D *MaskedArray*

Returns

edges
[ndarray or None] The indices of first and last non-masked value in the array. Returns None if all values are masked.

See also:

flatnotmasked_contiguous, ***notmasked_contiguous***, ***notmasked_edges***
clump_masked, ***clump_unmasked***

Notes

Only accepts 1-D arrays.

Examples

```
>>> import numpy as np
>>> a = np.ma.arange(10)
>>> np.ma.flatnotmasked_edges(a)
array([0, 9])
```

```
>>> mask = (a < 3) | (a > 8) | (a == 5)
>>> a[mask] = np.ma.masked
>>> np.array(a[~a.mask])
array([3, 4, 6, 7, 8])
```

```
>>> np.ma.flatnotmasked_edges(a)
array([3, 8])
```

```
>>> a[:] = np.ma.masked
>>> print(np.ma.flatnotmasked_edges(a))
None
```

ma.**notmasked_contiguous**(*a*, *axis=None*)

Find contiguous unmasked data in a masked array along the given axis.

Parameters

a
: [array_like] The input array.

axis
: [int, optional] Axis along which to perform the operation. If None (default), applies to a flattened version of the array, and this is the same as *flatnotmasked_contiguous*.

Returns

endpoints
: [list] A list of slices (start and end indexes) of unmasked indexes in the array.

  If the input is 2d and axis is specified, the result is a list of lists.

See also:

flatnotmasked_edges, ***flatnotmasked_contiguous***, ***notmasked_edges***
clump_masked, ***clump_unmasked***

Notes

Only accepts 2-D arrays at most.

Examples

```
>>> import numpy as np
>>> a = np.arange(12).reshape((3, 4))
>>> mask = np.zeros_like(a)
>>> mask[1:, :-1] = 1; mask[0, 1] = 1; mask[-1, 0] = 0
>>> ma = np.ma.array(a, mask=mask)
>>> ma
masked_array(
  data=[[0, --, 2, 3],
        [--, --, --, 7],
        [8, --, --, 11]],
  mask=[[False,  True, False, False],
        [ True,  True,  True, False],
        [False,  True,  True, False]],
  fill_value=999999)
>>> np.array(ma[~ma.mask])
array([ 0,  2,  3,  7, 8, 11])
```

```
>>> np.ma.notmasked_contiguous(ma)
[slice(0, 1, None), slice(2, 4, None), slice(7, 9, None), slice(11, 12, None)]
```

```
>>> np.ma.notmasked_contiguous(ma, axis=0)
[[slice(0, 1, None), slice(2, 3, None)], [], [slice(0, 1, None)], [slice(0, 3,␣
↪None)]]
```

```
>>> np.ma.notmasked_contiguous(ma, axis=1)
[[slice(0, 1, None), slice(2, 4, None)], [slice(3, 4, None)], [slice(0, 1, None),␣
↪slice(3, 4, None)]]
```

ma.**notmasked_edges**(*a*, *axis=None*)

Find the indices of the first and last unmasked values along an axis.

If all values are masked, return None. Otherwise, return a list of two tuples, corresponding to the indices of the first and last unmasked values respectively.

Parameters

a
[array_like] The input array.

axis
[int, optional] Axis along which to perform the operation. If None (default), applies to a flattened version of the array.

Returns

edges
[ndarray or list] An array of start and end indexes if there are any masked data in the array. If there are no masked data in the array, *edges* is a list of the first and last index.

See also:

flatnotmasked_contiguous, ***flatnotmasked_edges***, ***notmasked_contiguous*** ***clump_masked***, ***clump_unmasked***

Examples

```
>>> import numpy as np
>>> a = np.arange(9).reshape((3, 3))
>>> m = np.zeros_like(a)
>>> m[1:, 1:] = 1
```

```
>>> am = np.ma.array(a, mask=m)
>>> np.array(am[~am.mask])
array([0, 1, 2, 3, 6])
```

```
>>> np.ma.notmasked_edges(am)
array([0, 6])
```

ma.**clump_masked**(*a*)

Returns a list of slices corresponding to the masked clumps of a 1-D array. (A “clump” is defined as a contiguous region of the array).

Parameters

a
[ndarray] A one-dimensional masked array.

Returns

slices
[list of slice] The list of slices, one for each continuous region of masked elements in *a*.

See also:

flatnotmasked_edges, ***flatnotmasked_contiguous***, ***notmasked_edges*** ***notmasked_contiguous***, ***clump_unmasked***

Examples

```
>>> import numpy as np
>>> a = np.ma.masked_array(np.arange(10))
>>> a[[0, 1, 2, 6, 8, 9]] = np.ma.masked
>>> np.ma.clump_masked(a)
[slice(0, 3, None), slice(6, 7, None), slice(8, 10, None)]
```

ma.**clump_unmasked**(*a*)

Return list of slices corresponding to the unmasked clumps of a 1-D array. (A "clump" is defined as a contiguous region of the array).

Parameters

a
[ndarray] A one-dimensional masked array.

Returns

slices
[list of slice] The list of slices, one for each continuous region of unmasked elements in *a*.

See also:

flatnotmasked_edges, ***flatnotmasked_contiguous***, ***notmasked_edges*** ***notmasked_contiguous***, ***clump_masked***

Examples

```
>>> import numpy as np
>>> a = np.ma.masked_array(np.arange(10))
>>> a[[0, 1, 2, 6, 8, 9]] = np.ma.masked
>>> np.ma.clump_unmasked(a)
[slice(3, 6, None), slice(7, 8, None)]
```

Modifying a mask

ma.mask_cols(a[, axis])	Mask columns of a 2D array that contain masked values.
ma.mask_or(m1, m2[, copy, shrink])	Combine two masks with the `logical_or` operator.
ma.mask_rowcols(a[, axis])	Mask rows and/or columns of a 2D array that contain masked values.
ma.mask_rows(a[, axis])	Mask rows of a 2D array that contain masked values.
ma.harden_mask(self)	Force the mask to hard, preventing unmasking by assignment.
ma.soften_mask(self)	Force the mask to soft (default), allowing unmasking by assignment.
ma.MaskedArray.harden_mask()	Force the mask to hard, preventing unmasking by assignment.
ma.MaskedArray.soften_mask()	Force the mask to soft (default), allowing unmasking by assignment.
ma.MaskedArray.shrink_mask()	Reduce a mask to nomask when possible.
ma.MaskedArray.unshare_mask()	Copy the mask and set the *sharedmask* flag to `False`.

ma.**mask_cols**(*a*, *axis=<no value>*)

Mask columns of a 2D array that contain masked values.

This function is a shortcut to `mask_rowcols` with *axis* equal to 1.

See also:

mask_rowcols
Mask rows and/or columns of a 2D array.

masked_where
Mask where a condition is met.

Examples

```
>>> import numpy as np
>>> a = np.zeros((3, 3), dtype=int)
>>> a[1, 1] = 1
>>> a
array([[0, 0, 0],
       [0, 1, 0],
       [0, 0, 0]])
>>> a = np.ma.masked_equal(a, 1)
>>> a
masked_array(
  data=[[0, 0, 0],
        [0, --, 0],
        [0, 0, 0]],
  mask=[[False, False, False],
        [False,  True, False],
        [False, False, False]],
  fill_value=1)
>>> np.ma.mask_cols(a)
masked_array(
  data=[[0, --, 0],
        [0, --, 0],
        [0, --, 0]],
  mask=[[False,  True, False],
        [False,  True, False],
        [False,  True, False]],
  fill_value=1)
```

ma.**mask_rowcols**(*a*, *axis=None*)

Mask rows and/or columns of a 2D array that contain masked values.

Mask whole rows and/or columns of a 2D array that contain masked values. The masking behavior is selected using the *axis* parameter.

- If *axis* is None, rows *and* columns are masked.
- If *axis* is 0, only rows are masked.
- If *axis* is 1 or -1, only columns are masked.

Parameters

a
[array_like, MaskedArray] The array to mask. If not a MaskedArray instance (or if no array

elements are masked), the result is a MaskedArray with *mask* set to `nomask` (False). Must be a 2D array.

axis
[int, optional] Axis along which to perform the operation. If None, applies to a flattened version of the array.

Returns

a
[MaskedArray] A modified version of the input array, masked depending on the value of the *axis* parameter.

Raises

NotImplementedError
If input array *a* is not 2D.

See also:

mask_rows
Mask rows of a 2D array that contain masked values.

mask_cols
Mask cols of a 2D array that contain masked values.

masked_where
Mask where a condition is met.

Notes

The input array's mask is modified by this function.

Examples

```
>>> import numpy as np
>>> a = np.zeros((3, 3), dtype=int)
>>> a[1, 1] = 1
>>> a
array([[0, 0, 0],
       [0, 1, 0],
       [0, 0, 0]])
>>> a = np.ma.masked_equal(a, 1)
>>> a
masked_array(
  data=[[0, 0, 0],
        [0, --, 0],
        [0, 0, 0]],
  mask=[[False, False, False],
        [False,  True, False],
        [False, False, False]],
  fill_value=1)
>>> np.ma.mask_rowcols(a)
masked_array(
  data=[[0, --, 0],
        [--, --, --],
        [0, --, 0]],
```

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```
  mask=[[False,  True, False],
        [ True,  True,  True],
        [False,  True, False]],
  fill_value=1)
```

ma.**mask_rows**(*a*, *axis=<no value>*)

Mask rows of a 2D array that contain masked values.

This function is a shortcut to `mask_rowcols` with *axis* equal to 0.

See also:

mask_rowcols
Mask rows and/or columns of a 2D array.

masked_where
Mask where a condition is met.

Examples

```
>>> import numpy as np
>>> a = np.zeros((3, 3), dtype=int)
>>> a[1, 1] = 1
>>> a
array([[0, 0, 0],
       [0, 1, 0],
       [0, 0, 0]])
>>> a = np.ma.masked_equal(a, 1)
>>> a
masked_array(
  data=[[0, 0, 0],
        [0, --, 0],
        [0, 0, 0]],
  mask=[[False, False, False],
        [False,  True, False],
        [False, False, False]],
  fill_value=1)
```

```
>>> np.ma.mask_rows(a)
masked_array(
  data=[[0, 0, 0],
        [--, --, --],
        [0, 0, 0]],
  mask=[[False, False, False],
        [ True,  True,  True],
        [False, False, False]],
  fill_value=1)
```

ma.**harden_mask**(*self*) **= <numpy.ma.core._frommethod object>**

Force the mask to hard, preventing unmasking by assignment.

Whether the mask of a masked array is hard or soft is determined by its *hardmask* property. *harden_mask* sets *hardmask* to `True` (and returns the modified self).

See also:

ma.MaskedArray.hardmask
ma.MaskedArray.soften_mask

ma.**soften_mask**(*self*) **= <numpy.ma.core._frommethod object>**

Force the mask to soft (default), allowing unmasking by assignment.

Whether the mask of a masked array is hard or soft is determined by its *hardmask* property. *soften_mask* sets *hardmask* to `False` (and returns the modified self).

See also:

ma.MaskedArray.hardmask
ma.MaskedArray.harden_mask

method

ma.MaskedArray.**harden_mask**()

Force the mask to hard, preventing unmasking by assignment.

Whether the mask of a masked array is hard or soft is determined by its *hardmask* property. *harden_mask* sets *hardmask* to `True` (and returns the modified self).

See also:

ma.MaskedArray.hardmask
ma.MaskedArray.soften_mask

method

ma.MaskedArray.**soften_mask**()

Force the mask to soft (default), allowing unmasking by assignment.

Whether the mask of a masked array is hard or soft is determined by its *hardmask* property. *soften_mask* sets *hardmask* to `False` (and returns the modified self).

See also:

ma.MaskedArray.hardmask
ma.MaskedArray.harden_mask

method

ma.MaskedArray.**shrink_mask**()

Reduce a mask to nomask when possible.

Parameters

None

Returns

None

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2 ], [3, 4]], mask=[0]*4)
>>> x.mask
array([[False, False],
       [False, False]])
>>> x.shrink_mask()
masked_array(
  data=[[1, 2],
        [3, 4]],
  mask=False,
  fill_value=999999)
>>> x.mask
False
```

method

ma.MaskedArray.**unshare_mask**()

Copy the mask and set the *sharedmask* flag to `False`.

Whether the mask is shared between masked arrays can be seen from the *sharedmask* property. *unshare_mask* ensures the mask is not shared. A copy of the mask is only made if it was shared.

See also:

sharedmask

Conversion operations

> to a masked array

ma.asarray(a[, dtype, order])	Convert the input to a masked array of the given data-type.
ma.asanyarray(a[, dtype])	Convert the input to a masked array, conserving subclasses.
ma.fix_invalid(a[, mask, copy, fill_value])	Return input with invalid data masked and replaced by a fill value.
ma.masked_equal(x, value[, copy])	Mask an array where equal to a given value.
ma.masked_greater(x, value[, copy])	Mask an array where greater than a given value.
ma.masked_greater_equal(x, value[, copy])	Mask an array where greater than or equal to a given value.
ma.masked_inside(x, v1, v2[, copy])	Mask an array inside a given interval.
ma.masked_invalid(a[, copy])	Mask an array where invalid values occur (NaNs or infs).
ma.masked_less(x, value[, copy])	Mask an array where less than a given value.
ma.masked_less_equal(x, value[, copy])	Mask an array where less than or equal to a given value.
ma.masked_not_equal(x, value[, copy])	Mask an array where *not* equal to a given value.
ma.masked_object(x, value[, copy, shrink])	Mask the array *x* where the data are exactly equal to value.
ma.masked_outside(x, v1, v2[, copy])	Mask an array outside a given interval.
ma.masked_values(x, value[, rtol, atol, ...])	Mask using floating point equality.
ma.masked_where(condition, a[, copy])	Mask an array where a condition is met.

ma.**asarray**(*a*, *dtype=None*, *order=None*)

Convert the input to a masked array of the given data-type.

No copy is performed if the input is already an *ndarray*. If *a* is a subclass of *MaskedArray*, a base class *MaskedArray* is returned.

Parameters

a
[array_like] Input data, in any form that can be converted to a masked array. This includes lists, lists of tuples, tuples, tuples of tuples, tuples of lists, ndarrays and masked arrays.

dtype
[dtype, optional] By default, the data-type is inferred from the input data.

order
[{'C', 'F'}, optional] Whether to use row-major ('C') or column-major ('FORTRAN') memory representation. Default is 'C'.

Returns

out
[MaskedArray] Masked array interpretation of *a*.

See also:

asanyarray
Similar to *asarray*, but conserves subclasses.

Examples

```
>>> import numpy as np
>>> x = np.arange(10.).reshape(2, 5)
>>> x
array([[0., 1., 2., 3., 4.],
       [5., 6., 7., 8., 9.]])
>>> np.ma.asarray(x)
masked_array(
  data=[[0., 1., 2., 3., 4.],
        [5., 6., 7., 8., 9.]],
  mask=False,
  fill_value=1e+20)
>>> type(np.ma.asarray(x))
<class 'numpy.ma.MaskedArray'>
```

ma.**asanyarray**(*a*, *dtype=None*)

Convert the input to a masked array, conserving subclasses.

If *a* is a subclass of *MaskedArray*, its class is conserved. No copy is performed if the input is already an *ndarray*.

Parameters

a
[array_like] Input data, in any form that can be converted to an array.

dtype
[dtype, optional] By default, the data-type is inferred from the input data.

order
[{'C', 'F'}, optional] Whether to use row-major ('C') or column-major ('FORTRAN') memory representation. Default is 'C'.

Returns

out
[MaskedArray] MaskedArray interpretation of *a*.

See also:

asarray
Similar to *asanyarray*, but does not conserve subclass.

Examples

```
>>> import numpy as np
>>> x = np.arange(10.).reshape(2, 5)
>>> x
array([[0., 1., 2., 3., 4.],
       [5., 6., 7., 8., 9.]])
>>> np.ma.asanyarray(x)
masked_array(
  data=[[0., 1., 2., 3., 4.],
        [5., 6., 7., 8., 9.]],
  mask=False,
  fill_value=1e+20)
>>> type(np.ma.asanyarray(x))
<class 'numpy.ma.MaskedArray'>
```

ma.**fix_invalid**(*a*, *mask=np.False_*, *copy=True*, *fill_value=None*)

Return input with invalid data masked and replaced by a fill value.

Invalid data means values of *nan*, *inf*, etc.

Parameters

a
[array_like] Input array, a (subclass of) ndarray.

mask
[sequence, optional] Mask. Must be convertible to an array of booleans with the same shape as *data*. True indicates a masked (i.e. invalid) data.

copy
[bool, optional] Whether to use a copy of *a* (True) or to fix *a* in place (False). Default is True.

fill_value
[scalar, optional] Value used for fixing invalid data. Default is None, in which case the `a.fill_value` is used.

Returns

b
[MaskedArray] The input array with invalid entries fixed.

Notes

A copy is performed by default.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([1., -1, np.nan, np.inf], mask=[1] + [0]*3)
>>> x
masked_array(data=[--, -1.0, nan, inf],
             mask=[ True, False, False, False],
       fill_value=1e+20)
>>> np.ma.fix_invalid(x)
masked_array(data=[--, -1.0, --, --],
             mask=[ True, False,  True,  True],
       fill_value=1e+20)
```

```
>>> fixed = np.ma.fix_invalid(x)
>>> fixed.data
array([ 1.e+00, -1.e+00,  1.e+20,  1.e+20])
>>> x.data
array([ 1., -1., nan, inf])
```

ma.**masked_equal**(*x*, *value*, *copy=True*)

Mask an array where equal to a given value.

Return a MaskedArray, masked where the data in array *x* are equal to *value*. The fill_value of the returned MaskedArray is set to *value*.

For floating point arrays, consider using `masked_values(x, value)`.

See also:

masked_where
Mask where a condition is met.

masked_values
Mask using floating point equality.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_equal(a, 2)
masked_array(data=[0, 1, --, 3],
             mask=[False, False,  True, False],
       fill_value=2)
```

ma.**masked_greater**(*x*, *value*, *copy=True*)

Mask an array where greater than a given value.

This function is a shortcut to `masked_where`, with *condition* = (x > value).

See also:

masked_where
Mask where a condition is met.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_greater(a, 2)
masked_array(data=[0, 1, 2, --],
             mask=[False, False, False,  True],
       fill_value=999999)
```

ma.**masked_greater_equal**(*x*, *value*, *copy=True*)

Mask an array where greater than or equal to a given value.

This function is a shortcut to `masked_where`, with *condition* = (x >= value).

See also:

masked_where
Mask where a condition is met.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_greater_equal(a, 2)
masked_array(data=[0, 1, --, --],
             mask=[False, False,  True,  True],
       fill_value=999999)
```

ma.**masked_inside**(*x*, *v1*, *v2*, *copy=True*)

Mask an array inside a given interval.

Shortcut to `masked_where`, where *condition* is True for *x* inside the interval [v1,v2] (v1 <= x <= v2). The boundaries *v1* and *v2* can be given in either order.

See also:

masked_where
Mask where a condition is met.

Notes

The array *x* is prefilled with its filling value.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = [0.31, 1.2, 0.01, 0.2, -0.4, -1.1]
>>> ma.masked_inside(x, -0.3, 0.3)
masked_array(data=[0.31, 1.2, --, --, -0.4, -1.1],
             mask=[False, False,  True,  True, False, False],
       fill_value=1e+20)
```

The order of *v1* and *v2* doesn't matter.

```
>>> ma.masked_inside(x, 0.3, -0.3)
masked_array(data=[0.31, 1.2, --, --, -0.4, -1.1],
             mask=[False, False,  True,  True, False, False],
       fill_value=1e+20)
```

ma.**masked_invalid**(*a*, *copy=True*)

Mask an array where invalid values occur (NaNs or infs).

This function is a shortcut to `masked_where`, with *condition* = ~(np.isfinite(a)). Any pre-existing mask is conserved. Only applies to arrays with a dtype where NaNs or infs make sense (i.e. floating point types), but accepts any array_like object.

See also:

masked_where
Mask where a condition is met.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.arange(5, dtype=float)
>>> a[2] = np.nan
>>> a[3] = np.inf
>>> a
array([ 0.,  1., nan, inf,  4.])
>>> ma.masked_invalid(a)
masked_array(data=[0.0, 1.0, --, --, 4.0],
             mask=[False, False,  True,  True, False],
       fill_value=1e+20)
```

ma.**masked_less**(*x*, *value*, *copy=True*)

Mask an array where less than a given value.

This function is a shortcut to `masked_where`, with *condition* = (x < value).

See also:

masked_where
Mask where a condition is met.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_less(a, 2)
masked_array(data=[--, --, 2, 3],
             mask=[ True,  True, False, False],
       fill_value=999999)
```

ma.**masked_less_equal**(*x*, *value*, *copy=True*)

Mask an array where less than or equal to a given value.

This function is a shortcut to `masked_where`, with *condition* = (x <= value).

See also:

masked_where
Mask where a condition is met.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_less_equal(a, 2)
masked_array(data=[--, --, --, 3],
             mask=[ True,  True,  True, False],
       fill_value=999999)
```

ma.**masked_not_equal**(*x*, *value*, *copy=True*)

Mask an array where *not* equal to a given value.

This function is a shortcut to `masked_where`, with *condition* = (x != value).

See also:

masked_where
Mask where a condition is met.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_not_equal(a, 2)
masked_array(data=[--, --, 2, --],
             mask=[ True,  True, False,  True],
       fill_value=999999)
```

ma.**masked_object**(*x*, *value*, *copy=True*, *shrink=True*)

Mask the array *x* where the data are exactly equal to value.

This function is similar to *masked_values*, but only suitable for object arrays: for floating point, use *masked_values* instead.

Parameters

x
[array_like] Array to mask

value
[object] Comparison value

copy
[{True, False}, optional] Whether to return a copy of *x*.

shrink
[{True, False}, optional] Whether to collapse a mask full of False to nomask

Returns

result
[MaskedArray] The result of masking *x* where equal to *value*.

See also:

masked_where
Mask where a condition is met.

masked_equal
Mask where equal to a given value (integers).

masked_values
Mask using floating point equality.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> food = np.array(['green_eggs', 'ham'], dtype=object)
>>> # don't eat spoiled food
>>> eat = ma.masked_object(food, 'green_eggs')
>>> eat
masked_array(data=[--, 'ham'],
             mask=[ True, False],
       fill_value='green_eggs',
            dtype=object)
>>> # plain ol` ham is boring
>>> fresh_food = np.array(['cheese', 'ham', 'pineapple'], dtype=object)
>>> eat = ma.masked_object(fresh_food, 'green_eggs')
>>> eat
masked_array(data=['cheese', 'ham', 'pineapple'],
             mask=False,
       fill_value='green_eggs',
            dtype=object)
```

Note that *mask* is set to `nomask` if possible.

```
>>> eat
masked_array(data=['cheese', 'ham', 'pineapple'],
             mask=False,
       fill_value='green_eggs',
            dtype=object)
```

ma.**masked_outside**(*x*, *v1*, *v2*, *copy=True*)

Mask an array outside a given interval.

Shortcut to `masked_where`, where *condition* is True for *x* outside the interval [v1,v2] (x < v1)|(x > v2). The boundaries *v1* and *v2* can be given in either order.

See also:

masked_where
Mask where a condition is met.

Notes

The array *x* is prefilled with its filling value.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = [0.31, 1.2, 0.01, 0.2, -0.4, -1.1]
>>> ma.masked_outside(x, -0.3, 0.3)
masked_array(data=[--, --, 0.01, 0.2, --, --],
             mask=[ True,  True, False, False,  True,  True],
       fill_value=1e+20)
```

The order of *v1* and *v2* doesn't matter.

```
>>> ma.masked_outside(x, 0.3, -0.3)
masked_array(data=[--, --, 0.01, 0.2, --, --],
             mask=[ True,  True, False, False,  True,  True],
       fill_value=1e+20)
```

ma.**masked_values**(*x*, *value*, *rtol=1e-05*, *atol=1e-08*, *copy=True*, *shrink=True*)

Mask using floating point equality.

Return a MaskedArray, masked where the data in array *x* are approximately equal to *value*, determined using *isclose*. The default tolerances for *masked_values* are the same as those for *isclose*.

For integer types, exact equality is used, in the same way as *masked_equal*.

The fill_value is set to *value* and the mask is set to `nomask` if possible.

Parameters

x
[array_like] Array to mask.

value
[float] Masking value.

rtol, atol
[float, optional] Tolerance parameters passed on to *isclose*

copy
[bool, optional] Whether to return a copy of *x*.

shrink
[bool, optional] Whether to collapse a mask full of False to `nomask`.

Returns

result
[MaskedArray] The result of masking *x* where approximately equal to *value*.

See also:

masked_where
Mask where a condition is met.

masked_equal
Mask where equal to a given value (integers).

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = np.array([1, 1.1, 2, 1.1, 3])
>>> ma.masked_values(x, 1.1)
masked_array(data=[1.0, --, 2.0, --, 3.0],
             mask=[False,  True, False,  True, False],
       fill_value=1.1)
```

Note that *mask* is set to `nomask` if possible.

```
>>> ma.masked_values(x, 2.1)
masked_array(data=[1. , 1.1, 2. , 1.1, 3. ],
             mask=False,
       fill_value=2.1)
```

Unlike *masked_equal*, *masked_values* can perform approximate equalities.

```
>>> ma.masked_values(x, 2.1, atol=1e-1)
masked_array(data=[1.0, 1.1, --, 1.1, 3.0],
             mask=[False, False,  True, False, False],
       fill_value=2.1)
```

`ma.`**`masked_where`**(*condition*, *a*, *copy=True*)

Mask an array where a condition is met.

Return *a* as an array masked where *condition* is True. Any masked values of *a* or *condition* are also masked in the output.

Parameters

condition
[array_like] Masking condition. When *condition* tests floating point values for equality, consider using `masked_values` instead.

a
: [array_like] Array to mask.

copy
: [bool] If True (default) make a copy of *a* in the result. If False modify *a* in place and return a view.

Returns

result
: [MaskedArray] The result of masking *a* where *condition* is True.

See also:

masked_values
: Mask using floating point equality.

masked_equal
: Mask where equal to a given value.

masked_not_equal
: Mask where *not* equal to a given value.

masked_less_equal
: Mask where less than or equal to a given value.

masked_greater_equal
: Mask where greater than or equal to a given value.

masked_less
: Mask where less than a given value.

masked_greater
: Mask where greater than a given value.

masked_inside
: Mask inside a given interval.

masked_outside
: Mask outside a given interval.

masked_invalid
: Mask invalid values (NaNs or infs).

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.arange(4)
>>> a
array([0, 1, 2, 3])
>>> ma.masked_where(a <= 2, a)
masked_array(data=[--, --, --, 3],
             mask=[ True,  True,  True, False],
       fill_value=999999)
```

Mask array *b* conditional on *a*.

```
>>> b = ['a', 'b', 'c', 'd']
>>> ma.masked_where(a == 2, b)
masked_array(data=['a', 'b', --, 'd'],
             mask=[False, False,  True, False],
       fill_value='N/A',
            dtype='<U1')
```

Effect of the *copy* argument.

```
>>> c = ma.masked_where(a <= 2, a)
>>> c
masked_array(data=[--, --, --, 3],
             mask=[ True,  True,  True, False],
       fill_value=999999)
>>> c[0] = 99
>>> c
masked_array(data=[99, --, --, 3],
             mask=[False,  True,  True, False],
       fill_value=999999)
>>> a
array([0, 1, 2, 3])
>>> c = ma.masked_where(a <= 2, a, copy=False)
>>> c[0] = 99
>>> c
masked_array(data=[99, --, --, 3],
             mask=[False,  True,  True, False],
       fill_value=999999)
>>> a
array([99,  1,  2,  3])
```

When *condition* or *a* contain masked values.

```
>>> a = np.arange(4)
>>> a = ma.masked_where(a == 2, a)
>>> a
masked_array(data=[0, 1, --, 3],
             mask=[False, False,  True, False],
       fill_value=999999)
>>> b = np.arange(4)
>>> b = ma.masked_where(b == 0, b)
>>> b
masked_array(data=[--, 1, 2, 3],
             mask=[ True, False, False, False],
       fill_value=999999)
>>> ma.masked_where(a == 3, b)
masked_array(data=[--, 1, --, --],
             mask=[ True, False,  True,  True],
       fill_value=999999)
```

> to a ndarray

ma.compress_cols(a)	Suppress whole columns of a 2-D array that contain masked values.
ma.compress_rowcols(x[, axis])	Suppress the rows and/or columns of a 2-D array that contain masked values.
ma.compress_rows(a)	Suppress whole rows of a 2-D array that contain masked values.
ma.compressed(x)	Return all the non-masked data as a 1-D array.
ma.filled(a[, fill_value])	Return input as an *ndarray*, with masked values replaced by *fill_value*.
ma.MaskedArray.compressed()	Return all the non-masked data as a 1-D array.
ma.MaskedArray.filled([fill_value])	Return a copy of self, with masked values filled with a given value.

ma.**compress_cols**(*a*)

Suppress whole columns of a 2-D array that contain masked values.

This is equivalent to `np.ma.compress_rowcols(a, 1)`, see *compress_rowcols* for details.

Parameters

x
[array_like, MaskedArray] The array to operate on. If not a MaskedArray instance (or if no array elements are masked), *x* is interpreted as a MaskedArray with *mask* set to *nomask*. Must be a 2D array.

Returns

compressed_array
[ndarray] The compressed array.

See also:

compress_rowcols

Examples

```
>>> import numpy as np
>>> a = np.ma.array(np.arange(9).reshape(3, 3), mask=[[1, 0, 0],
...                                                   [1, 0, 0],
...                                                   [0, 0, 0]])
>>> np.ma.compress_cols(a)
array([[1, 2],
       [4, 5],
       [7, 8]])
```

ma.**compress_rowcols**(*x*, *axis=None*)

Suppress the rows and/or columns of a 2-D array that contain masked values.

The suppression behavior is selected with the *axis* parameter.

- If axis is None, both rows and columns are suppressed.
- If axis is 0, only rows are suppressed.

- If axis is 1 or -1, only columns are suppressed.

Parameters

x
[array_like, MaskedArray] The array to operate on. If not a MaskedArray instance (or if no array elements are masked), *x* is interpreted as a MaskedArray with *mask* set to *nomask*. Must be a 2D array.

axis
[int, optional] Axis along which to perform the operation. Default is None.

Returns

compressed_array
[ndarray] The compressed array.

Examples

```
>>> import numpy as np
>>> x = np.ma.array(np.arange(9).reshape(3, 3), mask=[[1, 0, 0],
...                                                   [1, 0, 0],
...                                                   [0, 0, 0]])
>>> x
masked_array(
  data=[[--, 1, 2],
        [--, 4, 5],
        [6, 7, 8]],
  mask=[[ True, False, False],
        [ True, False, False],
        [False, False, False]],
  fill_value=999999)
```

```
>>> np.ma.compress_rowcols(x)
array([[7, 8]])
>>> np.ma.compress_rowcols(x, 0)
array([[6, 7, 8]])
>>> np.ma.compress_rowcols(x, 1)
array([[1, 2],
       [4, 5],
       [7, 8]])
```

ma.**compress_rows**(*a*)

Suppress whole rows of a 2-D array that contain masked values.

This is equivalent to `np.ma.compress_rowcols(a, 0)`, see *compress_rowcols* for details.

Parameters

x
[array_like, MaskedArray] The array to operate on. If not a MaskedArray instance (or if no array elements are masked), *x* is interpreted as a MaskedArray with *mask* set to *nomask*. Must be a 2D array.

Returns

compressed_array
[ndarray] The compressed array.

See also:

compress_rowcols

Examples

```
>>> import numpy as np
>>> a = np.ma.array(np.arange(9).reshape(3, 3), mask=[[1, 0, 0],
...                                                   [1, 0, 0],
...                                                   [0, 0, 0]])
>>> np.ma.compress_rows(a)
array([[6, 7, 8]])
```

ma.**compressed**(*x*)

Return all the non-masked data as a 1-D array.

This function is equivalent to calling the "compressed" method of a *ma.MaskedArray*, see *ma.MaskedArray.compressed* for details.

See also:

ma.MaskedArray.compressed
Equivalent method.

Examples

```
>>> import numpy as np
```

Create an array with negative values masked:

```
>>> import numpy as np
>>> x = np.array([[1, -1, 0], [2, -1, 3], [7, 4, -1]])
>>> masked_x = np.ma.masked_array(x, mask=x < 0)
>>> masked_x
masked_array(
  data=[[1, --, 0],
        [2, --, 3],
        [7, 4, --]],
  mask=[[False,  True, False],
        [False,  True, False],
        [False, False,  True]],
  fill_value=999999)
```

Compress the masked array into a 1-D array of non-masked values:

```
>>> np.ma.compressed(masked_x)
array([1, 0, 2, 3, 7, 4])
```

ma.**filled**(*a*, *fill_value=None*)

Return input as an *ndarray*, with masked values replaced by *fill_value*.

If *a* is not a *MaskedArray*, *a* itself is returned. If *a* is a *MaskedArray* with no masked values, then `a.data` is returned. If *a* is a *MaskedArray* and *fill_value* is None, *fill_value* is set to `a.fill_value`.

Parameters

a
[MaskedArray or array_like] An input object.

fill_value
[array_like, optional.] Can be scalar or non-scalar. If non-scalar, the resulting filled array should be broadcastable over input array. Default is None.

Returns

a
[ndarray] The filled array.

See also:

compressed

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = ma.array(np.arange(9).reshape(3, 3), mask=[[1, 0, 0],
...                                                [1, 0, 0],
...                                                [0, 0, 0]])
>>> x.filled()
array([[999999,      1,      2],
       [999999,      4,      5],
       [     6,      7,      8]])
>>> x.filled(fill_value=333)
array([[333,   1,   2],
       [333,   4,   5],
       [  6,   7,   8]])
>>> x.filled(fill_value=np.arange(3))
array([[0, 1, 2],
       [0, 4, 5],
       [6, 7, 8]])
```

method

ma.MaskedArray.**compressed**()

Return all the non-masked data as a 1-D array.

Returns

data
[ndarray] A new *ndarray* holding the non-masked data is returned.

Notes

The result is **not** a MaskedArray!

Examples

```
>>> import numpy as np
>>> x = np.ma.array(np.arange(5), mask=[0]*2 + [1]*3)
>>> x.compressed()
array([0, 1])
>>> type(x.compressed())
<class 'numpy.ndarray'>
```

N-D arrays are compressed to 1-D.

```
>>> arr = [[1, 2], [3, 4]]
>>> mask = [[1, 0], [0, 1]]
>>> x = np.ma.array(arr, mask=mask)
>>> x.compressed()
array([2, 3])
```

method

ma.MaskedArray.**filled**(*fill_value=None*)

Return a copy of self, with masked values filled with a given value. **However**, if there are no masked values to fill, self will be returned instead as an ndarray.

Parameters

fill_value
[array_like, optional] The value to use for invalid entries. Can be scalar or non-scalar. If non-scalar, the resulting ndarray must be broadcastable over input array. Default is None, in which case, the *fill_value* attribute of the array is used instead.

Returns

filled_array
[ndarray] A copy of `self` with invalid entries replaced by *fill_value* (be it the function argument or the attribute of `self`), or `self` itself as an ndarray if there are no invalid entries to be replaced.

Notes

The result is **not** a MaskedArray!

Examples

```
>>> import numpy as np
>>> x = np.ma.array([1,2,3,4,5], mask=[0,0,1,0,1], fill_value=-999)
>>> x.filled()
array([   1,    2, -999,    4, -999])
>>> x.filled(fill_value=1000)
array([   1,    2, 1000,    4, 1000])
>>> type(x.filled())
<class 'numpy.ndarray'>
```

Subclassing is preserved. This means that if, e.g., the data part of the masked array is a recarray, *filled* returns a recarray:

```
>>> x = np.array([(-1, 2), (-3, 4)], dtype='i8,i8').view(np.recarray)
>>> m = np.ma.array(x, mask=[(True, False), (False, True)])
>>> m.filled()
rec.array([(999999,      2), (    -3, 999999)],
          dtype=[('f0', '<i8'), ('f1', '<i8')])
```

> to another object

ma.MaskedArray.tofile(fid[, sep, format])	Save a masked array to a file in binary format.
ma.MaskedArray.tolist([fill_value])	Return the data portion of the masked array as a hierarchical Python list.
ma.MaskedArray.torecords()	Transforms a masked array into a flexible-type array.
ma.MaskedArray.tobytes([fill_value, order])	Return the array data as a string containing the raw bytes in the array.

method

ma.MaskedArray.**tofile**(*fid*, *sep=''*, *format='%s'*)

Save a masked array to a file in binary format.

> **Warning:** This function is not implemented yet.

Raises

NotImplementedError
When *tofile* is called.

method

ma.MaskedArray.**tolist**(*fill_value=None*)

Return the data portion of the masked array as a hierarchical Python list.

Data items are converted to the nearest compatible Python type. Masked values are converted to *fill_value*. If *fill_value* is None, the corresponding entries in the output list will be None.

Parameters

fill_value
[scalar, optional] The value to use for invalid entries. Default is None.

Returns

result
[list] The Python list representation of the masked array.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2,3], [4,5,6], [7,8,9]], mask=[0] + [1,0]*4)
>>> x.tolist()
[[1, None, 3], [None, 5, None], [7, None, 9]]
>>> x.tolist(-999)
[[1, -999, 3], [-999, 5, -999], [7, -999, 9]]
```

method

ma.MaskedArray.**torecords**()

Transforms a masked array into a flexible-type array.

The flexible type array that is returned will have two fields:

- the _data field stores the _data part of the array.
- the _mask field stores the _mask part of the array.

Parameters

None

Returns

record

[ndarray] A new flexible-type *ndarray* with two fields: the first element containing a value, the second element containing the corresponding mask boolean. The returned record shape matches self.shape.

Notes

A side-effect of transforming a masked array into a flexible *ndarray* is that meta information (fill_value, …) will be lost.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> x
masked_array(
  data=[[1, --, 3],
        [--, 5, --],
        [7, --, 9]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
>>> x.toflex()
array([[(1, False), (2,  True), (3, False)],
       [(4,  True), (5, False), (6,  True)],
       [(7, False), (8,  True), (9, False)]],
      dtype=[('_data', '<i8'), ('_mask', '?')])
```

method

ma.MaskedArray.**tobytes**(*fill_value=None*, *order='C'*)

Return the array data as a string containing the raw bytes in the array.

The array is filled with a fill value before the string conversion.

Parameters

fill_value
[scalar, optional] Value used to fill in the masked values. Default is None, in which case *MaskedArray.fill_value* is used.

order
[{'C','F','A'}, optional] Order of the data item in the copy. Default is 'C'.

- 'C' – C order (row major).
- 'F' – Fortran order (column major).
- 'A' – Any, current order of array.
- None – Same as 'A'.

See also:

numpy.ndarray.tobytes
tolist, ***tofile***

Notes

As for *ndarray.tobytes*, information about the shape, dtype, etc., but also about *fill_value*, will be lost.

Examples

```
>>> import numpy as np
>>> x = np.ma.array(np.array([[1, 2], [3, 4]]), mask=[[0, 1], [1, 0]])
>>> x.tobytes()
b'\x01\x00\x00\x00\x00\x00\x00\x00?B\x0f\x00\x00\x00\x00\x00?B\x0f\x00\x00\x00\
↪x00\x00\x04\x00\x00\x00\x00\x00\x00\x00'
```

Filling a masked array

ma.common_fill_value(a, b)	Return the common filling value of two masked arrays, if any.
ma.default_fill_value(obj)	Return the default fill value for the argument object.
ma.maximum_fill_value(obj)	Return the minimum value that can be represented by the dtype of an object.
ma.minimum_fill_value(obj)	Return the maximum value that can be represented by the dtype of an object.
ma.set_fill_value(a, fill_value)	Set the filling value of a, if a is a masked array.
ma.MaskedArray.get_fill_value()	The filling value of the masked array is a scalar.
ma.MaskedArray.set_fill_value([value])	

ma.**common_fill_value**(*a*, *b*)

Return the common filling value of two masked arrays, if any.

If `a.fill_value == b.fill_value`, return the fill value, otherwise return None.

Parameters

a, b
[MaskedArray] The masked arrays for which to compare fill values.

Returns

fill_value
[scalar or None] The common fill value, or None.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([0, 1.], fill_value=3)
>>> y = np.ma.array([0, 1.], fill_value=3)
>>> np.ma.common_fill_value(x, y)
3.0
```

ma.**default_fill_value**(*obj*)

Return the default fill value for the argument object.

The default filling value depends on the datatype of the input array or the type of the input scalar:

datatype	default
bool	True
int	999999
float	1.e20
complex	1.e20+0j
object	'?'
string	'N/A'

For structured types, a structured scalar is returned, with each field the default fill value for its type.

For subarray types, the fill value is an array of the same size containing the default scalar fill value.

Parameters

obj
[ndarray, dtype or scalar] The array data-type or scalar for which the default fill value is returned.

Returns

fill_value
[scalar] The default fill value.

Examples

```
>>> import numpy as np
>>> np.ma.default_fill_value(1)
999999
>>> np.ma.default_fill_value(np.array([1.1, 2., np.pi]))
1e+20
>>> np.ma.default_fill_value(np.dtype(complex))
(1e+20+0j)
```

ma.**maximum_fill_value**(*obj*)

Return the minimum value that can be represented by the dtype of an object.

This function is useful for calculating a fill value suitable for taking the maximum of an array with a given dtype.

Parameters

obj
[ndarray, dtype or scalar] An object that can be queried for it's numeric type.

Returns

val
[scalar] The minimum representable value.

Raises

TypeError
If *obj* isn't a suitable numeric type.

See also:

minimum_fill_value
The inverse function.

set_fill_value
Set the filling value of a masked array.

MaskedArray.fill_value
Return current fill value.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.int8()
>>> ma.maximum_fill_value(a)
-128
>>> a = np.int32()
>>> ma.maximum_fill_value(a)
-2147483648
```

An array of numeric data can also be passed.

```
>>> a = np.array([1, 2, 3], dtype=np.int8)
>>> ma.maximum_fill_value(a)
-128
>>> a = np.array([1, 2, 3], dtype=np.float32)
```

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```
>>> ma.maximum_fill_value(a)
-inf
```

ma.**minimum_fill_value**(*obj*)

Return the maximum value that can be represented by the dtype of an object.

This function is useful for calculating a fill value suitable for taking the minimum of an array with a given dtype.

Parameters

obj
[ndarray, dtype or scalar] An object that can be queried for it's numeric type.

Returns

val
[scalar] The maximum representable value.

Raises

TypeError
If *obj* isn't a suitable numeric type.

See also:

maximum_fill_value
The inverse function.

set_fill_value
Set the filling value of a masked array.

MaskedArray.fill_value
Return current fill value.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.int8()
>>> ma.minimum_fill_value(a)
127
>>> a = np.int32()
>>> ma.minimum_fill_value(a)
2147483647
```

An array of numeric data can also be passed.

```
>>> a = np.array([1, 2, 3], dtype=np.int8)
>>> ma.minimum_fill_value(a)
127
>>> a = np.array([1, 2, 3], dtype=np.float32)
>>> ma.minimum_fill_value(a)
inf
```

ma.**set_fill_value**(*a*, *fill_value*)

Set the filling value of a, if a is a masked array.

This function changes the fill value of the masked array *a* in place. If *a* is not a masked array, the function returns silently, without doing anything.

Parameters

a
[array_like] Input array.

fill_value
[dtype] Filling value. A consistency test is performed to make sure the value is compatible with the dtype of *a*.

Returns

None
Nothing returned by this function.

See also:

maximum_fill_value
Return the default fill value for a dtype.

MaskedArray.fill_value
Return current fill value.

MaskedArray.set_fill_value
Equivalent method.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> a = np.arange(5)
>>> a
array([0, 1, 2, 3, 4])
>>> a = ma.masked_where(a < 3, a)
>>> a
masked_array(data=[--, --, --, 3, 4],
             mask=[ True,  True,  True, False, False],
       fill_value=999999)
>>> ma.set_fill_value(a, -999)
>>> a
masked_array(data=[--, --, --, 3, 4],
             mask=[ True,  True,  True, False, False],
       fill_value=-999)
```

Nothing happens if *a* is not a masked array.

```
>>> a = list(range(5))
>>> a
[0, 1, 2, 3, 4]
>>> ma.set_fill_value(a, 100)
>>> a
[0, 1, 2, 3, 4]
>>> a = np.arange(5)
>>> a
array([0, 1, 2, 3, 4])
>>> ma.set_fill_value(a, 100)
```

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```
>>> a
array([0, 1, 2, 3, 4])
```

method

ma.MaskedArray.**get_fill_value**()

The filling value of the masked array is a scalar. When setting, None will set to a default based on the data type.

Examples

```
>>> import numpy as np
>>> for dt in [np.int32, np.int64, np.float64, np.complex128]:
...     np.ma.array([0, 1], dtype=dt).get_fill_value()
...
np.int64(999999)
np.int64(999999)
np.float64(1e+20)
np.complex128(1e+20+0j)
```

```
>>> x = np.ma.array([0, 1.], fill_value=-np.inf)
>>> x.fill_value
np.float64(-inf)
>>> x.fill_value = np.pi
>>> x.fill_value
np.float64(3.1415926535897931)
```

Reset to default:

```
>>> x.fill_value = None
>>> x.fill_value
np.float64(1e+20)
```

method

ma.MaskedArray.**set_fill_value**(*value=None*)

ma.MaskedArray.fill_value	The filling value of the masked array is a scalar.

Masked arrays arithmetic

Arithmetic

ma.anom(self[, axis, dtype])	Compute the anomalies (deviations from the arithmetic mean) along the given axis.
ma.anomalies(self[, axis, dtype])	Compute the anomalies (deviations from the arithmetic mean) along the given axis.
ma.average(a[, axis, weights, returned, ...])	Return the weighted average of array over the given axis.
ma.conjugate(x, /[, out, where, casting, ...])	Return the complex conjugate, element-wise.
ma.corrcoef(x[, y, rowvar, bias, ...])	Return Pearson product-moment correlation coefficients.
ma.cov(x[, y, rowvar, bias, allow_masked, ddof])	Estimate the covariance matrix.
ma.cumsum(self[, axis, dtype, out])	Return the cumulative sum of the array elements over the given axis.
ma.cumprod(self[, axis, dtype, out])	Return the cumulative product of the array elements over the given axis.
ma.mean(self[, axis, dtype, out, keepdims])	Returns the average of the array elements along given axis.
ma.median(a[, axis, out, overwrite_input, ...])	Compute the median along the specified axis.
ma.power(a, b[, third])	Returns element-wise base array raised to power from second array.
ma.prod(self[, axis, dtype, out, keepdims])	Return the product of the array elements over the given axis.
ma.std(self[, axis, dtype, out, ddof, ...])	Returns the standard deviation of the array elements along given axis.
ma.sum(self[, axis, dtype, out, keepdims])	Return the sum of the array elements over the given axis.
ma.var(self[, axis, dtype, out, ddof, ...])	Compute the variance along the specified axis.
ma.MaskedArray.anom([axis, dtype])	Compute the anomalies (deviations from the arithmetic mean) along the given axis.
ma.MaskedArray.cumprod([axis, dtype, out])	Return the cumulative product of the array elements over the given axis.
ma.MaskedArray.cumsum([axis, dtype, out])	Return the cumulative sum of the array elements over the given axis.
ma.MaskedArray.mean([axis, dtype, out, keepdims])	Returns the average of the array elements along given axis.
ma.MaskedArray.prod([axis, dtype, out, keepdims])	Return the product of the array elements over the given axis.
ma.MaskedArray.std([axis, dtype, out, ddof, ...])	Returns the standard deviation of the array elements along given axis.
ma.MaskedArray.sum([axis, dtype, out, keepdims])	Return the sum of the array elements over the given axis.
ma.MaskedArray.var([axis, dtype, out, ddof, ...])	Compute the variance along the specified axis.

ma.**anom**(*self*, *axis=None*, *dtype=None*) **= <numpy.ma.core._frommethod object>**

Compute the anomalies (deviations from the arithmetic mean) along the given axis.

Returns an array of anomalies, with the same shape as the input and where the arithmetic mean is computed along the given axis.

Parameters

axis
[int, optional] Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

dtype
[dtype, optional]

Type to use in computing the variance. For arrays of integer type
the default is float32; for arrays of float types it is the same as the array type.

See also:

mean
Compute the mean of the array.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([1,2,3])
>>> a.anom()
masked_array(data=[-1.,  0.,  1.],
             mask=False,
       fill_value=1e+20)
```

ma.**anomalies**(*self*, *axis=None*, *dtype=None*) **= <numpy.ma.core._frommethod object>**

Compute the anomalies (deviations from the arithmetic mean) along the given axis.

Returns an array of anomalies, with the same shape as the input and where the arithmetic mean is computed along the given axis.

Parameters

axis
[int, optional] Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

dtype
[dtype, optional]

Type to use in computing the variance. For arrays of integer type
the default is float32; for arrays of float types it is the same as the array type.

See also:

mean
Compute the mean of the array.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([1,2,3])
>>> a.anom()
masked_array(data=[-1.,  0.,  1.],
             mask=False,
       fill_value=1e+20)
```

ma.**average**(*a*, *axis=None*, *weights=None*, *returned=False*, ***, *keepdims=<no value>*)

Return the weighted average of array over the given axis.

Parameters

a
[array_like] Data to be averaged. Masked entries are not taken into account in the computation.

axis
: [None or int or tuple of ints, optional] Axis or axes along which to average *a*. The default, *axis=None*, will average over all of the elements of the input array. If axis is a tuple of ints, averaging is performed on all of the axes specified in the tuple instead of a single axis or all the axes as before.

weights
: [array_like, optional] An array of weights associated with the values in *a*. Each value in *a* contributes to the average according to its associated weight. The array of weights must be the same shape as *a* if no axis is specified, otherwise the weights must have dimensions and shape consistent with *a* along the specified axis. If *weights=None*, then all data in *a* are assumed to have a weight equal to one. The calculation is:

```
avg = sum(a * weights) / sum(weights)
```

where the sum is over all included elements. The only constraint on the values of *weights* is that *sum(weights)* must not be 0.

returned
: [bool, optional] Flag indicating whether a tuple `(result, sum of weights)` should be returned as output (True), or just the result (False). Default is False.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*. *Note: keepdims* will not work with instances of `numpy.matrix` or other classes whose methods do not support *keepdims*.

New in version 1.23.0.

Returns

average, [sum_of_weights]
: [(tuple of) scalar or MaskedArray] The average along the specified axis. When returned is *True*, return a tuple with the average as the first element and the sum of the weights as the second element. The return type is *np.float64* if *a* is of integer type and floats smaller than `float64`, or the input data-type, otherwise. If returned, *sum_of_weights* is always `float64`.

Raises

ZeroDivisionError
: When all weights along axis are zero. See `numpy.ma.average` for a version robust to this type of error.

TypeError
: When *weights* does not have the same shape as *a*, and *axis=None*.

ValueError
: When *weights* does not have dimensions and shape consistent with *a* along specified *axis*.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([1., 2., 3., 4.], mask=[False, False, True, True])
>>> np.ma.average(a, weights=[3, 1, 0, 0])
1.25
```

```
>>> x = np.ma.arange(6.).reshape(3, 2)
>>> x
masked_array(
  data=[[0., 1.],
        [2., 3.],
        [4., 5.]],
  mask=False,
  fill_value=1e+20)
>>> data = np.arange(8).reshape((2, 2, 2))
>>> data
array([[[0, 1],
        [2, 3]],
       [[4, 5],
        [6, 7]]])
>>> np.ma.average(data, axis=(0, 1), weights=[[1./4, 3./4], [1., 1./2]])
masked_array(data=[3.4, 4.4],
         mask=[False, False],
   fill_value=1e+20)
>>> np.ma.average(data, axis=0, weights=[[1./4, 3./4], [1., 1./2]])
Traceback (most recent call last):
    ...
ValueError: Shape of weights must be consistent
with shape of a along specified axis.
```

```
>>> avg, sumweights = np.ma.average(x, axis=0, weights=[1, 2, 3],
...                                 returned=True)
>>> avg
masked_array(data=[2.6666666666666665, 3.6666666666666665],
             mask=[False, False],
       fill_value=1e+20)
```

With `keepdims=True`, the following result has shape (3, 1).

```
>>> np.ma.average(x, axis=1, keepdims=True)
masked_array(
  data=[[0.5],
        [2.5],
        [4.5]],
  mask=False,
  fill_value=1e+20)
```

ma.**conjugate**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <numpy.ma.core._MaskedUnaryOperation object>**

Return the complex conjugate, element-wise.

The complex conjugate of a complex number is obtained by changing the sign of its imaginary part.

Parameters

x

[array_like] Input value.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The complex conjugate of *x*, with same dtype as *y*. This is a scalar if *x* is a scalar.

Notes

conj is an alias for *conjugate*:

```
>>> np.conj is np.conjugate
True
```

Examples

```
>>> import numpy as np
>>> np.conjugate(1+2j)
(1-2j)
```

```
>>> x = np.eye(2) + 1j * np.eye(2)
>>> np.conjugate(x)
array([[ 1.-1.j,  0.-0.j],
       [ 0.-0.j,  1.-1.j]])
```

ma.**corrcoef**(*x*, *y=None*, *rowvar=True*, *bias=<no value>*, *allow_masked=True*, *ddof=<no value>*)

Return Pearson product-moment correlation coefficients.

Except for the handling of missing data this function does the same as *numpy.corrcoef*. For more details and examples, see *numpy.corrcoef*.

Parameters

x
[array_like] A 1-D or 2-D array containing multiple variables and observations. Each row of *x* represents a variable, and each column a single observation of all those variables. Also see *rowvar* below.

y
[array_like, optional] An additional set of variables and observations. *y* has the same shape as *x*.

rowvar
: [bool, optional] If *rowvar* is True (default), then each row represents a variable, with observations in the columns. Otherwise, the relationship is transposed: each column represents a variable, while the rows contain observations.

bias
: [_NoValue, optional] Has no effect, do not use.

  Deprecated since version 1.10.0.

allow_masked
: [bool, optional] If True, masked values are propagated pair-wise: if a value is masked in *x*, the corresponding value is masked in *y*. If False, raises an exception. Because *bias* is deprecated, this argument needs to be treated as keyword only to avoid a warning.

ddof
: [_NoValue, optional] Has no effect, do not use.

  Deprecated since version 1.10.0.

See also:

numpy.corrcoef
: Equivalent function in top-level NumPy module.

cov
: Estimate the covariance matrix.

Notes

This function accepts but discards arguments *bias* and *ddof*. This is for backwards compatibility with previous versions of this function. These arguments had no effect on the return values of the function and can be safely ignored in this and previous versions of numpy.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[0, 1], [1, 1]], mask=[0, 1, 0, 1])
>>> np.ma.corrcoef(x)
masked_array(
  data=[[--, --],
        [--, --]],
  mask=[[ True,  True],
        [ True,  True]],
  fill_value=1e+20,
  dtype=float64)
```

ma.**cov**(*x*, *y=None*, *rowvar=True*, *bias=False*, *allow_masked=True*, *ddof=None*)

Estimate the covariance matrix.

Except for the handling of missing data this function does the same as *numpy.cov*. For more details and examples, see *numpy.cov*.

By default, masked values are recognized as such. If *x* and *y* have the same shape, a common mask is allocated: if `x[i,j]` is masked, then `y[i,j]` will also be masked. Setting *allow_masked* to False will raise an exception if values are missing in either of the input arrays.

Parameters

x
: [array_like] A 1-D or 2-D array containing multiple variables and observations. Each row of *x* represents a variable, and each column a single observation of all those variables. Also see *rowvar* below.

y
: [array_like, optional] An additional set of variables and observations. *y* has the same shape as *x*.

rowvar
: [bool, optional] If *rowvar* is True (default), then each row represents a variable, with observations in the columns. Otherwise, the relationship is transposed: each column represents a variable, while the rows contain observations.

bias
: [bool, optional] Default normalization (False) is by `(N-1)`, where `N` is the number of observations given (unbiased estimate). If *bias* is True, then normalization is by `N`. This keyword can be overridden by the keyword `ddof` in numpy versions >= 1.5.

allow_masked
: [bool, optional] If True, masked values are propagated pair-wise: if a value is masked in *x*, the corresponding value is masked in *y*. If False, raises a *ValueError* exception when some values are missing.

ddof
: [{None, int}, optional] If not `None` normalization is by `(N - ddof)`, where `N` is the number of observations; this overrides the value implied by `bias`. The default value is `None`.

Raises

ValueError
: Raised if some values are missing and *allow_masked* is False.

See also:

numpy.cov

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[0, 1], [1, 1]], mask=[0, 1, 0, 1])
>>> y = np.ma.array([[1, 0], [0, 1]], mask=[0, 0, 1, 1])
>>> np.ma.cov(x, y)
masked_array(
data=[[--, --, --, --],
      [--, --, --, --],
      [--, --, --, --],
      [--, --, --, --]],
mask=[[ True,  True,  True,  True],
      [ True,  True,  True,  True],
      [ True,  True,  True,  True],
      [ True,  True,  True,  True]],
fill_value=1e+20,
dtype=float64)
```

ma.**cumsum**(*self*, *axis=None*, *dtype=None*, *out=None*) **= <numpy.ma.core._frommethod object>**

Return the cumulative sum of the array elements over the given axis.

Masked values are set to 0 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

Refer to *numpy.cumsum* for full documentation.

See also:

numpy.ndarray.cumsum
corresponding function for ndarrays

numpy.cumsum
equivalent function

Notes

The mask is lost if *out* is not a valid *ma.MaskedArray* !

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

```
>>> import numpy as np
>>> marr = np.ma.array(np.arange(10), mask=[0,0,0,1,1,1,0,0,0,0])
>>> marr.cumsum()
masked_array(data=[0, 1, 3, --, --, --, 9, 16, 24, 33],
             mask=[False, False, False,  True,  True,  True, False, False,
                   False, False],
       fill_value=999999)
```

ma.**cumprod**(*self*, *axis=None*, *dtype=None*, *out=None*) **= <numpy.ma.core._frommethod object>**

Return the cumulative product of the array elements over the given axis.

Masked values are set to 1 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

Refer to *numpy.cumprod* for full documentation.

See also:

numpy.ndarray.cumprod
corresponding function for ndarrays

numpy.cumprod
equivalent function

Notes

The mask is lost if *out* is not a valid MaskedArray !

Arithmetic is modular when using integer types, and no error is raised on overflow.

ma.**mean**(*self*, *axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*) **= <numpy.ma.core._frommethod object>**

Returns the average of the array elements along given axis.

Masked entries are ignored, and result elements which are not finite will be masked.

Refer to *numpy.mean* for full documentation.

See also:

numpy.ndarray.mean
corresponding function for ndarrays

numpy.mean
Equivalent function

numpy.ma.average
Weighted average.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([1,2,3], mask=[False, False, True])
>>> a
masked_array(data=[1, 2, --],
             mask=[False, False,  True],
       fill_value=999999)
>>> a.mean()
1.5
```

ma.**median**(*a*, *axis=None*, *out=None*, *overwrite_input=False*, *keepdims=False*)

Compute the median along the specified axis.

Returns the median of the array elements.

Parameters

a
[array_like] Input array or object that can be converted to an array.

axis
[int, optional] Axis along which the medians are computed. The default (None) is to compute the median along a flattened version of the array.

out
[ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

overwrite_input
[bool, optional] If True, then allow use of memory of input array (a) for calculations. The input array will be modified by the call to median. This will save memory when you do not need to preserve the contents of the input array. Treat the input as undefined, but it will probably be fully or partially sorted. Default is False. Note that, if *overwrite_input* is True, and the input is not already an *ndarray*, an error will be raised.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

Returns

median
[ndarray] A new array holding the result is returned unless out is specified, in which case a

reference to out is returned. Return data-type is *float64* for integers and floats smaller than *float64*, or the input data-type, otherwise.

See also:

mean

Notes

Given a vector `V` with `N` non masked values, the median of `V` is the middle value of a sorted copy of `V` (`Vs`) - i.e. `Vs[(N-1)/2]`, when `N` is odd, or `{Vs[N/2 - 1] + Vs[N/2]}/2` when `N` is even.

Examples

```
>>> import numpy as np
>>> x = np.ma.array(np.arange(8), mask=[0]*4 + [1]*4)
>>> np.ma.median(x)
1.5
```

```
>>> x = np.ma.array(np.arange(10).reshape(2, 5), mask=[0]*6 + [1]*4)
>>> np.ma.median(x)
2.5
>>> np.ma.median(x, axis=-1, overwrite_input=True)
masked_array(data=[2.0, 5.0],
             mask=[False, False],
       fill_value=1e+20)
```

ma.**power**(*a*, *b*, *third=None*)

Returns element-wise base array raised to power from second array.

This is the masked array version of *numpy.power*. For details see *numpy.power*.

See also:

numpy.power

Notes

The *out* argument to *numpy.power* is not supported, *third* has to be None.

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = [11.2, -3.973, 0.801, -1.41]
>>> mask = [0, 0, 0, 1]
>>> masked_x = ma.masked_array(x, mask)
>>> masked_x
masked_array(data=[11.2, -3.973, 0.801, --],
             mask=[False, False, False,  True],
   fill_value=1e+20)
>>> ma.power(masked_x, 2)
```

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```
masked_array(data=[125.43999999999998, 15.784728999999999,
                   0.6416010000000001, --],
             mask=[False, False, False,  True],
       fill_value=1e+20)
>>> y = [-0.5, 2, 0, 17]
>>> masked_y = ma.masked_array(y, mask)
>>> masked_y
masked_array(data=[-0.5, 2.0, 0.0, --],
             mask=[False, False, False,  True],
       fill_value=1e+20)
>>> ma.power(masked_x, masked_y)
masked_array(data=[0.2988071523335984, 15.784728999999999, 1.0, --],
             mask=[False, False, False,  True],
       fill_value=1e+20)
```

ma.**prod**(*self*, *axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*) = **<numpy.ma.core._frommethod object>**

Return the product of the array elements over the given axis.

Masked elements are set to 1 internally for computation.

Refer to *numpy.prod* for full documentation.

See also:

numpy.ndarray.prod
corresponding function for ndarrays

numpy.prod
equivalent function

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

ma.**std**(*self*, *axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=<no value>*, *mean=<no value>*) = **<numpy.ma.core._frommethod object>**

Returns the standard deviation of the array elements along given axis.

Masked entries are ignored.

Refer to *numpy.std* for full documentation.

See also:

numpy.ndarray.std
corresponding function for ndarrays

numpy.std
Equivalent function

ma.**sum**(*self*, *axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*) = **<numpy.ma.core._frommethod object>**

Return the sum of the array elements over the given axis.

Masked elements are set to 0 internally.

Refer to *numpy.sum* for full documentation.

See also:

numpy.ndarray.sum
corresponding function for ndarrays

numpy.sum
equivalent function

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> x
masked_array(
  data=[[1, --, 3],
        [--, 5, --],
        [7, --, 9]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
>>> x.sum()
25
>>> x.sum(axis=1)
masked_array(data=[4, 5, 16],
             mask=[False, False, False],
       fill_value=999999)
>>> x.sum(axis=0)
masked_array(data=[8, 5, 12],
             mask=[False, False, False],
       fill_value=999999)
>>> print(type(x.sum(axis=0, dtype=np.int64)[0]))
<class 'numpy.int64'>
```

ma.**var**(*self*, *axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=<no value>*, *mean=<no value>*) **=**
<numpy.ma.core._frommethod object>

Compute the variance along the specified axis.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed for the flattened array by default, otherwise over the specified axis.

Parameters

a
[array_like] Array containing numbers whose variance is desired. If *a* is not an array, a conversion is attempted.

axis
[None or int or tuple of ints, optional] Axis or axes along which the variance is computed. The default is to compute the variance of the flattened array. If this is a tuple of ints, a variance is performed over multiple axes, instead of a single axis or all the axes as before.

dtype
[data-type, optional] Type to use in computing the variance. For arrays of integer type the default is *float64*; for arrays of float types it is the same as the array type.

out
: [ndarray, optional] Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

ddof
: [{int, float}, optional] "Delta Degrees of Freedom": the divisor used in the calculation is `N - ddof`, where `N` represents the number of elements. By default *ddof* is zero. See notes for details about use of *ddof*.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

  If the default value is passed, then *keepdims* will not be passed through to the *var* method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

where
: [array_like of bool, optional] Elements to include in the variance. See *reduce* for details.

  New in version 1.20.0.

mean
: [array like, optional] Provide the mean to prevent its recalculation. The mean should have a shape as if it was calculated with `keepdims=True`. The axis for the calculation of the mean should be the same as used in the call to this var function.

  New in version 2.0.0.

correction
: [{int, float}, optional] Array API compatible name for the `ddof` parameter. Only one of them can be provided at the same time.

  New in version 2.0.0.

Returns

variance
: [ndarray, see dtype parameter above] If `out=None`, returns a new array containing the variance; otherwise, a reference to the output array is returned.

See also:

std*, *mean*, *nanmean*, *nanstd*, *nanvar
ufuncs-output-type

Notes

There are several common variants of the array variance calculation. Assuming the input *a* is a one-dimensional NumPy array and `mean` is either provided as an argument or computed as `a.mean()`, NumPy computes the variance of an array as:

```
N = len(a)
d2 = abs(a - mean)**2  # abs is for complex `a`
var = d2.sum() / (N - ddof)  # note use of `ddof`
```

Different values of the argument *ddof* are useful in different contexts. NumPy's default `ddof=0` corresponds with the expression:

$$\frac{\sum_i |a_i - \bar{a}|^2}{N}$$

which is sometimes called the "population variance" in the field of statistics because it applies the definition of variance to a as if a were a complete population of possible observations.

Many other libraries define the variance of an array differently, e.g.:

$$\frac{\sum_i |a_i - \bar{a}|^2}{N - 1}$$

In statistics, the resulting quantity is sometimes called the "sample variance" because if a is a random sample from a larger population, this calculation provides an unbiased estimate of the variance of the population. The use of $N - 1$ in the denominator is often called "Bessel's correction" because it corrects for bias (toward lower values) in the variance estimate introduced when the sample mean of a is used in place of the true mean of the population. For this quantity, use `ddof=1`.

Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.

For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for *`float32`* (see example below). Specifying a higher-accuracy accumulator using the `dtype` keyword can alleviate this issue.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> np.var(a)
1.25
>>> np.var(a, axis=0)
array([1.,  1.])
>>> np.var(a, axis=1)
array([0.25,  0.25])
```

In single precision, var() can be inaccurate:

```
>>> a = np.zeros((2, 512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.var(a)
np.float32(0.20250003)
```

Computing the variance in float64 is more accurate:

```
>>> np.var(a, dtype=np.float64)
0.20249999932944759 # may vary
>>> ((1-0.55)**2 + (0.1-0.55)**2)/2
0.2025
```

Specifying a where argument:

```
>>> a = np.array([[14, 8, 11, 10], [7, 9, 10, 11], [10, 15, 5, 10]])
>>> np.var(a)
```

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```
6.833333333333333 # may vary
>>> np.var(a, where=[[True], [True], [False]])
4.0
```

Using the mean keyword to save computation time:

```
>>> import numpy as np
>>> from timeit import timeit
>>>
>>> a = np.array([[14, 8, 11, 10], [7, 9, 10, 11], [10, 15, 5, 10]])
>>> mean = np.mean(a, axis=1, keepdims=True)
>>>
>>> g = globals()
>>> n = 10000
>>> t1 = timeit("var = np.var(a, axis=1, mean=mean)", globals=g, number=n)
>>> t2 = timeit("var = np.var(a, axis=1)", globals=g, number=n)
>>> print(f'Percentage execution time saved {100*(t2-t1)/t2:.0f}%')

Percentage execution time saved 32%
```

method

ma.MaskedArray.**anom**(*axis=None*, *dtype=None*)

Compute the anomalies (deviations from the arithmetic mean) along the given axis.

Returns an array of anomalies, with the same shape as the input and where the arithmetic mean is computed along the given axis.

Parameters

axis
[int, optional] Axis over which the anomalies are taken. The default is to use the mean of the flattened array as reference.

dtype
[dtype, optional]

Type to use in computing the variance. For arrays of integer type
the default is float32; for arrays of float types it is the same as the array type.

See also:

mean
Compute the mean of the array.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([1,2,3])
>>> a.anom()
masked_array(data=[-1.,  0.,  1.],
             mask=False,
       fill_value=1e+20)
```

method

ma.MaskedArray.**cumprod**(*axis=None*, *dtype=None*, *out=None*)

Return the cumulative product of the array elements over the given axis.

Masked values are set to 1 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

Refer to *numpy.cumprod* for full documentation.

See also:

numpy.ndarray.cumprod
corresponding function for ndarrays

numpy.cumprod
equivalent function

Notes

The mask is lost if *out* is not a valid MaskedArray !

Arithmetic is modular when using integer types, and no error is raised on overflow.

method

ma.MaskedArray.**cumsum**(*axis=None*, *dtype=None*, *out=None*)

Return the cumulative sum of the array elements over the given axis.

Masked values are set to 0 internally during the computation. However, their position is saved, and the result will be masked at the same locations.

Refer to *numpy.cumsum* for full documentation.

See also:

numpy.ndarray.cumsum
corresponding function for ndarrays

numpy.cumsum
equivalent function

Notes

The mask is lost if *out* is not a valid *ma.MaskedArray* !

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

```
>>> import numpy as np
>>> marr = np.ma.array(np.arange(10), mask=[0,0,0,1,1,1,0,0,0,0])
>>> marr.cumsum()
masked_array(data=[0, 1, 3, --, --, --, 9, 16, 24, 33],
             mask=[False, False, False,  True,  True,  True, False, False,
                   False, False],
       fill_value=999999)
```

method

ma.MaskedArray.**mean**(*axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*)

Returns the average of the array elements along given axis.

Masked entries are ignored, and result elements which are not finite will be masked.

Refer to *numpy.mean* for full documentation.

See also:

numpy.ndarray.mean
corresponding function for ndarrays

numpy.mean
Equivalent function

numpy.ma.average
Weighted average.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([1,2,3], mask=[False, False, True])
>>> a
masked_array(data=[1, 2, --],
             mask=[False, False,  True],
       fill_value=999999)
>>> a.mean()
1.5
```

method

ma.MaskedArray.**prod**(*axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*)

Return the product of the array elements over the given axis.

Masked elements are set to 1 internally for computation.

Refer to *numpy.prod* for full documentation.

See also:

numpy.ndarray.prod
corresponding function for ndarrays

numpy.prod
equivalent function

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

method

ma.MaskedArray.**std**(*axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=<no value>*, *mean=<no value>*)

Returns the standard deviation of the array elements along given axis.

Masked entries are ignored.

Refer to *numpy.std* for full documentation.

See also:

numpy.ndarray.std
corresponding function for ndarrays

numpy.std
Equivalent function

method

ma.MaskedArray.**sum**(*axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*)

Return the sum of the array elements over the given axis.

Masked elements are set to 0 internally.

Refer to *numpy.sum* for full documentation.

See also:

numpy.ndarray.sum
corresponding function for ndarrays

numpy.sum
equivalent function

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> x
masked_array(
  data=[[1, --, 3],
        [--, 5, --],
        [7, --, 9]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
>>> x.sum()
25
>>> x.sum(axis=1)
masked_array(data=[4, 5, 16],
             mask=[False, False, False],
       fill_value=999999)
>>> x.sum(axis=0)
masked_array(data=[8, 5, 12],
             mask=[False, False, False],
       fill_value=999999)
>>> print(type(x.sum(axis=0, dtype=np.int64)[0]))
<class 'numpy.int64'>
```

method

ma.MaskedArray.**var**(*axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=<no value>*, *mean=<no value>*)

Compute the variance along the specified axis.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed for the flattened array by default, otherwise over the specified axis.

Parameters

a
: [array_like] Array containing numbers whose variance is desired. If *a* is not an array, a conversion is attempted.

axis
: [None or int or tuple of ints, optional] Axis or axes along which the variance is computed. The default is to compute the variance of the flattened array. If this is a tuple of ints, a variance is performed over multiple axes, instead of a single axis or all the axes as before.

dtype
: [data-type, optional] Type to use in computing the variance. For arrays of integer type the default is *float64*; for arrays of float types it is the same as the array type.

out
: [ndarray, optional] Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

ddof
: [{int, float}, optional] "Delta Degrees of Freedom": the divisor used in the calculation is `N - ddof`, where `N` represents the number of elements. By default *ddof* is zero. See notes for details about use of *ddof*.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

  If the default value is passed, then *keepdims* will not be passed through to the *var* method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

where
: [array_like of bool, optional] Elements to include in the variance. See *reduce* for details.

  New in version 1.20.0.

mean
: [array like, optional] Provide the mean to prevent its recalculation. The mean should have a shape as if it was calculated with `keepdims=True`. The axis for the calculation of the mean should be the same as used in the call to this var function.

  New in version 2.0.0.

correction
: [{int, float}, optional] Array API compatible name for the `ddof` parameter. Only one of them can be provided at the same time.

  New in version 2.0.0.

Returns

variance
: [ndarray, see dtype parameter above] If `out=None`, returns a new array containing the variance; otherwise, a reference to the output array is returned.

See also:

std*, *mean*, *nanmean*, *nanstd*, *nanvar
ufuncs-output-type

Notes

There are several common variants of the array variance calculation. Assuming the input a is a one-dimensional NumPy array and `mean` is either provided as an argument or computed as `a.mean()`, NumPy computes the variance of an array as:

```
N = len(a)
d2 = abs(a - mean)**2  # abs is for complex `a`
var = d2.sum() / (N - ddof)  # note use of `ddof`
```

Different values of the argument *ddof* are useful in different contexts. NumPy's default `ddof=0` corresponds with the expression:

$$\frac{\sum_i |a_i - \bar{a}|^2}{N}$$

which is sometimes called the "population variance" in the field of statistics because it applies the definition of variance to a as if a were a complete population of possible observations.

Many other libraries define the variance of an array differently, e.g.:

$$\frac{\sum_i |a_i - \bar{a}|^2}{N - 1}$$

In statistics, the resulting quantity is sometimes called the "sample variance" because if a is a random sample from a larger population, this calculation provides an unbiased estimate of the variance of the population. The use of $N - 1$ in the denominator is often called "Bessel's correction" because it corrects for bias (toward lower values) in the variance estimate introduced when the sample mean of a is used in place of the true mean of the population. For this quantity, use `ddof=1`.

Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.

For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for *`float32`* (see example below). Specifying a higher-accuracy accumulator using the `dtype` keyword can alleviate this issue.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> np.var(a)
1.25
>>> np.var(a, axis=0)
array([1.,  1.])
>>> np.var(a, axis=1)
array([0.25,  0.25])
```

In single precision, var() can be inaccurate:

```
>>> a = np.zeros((2, 512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.var(a)
np.float32(0.20250003)
```

Computing the variance in float64 is more accurate:

```
>>> np.var(a, dtype=np.float64)
0.20249999932944759 # may vary
>>> ((1-0.55)**2 + (0.1-0.55)**2)/2
0.2025
```

Specifying a where argument:

```
>>> a = np.array([[14, 8, 11, 10], [7, 9, 10, 11], [10, 15, 5, 10]])
>>> np.var(a)
6.833333333333333 # may vary
>>> np.var(a, where=[[True], [True], [False]])
4.0
```

Using the mean keyword to save computation time:

```
>>> import numpy as np
>>> from timeit import timeit
>>>
>>> a = np.array([[14, 8, 11, 10], [7, 9, 10, 11], [10, 15, 5, 10]])
>>> mean = np.mean(a, axis=1, keepdims=True)
>>>
>>> g = globals()
>>> n = 10000
>>> t1 = timeit("var = np.var(a, axis=1, mean=mean)", globals=g, number=n)
>>> t2 = timeit("var = np.var(a, axis=1)", globals=g, number=n)
>>> print(f'Percentage execution time saved {100*(t2-t1)/t2:.0f}%')

Percentage execution time saved 32%
```

Minimum/maximum

ma.argmax(self[, axis, fill_value, out])	Returns array of indices of the maximum values along the given axis.
ma.argmin(self[, axis, fill_value, out])	Return array of indices to the minimum values along the given axis.
ma.max(obj[, axis, out, fill_value, keepdims])	Return the maximum along a given axis.
ma.min(obj[, axis, out, fill_value, keepdims])	Return the minimum along a given axis.
ma.ptp(obj[, axis, out, fill_value, keepdims])	Return (maximum - minimum) along the given dimension (i.e. peak-to-peak value).
ma.diff(a, /[, n, axis, prepend, append])	Calculate the n-th discrete difference along the given axis.
ma.MaskedArray.argmax([axis, fill_value, ...])	Returns array of indices of the maximum values along the given axis.
ma.MaskedArray.argmin([axis, fill_value, ...])	Return array of indices to the minimum values along the given axis.
ma.MaskedArray.max([axis, out, fill_value, ...])	Return the maximum along a given axis.
ma.MaskedArray.min([axis, out, fill_value, ...])	Return the minimum along a given axis.
ma.MaskedArray.ptp([axis, out, fill_value, ...])	Return (maximum - minimum) along the given dimension (i.e. peak-to-peak value).

ma.**argmax**(*self*, *axis=None*, *fill_value=None*, *out=None*) **= <numpy.ma.core._frommethod object>**

Returns array of indices of the maximum values along the given axis. Masked values are treated as if they had the value fill_value.

Parameters

axis
[{None, integer}] If None, the index is into the flattened array, otherwise along the specified axis

fill_value
[scalar or None, optional] Value used to fill in the masked values. If None, the output of maximum_fill_value(self._data) is used instead.

out
[{None, array}, optional] Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

Returns

index_array
[{integer_array}]

Examples

```
>>> import numpy as np
>>> a = np.arange(6).reshape(2,3)
>>> a.argmax()
5
>>> a.argmax(0)
array([1, 1, 1])
>>> a.argmax(1)
array([2, 2])
```

ma.**argmin**(*self*, *axis=None*, *fill_value=None*, *out=None*) **= <numpy.ma.core._frommethod object>**

Return array of indices to the minimum values along the given axis.

Parameters

axis
[{None, integer}] If None, the index is into the flattened array, otherwise along the specified axis

fill_value
[scalar or None, optional] Value used to fill in the masked values. If None, the output of minimum_fill_value(self._data) is used instead.

out
[{None, array}, optional] Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

Returns

ndarray or scalar
If multi-dimension input, returns a new ndarray of indices to the minimum values along the given axis. Otherwise, returns a scalar of index to the minimum values along the given axis.

Examples

```
>>> import numpy as np
>>> x = np.ma.array(np.arange(4), mask=[1,1,0,0])
>>> x.shape = (2,2)
>>> x
masked_array(
  data=[[--, --],
        [2, 3]],
  mask=[[ True,  True],
        [False, False]],
  fill_value=999999)
>>> x.argmin(axis=0, fill_value=-1)
array([0, 0])
>>> x.argmin(axis=0, fill_value=9)
array([1, 1])
```

ma.**max**(*obj*, *axis=None*, *out=None*, *fill_value=None*, *keepdims=<no value>*)

Return the maximum along a given axis.

Parameters

axis
: [None or int or tuple of ints, optional] Axis along which to operate. By default, `axis` is None and the flattened input is used. If this is a tuple of ints, the maximum is selected over multiple axes, instead of a single axis or all the axes as before.

out
: [array_like, optional] Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

fill_value
: [scalar or None, optional] Value used to fill in the masked values. If None, use the output of maximum_fill_value().

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

Returns

amax
: [array_like] New array holding the result. If `out` was specified, `out` is returned.

See also:

ma.maximum_fill_value
: Returns the maximum filling value for a given datatype.

Examples

```
>>> import numpy.ma as ma
>>> x = [[-1., 2.5], [4., -2.], [3., 0.]]
>>> mask = [[0, 0], [1, 0], [1, 0]]
>>> masked_x = ma.masked_array(x, mask)
>>> masked_x
masked_array(
  data=[[-1.0, 2.5],
        [--, -2.0],
        [--, 0.0]],
  mask=[[False, False],
        [ True, False],
        [ True, False]],
  fill_value=1e+20)
>>> ma.max(masked_x)
2.5
>>> ma.max(masked_x, axis=0)
masked_array(data=[-1.0, 2.5],
             mask=[False, False],
       fill_value=1e+20)
>>> ma.max(masked_x, axis=1, keepdims=True)
masked_array(
  data=[[2.5],
        [-2.0],
        [0.0]],
  mask=[[False],
        [False],
        [False]],
  fill_value=1e+20)
>>> mask = [[1, 1], [1, 1], [1, 1]]
>>> masked_x = ma.masked_array(x, mask)
>>> ma.max(masked_x, axis=1)
masked_array(data=[--, --, --],
             mask=[ True,  True,  True],
       fill_value=1e+20,
            dtype=float64)
```

ma.**min**(*obj*, *axis=None*, *out=None*, *fill_value=None*, *keepdims=<no value>*)

Return the minimum along a given axis.

Parameters

axis
: [None or int or tuple of ints, optional] Axis along which to operate. By default, `axis` is None and the flattened input is used. If this is a tuple of ints, the minimum is selected over multiple axes, instead of a single axis or all the axes as before.

out
: [array_like, optional] Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

fill_value
: [scalar or None, optional] Value used to fill in the masked values. If None, use the output of *minimum_fill_value*.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

Returns

amin
[array_like] New array holding the result. If `out` was specified, `out` is returned.

See also:

ma.minimum_fill_value
Returns the minimum filling value for a given datatype.

Examples

```
>>> import numpy.ma as ma
>>> x = [[1., -2., 3.], [0.2, -0.7, 0.1]]
>>> mask = [[1, 1, 0], [0, 0, 1]]
>>> masked_x = ma.masked_array(x, mask)
>>> masked_x
masked_array(
  data=[[--, --, 3.0],
        [0.2, -0.7, --]],
  mask=[[ True,  True, False],
        [False, False,  True]],
  fill_value=1e+20)
>>> ma.min(masked_x)
-0.7
>>> ma.min(masked_x, axis=-1)
masked_array(data=[3.0, -0.7],
             mask=[False, False],
       fill_value=1e+20)
>>> ma.min(masked_x, axis=0, keepdims=True)
masked_array(data=[[0.2, -0.7, 3.0]],
             mask=[[False, False, False]],
       fill_value=1e+20)
>>> mask = [[1, 1, 1,], [1, 1, 1]]
>>> masked_x = ma.masked_array(x, mask)
>>> ma.min(masked_x, axis=0)
masked_array(data=[--, --, --],
             mask=[ True,  True,  True],
       fill_value=1e+20,
           dtype=float64)
```

`ma.`**`ptp`**(*obj*, *axis=None*, *out=None*, *fill_value=None*, *keepdims=<no value>*)

Return (maximum - minimum) along the given dimension (i.e. peak-to-peak value).

> **Warning:** *ptp* preserves the data type of the array. This means the return value for an input of signed integers with n bits (e.g. *np.int8*, *np.int16*, etc) is also a signed integer with n bits. In that case, peak-to-peak values greater than `2**(n-1)-1` will be returned as negative values. An example with a work-around is shown below.

Parameters

axis
[{None, int}, optional] Axis along which to find the peaks. If None (default) the flattened array is used.

out
: [{None, array_like}, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

fill_value
: [scalar or None, optional] Value used to fill in the masked values.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

Returns

ptp
: [ndarray.] A new array holding the result, unless `out` was specified, in which case a reference to `out` is returned.

Examples

```
>>> import numpy as np
>>> x = np.ma.MaskedArray([[4, 9, 2, 10],
...                        [6, 9, 7, 12]])
```

```
>>> x.ptp(axis=1)
masked_array(data=[8, 6],
             mask=False,
       fill_value=999999)
```

```
>>> x.ptp(axis=0)
masked_array(data=[2, 0, 5, 2],
             mask=False,
       fill_value=999999)
```

```
>>> x.ptp()
10
```

This example shows that a negative value can be returned when the input is an array of signed integers.

```
>>> y = np.ma.MaskedArray([[1, 127],
...                        [0, 127],
...                        [-1, 127],
...                        [-2, 127]], dtype=np.int8)
>>> y.ptp(axis=1)
masked_array(data=[ 126,  127, -128, -127],
             mask=False,
       fill_value=np.int64(999999),
            dtype=int8)
```

A work-around is to use the *view()* method to view the result as unsigned integers with the same bit width:

```
>>> y.ptp(axis=1).view(np.uint8)
masked_array(data=[126, 127, 128, 129],
             mask=False,
       fill_value=np.uint64(999999),
            dtype=uint8)
```

ma.**diff**(*a*, */*, *n=1*, *axis=-1*, *prepend=<no value>*, *append=<no value>*)

Calculate the n-th discrete difference along the given axis. The first difference is given by `out[i] = a[i+1] - a[i]` along the given axis, higher differences are calculated by using *diff* recursively. Preserves the input mask.

Parameters

a
[array_like] Input array

n
[int, optional] The number of times values are differenced. If zero, the input is returned as-is.

axis
[int, optional] The axis along which the difference is taken, default is the last axis.

prepend, append
[array_like, optional] Values to prepend or append to *a* along axis prior to performing the difference. Scalar values are expanded to arrays with length 1 in the direction of axis and the shape of the input array in along all other axes. Otherwise the dimension and shape must match *a* except along axis.

Returns

diff
[MaskedArray] The n-th differences. The shape of the output is the same as *a* except along *axis* where the dimension is smaller by *n*. The type of the output is the same as the type of the difference between any two elements of *a*. This is the same as the type of *a* in most cases. A notable exception is *datetime64*, which results in a *timedelta64* output array.

See also:

numpy.diff
Equivalent function in the top-level NumPy module.

Notes

Type is preserved for boolean arrays, so the result will contain *False* when consecutive elements are the same and *True* when they differ.

For unsigned integer arrays, the results will also be unsigned. This should not be surprising, as the result is consistent with calculating the difference directly:

```
>>> u8_arr = np.array([1, 0], dtype=np.uint8)
>>> np.ma.diff(u8_arr)
masked_array(data=[255],
             mask=False,
       fill_value=np.uint64(999999),
            dtype=uint8)
>>> u8_arr[1,...] - u8_arr[0,...]
np.uint8(255)
```

If this is not desirable, then the array should be cast to a larger integer type first:

```
>>> i16_arr = u8_arr.astype(np.int16)
>>> np.ma.diff(i16_arr)
masked_array(data=[-1],
             mask=False,
       fill_value=np.int64(999999),
            dtype=int16)
```

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2, 3, 4, 7, 0, 2, 3])
>>> x = np.ma.masked_where(a < 2, a)
>>> np.ma.diff(x)
masked_array(data=[--, 1, 1, 3, --, --, 1],
             mask=[ True, False, False, False,  True,  True, False],
       fill_value=999999)
```

```
>>> np.ma.diff(x, n=2)
masked_array(data=[--, 0, 2, --, --, --],
                  mask=[ True, False, False,  True,  True,  True],
       fill_value=999999)
```

```
>>> a = np.array([[1, 3, 1, 5, 10], [0, 1, 5, 6, 8]])
>>> x = np.ma.masked_equal(a, value=1)
>>> np.ma.diff(x)
masked_array(
    data=[[--, --, --, 5],
          [--, --, 1, 2]],
    mask=[[ True,  True,  True, False],
          [ True,  True, False, False]],
    fill_value=1)
```

```
>>> np.ma.diff(x, axis=0)
masked_array(data=[[--, --, --, 1, -2]],
             mask=[[ True,  True,  True, False, False]],
       fill_value=1)
```

method

ma.MaskedArray.**argmax**(*axis=None*, *fill_value=None*, *out=None*, ***, *keepdims=<no value>*)

Returns array of indices of the maximum values along the given axis. Masked values are treated as if they had the value fill_value.

Parameters

axis
[{None, integer}] If None, the index is into the flattened array, otherwise along the specified axis

fill_value
[scalar or None, optional] Value used to fill in the masked values. If None, the output of maximum_fill_value(self._data) is used instead.

out
[{None, array}, optional] Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

Returns

index_array
[{integer_array}]

Examples

```
>>> import numpy as np
>>> a = np.arange(6).reshape(2,3)
>>> a.argmax()
5
>>> a.argmax(0)
array([1, 1, 1])
>>> a.argmax(1)
array([2, 2])
```

method

ma.MaskedArray.**argmin**(*axis=None*, *fill_value=None*, *out=None*, ***, *keepdims=<no value>*)

Return array of indices to the minimum values along the given axis.

Parameters

axis
[{None, integer}] If None, the index is into the flattened array, otherwise along the specified axis

fill_value
[scalar or None, optional] Value used to fill in the masked values. If None, the output of minimum_fill_value(self._data) is used instead.

out
[{None, array}, optional] Array into which the result can be placed. Its type is preserved and it must be of the right shape to hold the output.

Returns

ndarray or scalar
If multi-dimension input, returns a new ndarray of indices to the minimum values along the given axis. Otherwise, returns a scalar of index to the minimum values along the given axis.

Examples

```
>>> import numpy as np
>>> x = np.ma.array(np.arange(4), mask=[1,1,0,0])
>>> x.shape = (2,2)
>>> x
masked_array(
  data=[[--, --],
        [2, 3]],
  mask=[[ True,  True],
        [False, False]],
  fill_value=999999)
>>> x.argmin(axis=0, fill_value=-1)
array([0, 0])
>>> x.argmin(axis=0, fill_value=9)
array([1, 1])
```

method

ma.MaskedArray.**max**(*axis=None*, *out=None*, *fill_value=None*, *keepdims=<no value>*)

Return the maximum along a given axis.

Parameters

axis
[None or int or tuple of ints, optional] Axis along which to operate. By default, `axis` is None and the flattened input is used. If this is a tuple of ints, the maximum is selected over multiple axes, instead of a single axis or all the axes as before.

out
[array_like, optional] Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

fill_value
[scalar or None, optional] Value used to fill in the masked values. If None, use the output of maximum_fill_value().

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

Returns

amax
[array_like] New array holding the result. If `out` was specified, `out` is returned.

See also:

ma.maximum_fill_value
Returns the maximum filling value for a given datatype.

Examples

```
>>> import numpy.ma as ma
>>> x = [[-1., 2.5], [4., -2.], [3., 0.]]
>>> mask = [[0, 0], [1, 0], [1, 0]]
>>> masked_x = ma.masked_array(x, mask)
>>> masked_x
masked_array(
  data=[[-1.0, 2.5],
        [--, -2.0],
        [--, 0.0]],
  mask=[[False, False],
        [ True, False],
        [ True, False]],
  fill_value=1e+20)
>>> ma.max(masked_x)
2.5
>>> ma.max(masked_x, axis=0)
masked_array(data=[-1.0, 2.5],
             mask=[False, False],
       fill_value=1e+20)
>>> ma.max(masked_x, axis=1, keepdims=True)
masked_array(
  data=[[2.5],
        [-2.0],
        [0.0]],
  mask=[[False],
        [False],
        [False]],
```

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```
  fill_value=1e+20)
>>> mask = [[1, 1], [1, 1], [1, 1]]
>>> masked_x = ma.masked_array(x, mask)
>>> ma.max(masked_x, axis=1)
masked_array(data=[--, --, --],
             mask=[ True,  True,  True],
       fill_value=1e+20,
            dtype=float64)
```

method

ma.MaskedArray.**min**(*axis=None*, *out=None*, *fill_value=None*, *keepdims=<no value>*)

Return the minimum along a given axis.

Parameters

axis
[None or int or tuple of ints, optional] Axis along which to operate. By default, `axis` is None and the flattened input is used. If this is a tuple of ints, the minimum is selected over multiple axes, instead of a single axis or all the axes as before.

out
[array_like, optional] Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output.

fill_value
[scalar or None, optional] Value used to fill in the masked values. If None, use the output of *minimum_fill_value*.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

Returns

amin
[array_like] New array holding the result. If `out` was specified, `out` is returned.

See also:

ma.minimum_fill_value
Returns the minimum filling value for a given datatype.

Examples

```
>>> import numpy.ma as ma
>>> x = [[1., -2., 3.], [0.2, -0.7, 0.1]]
>>> mask = [[1, 1, 0], [0, 0, 1]]
>>> masked_x = ma.masked_array(x, mask)
>>> masked_x
masked_array(
  data=[[--, --, 3.0],
        [0.2, -0.7, --]],
  mask=[[ True,  True, False],
        [False, False,  True]],
  fill_value=1e+20)
>>> ma.min(masked_x)
```

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```
-0.7
>>> ma.min(masked_x, axis=-1)
masked_array(data=[3.0, -0.7],
             mask=[False, False],
       fill_value=1e+20)
>>> ma.min(masked_x, axis=0, keepdims=True)
masked_array(data=[[0.2, -0.7, 3.0]],
             mask=[[False, False, False]],
       fill_value=1e+20)
>>> mask = [[1, 1, 1,], [1, 1, 1]]
>>> masked_x = ma.masked_array(x, mask)
>>> ma.min(masked_x, axis=0)
masked_array(data=[--, --, --],
             mask=[ True,  True,  True],
       fill_value=1e+20,
           dtype=float64)
```

method

`ma.MaskedArray.`**`ptp`**(*axis=None*, *out=None*, *fill_value=None*, *keepdims=False*)

Return (maximum - minimum) along the given dimension (i.e. peak-to-peak value).

Warning: *ptp* preserves the data type of the array. This means the return value for an input of signed integers with n bits (e.g. *np.int8*, *np.int16*, etc) is also a signed integer with n bits. In that case, peak-to-peak values greater than `2**(n-1)-1` will be returned as negative values. An example with a work-around is shown below.

Parameters

axis
[{None, int}, optional] Axis along which to find the peaks. If None (default) the flattened array is used.

out
[{None, array_like}, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary.

fill_value
[scalar or None, optional] Value used to fill in the masked values.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

Returns

ptp
[ndarray.] A new array holding the result, unless `out` was specified, in which case a reference to `out` is returned.

Examples

```
>>> import numpy as np
>>> x = np.ma.MaskedArray([[4, 9, 2, 10],
...                        [6, 9, 7, 12]])
```

```
>>> x.ptp(axis=1)
masked_array(data=[8, 6],
             mask=False,
       fill_value=999999)
```

```
>>> x.ptp(axis=0)
masked_array(data=[2, 0, 5, 2],
             mask=False,
       fill_value=999999)
```

```
>>> x.ptp()
10
```

This example shows that a negative value can be returned when the input is an array of signed integers.

```
>>> y = np.ma.MaskedArray([[1, 127],
...                        [0, 127],
...                        [-1, 127],
...                        [-2, 127]], dtype=np.int8)
>>> y.ptp(axis=1)
masked_array(data=[ 126,  127, -128, -127],
             mask=False,
       fill_value=np.int64(999999),
            dtype=int8)
```

A work-around is to use the *view()* method to view the result as unsigned integers with the same bit width:

```
>>> y.ptp(axis=1).view(np.uint8)
masked_array(data=[126, 127, 128, 129],
             mask=False,
       fill_value=np.uint64(999999),
            dtype=uint8)
```

Sorting

ma.argsort(a[, axis, kind, order, endwith, ...])	Return an ndarray of indices that sort the array along the specified axis.
ma.sort(a[, axis, kind, order, endwith, ...])	Return a sorted copy of the masked array.
ma.MaskedArray.argsort([axis, kind, order, ...])	Return an ndarray of indices that sort the array along the specified axis.
ma.MaskedArray.sort([axis, kind, order, ...])	Sort the array, in-place

ma.**argsort**(*a*, *axis=<no value>*, *kind=None*, *order=None*, *endwith=True*, *fill_value=None*, *, *stable=None*)

Return an ndarray of indices that sort the array along the specified axis. Masked values are filled beforehand to *fill_value*.

Parameters

axis
[int, optional] Axis along which to sort. If None, the default, the flattened array is used.

kind
[{'quicksort', 'mergesort', 'heapsort', 'stable'}, optional] The sorting algorithm used.

order
[list, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

endwith
[{True, False}, optional] Whether missing values (if any) should be treated as the largest values (True) or the smallest values (False) When the array contains unmasked values at the same extremes of the datatype, the ordering of these values and the masked values is undefined.

fill_value
[scalar or None, optional] Value used internally for the masked values. If `fill_value` is not None, it supersedes `endwith`.

stable
[bool, optional] Only for compatibility with `np.argsort`. Ignored.

Returns

index_array
[ndarray, int] Array of indices that sort *a* along the specified axis. In other words, `a[index_array]` yields a sorted *a*.

See also:

ma.MaskedArray.sort
Describes sorting algorithms used.

lexsort
Indirect stable sort with multiple keys.

numpy.ndarray.sort
Inplace sort.

Notes

See *sort* for notes on the different sorting algorithms.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([3,2,1], mask=[False, False, True])
>>> a
masked_array(data=[3, 2, --],
             mask=[False, False,  True],
       fill_value=999999)
>>> a.argsort()
array([1, 0, 2])
```

`ma.sort`(*a*, *axis=-1*, *kind=None*, *order=None*, *endwith=True*, *fill_value=None*, ***, *stable=None*)

Return a sorted copy of the masked array.

Equivalent to creating a copy of the array and applying the MaskedArray `sort()` method.

Refer to `MaskedArray.sort` for the full documentation

See also:

MaskedArray.sort
equivalent method

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = [11.2, -3.973, 0.801, -1.41]
>>> mask = [0, 0, 0, 1]
>>> masked_x = ma.masked_array(x, mask)
>>> masked_x
masked_array(data=[11.2, -3.973, 0.801, --],
             mask=[False, False, False,  True],
       fill_value=1e+20)
>>> ma.sort(masked_x)
masked_array(data=[-3.973, 0.801, 11.2, --],
             mask=[False, False, False,  True],
       fill_value=1e+20)
```

method

`ma.MaskedArray.`**`argsort`**(*axis=<no value>*, *kind=None*, *order=None*, *endwith=True*, *fill_value=None*, *, *stable=False*)

Return an ndarray of indices that sort the array along the specified axis. Masked values are filled beforehand to *fill_value*.

Parameters

axis
[int, optional] Axis along which to sort. If None, the default, the flattened array is used.

kind
[{'quicksort', 'mergesort', 'heapsort', 'stable'}, optional] The sorting algorithm used.

order
[list, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. Not all fields need be specified.

endwith
[{True, False}, optional] Whether missing values (if any) should be treated as the largest values (True) or the smallest values (False) When the array contains unmasked values at the same extremes of the datatype, the ordering of these values and the masked values is undefined.

fill_value
[scalar or None, optional] Value used internally for the masked values. If `fill_value` is not None, it supersedes `endwith`.

stable
[bool, optional] Only for compatibility with `np.argsort`. Ignored.

Returns

index_array
[ndarray, int] Array of indices that sort *a* along the specified axis. In other words, `a[index_array]` yields a sorted *a*.

See also:

ma.MaskedArray.sort
Describes sorting algorithms used.

lexsort
Indirect stable sort with multiple keys.

numpy.ndarray.sort
Inplace sort.

Notes

See *sort* for notes on the different sorting algorithms.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([3,2,1], mask=[False, False, True])
>>> a
masked_array(data=[3, 2, --],
             mask=[False, False,  True],
       fill_value=999999)
>>> a.argsort()
array([1, 0, 2])
```

method

ma.MaskedArray.**sort**(*axis=-1*, *kind=None*, *order=None*, *endwith=True*, *fill_value=None*, *, *stable=False*)

Sort the array, in-place

Parameters

a
[array_like] Array to be sorted.

axis
[int, optional] Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.

kind
[{'quicksort', 'mergesort', 'heapsort', 'stable'}, optional] The sorting algorithm used.

order
[list, optional] When *a* is a structured array, this argument specifies which fields to compare first, second, and so on. This list does not need to include all of the fields.

endwith
[{True, False}, optional] Whether missing values (if any) should be treated as the largest values (True) or the smallest values (False) When the array contains unmasked values sorting at the same extremes of the datatype, the ordering of these values and the masked values is undefined.

fill_value
[scalar or None, optional] Value used internally for the masked values. If `fill_value` is not None, it supersedes `endwith`.

stable
[bool, optional] Only for compatibility with `np.sort`. Ignored.

Returns

sorted_array
[ndarray] Array of the same type and shape as *a*.

See also:

numpy.ndarray.sort
Method to sort an array in-place.

argsort
Indirect sort.

lexsort
Indirect stable sort on multiple keys.

searchsorted
Find elements in a sorted array.

Notes

See `sort` for notes on the different sorting algorithms.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # Default
>>> a.sort()
>>> a
masked_array(data=[1, 3, 5, --, --],
             mask=[False, False, False,  True,  True],
       fill_value=999999)
```

```
>>> a = np.ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # Put missing values in the front
>>> a.sort(endwith=False)
>>> a
masked_array(data=[--, --, 1, 3, 5],
             mask=[ True,  True, False, False, False],
       fill_value=999999)
```

```
>>> a = np.ma.array([1, 2, 5, 4, 3],mask=[0, 1, 0, 1, 0])
>>> # fill_value takes over endwith
>>> a.sort(endwith=False, fill_value=3)
>>> a
masked_array(data=[1, --, --, 3, 5],
             mask=[False,  True,  True, False, False],
       fill_value=999999)
```

Algebra

ma.diag(v[, k])	Extract a diagonal or construct a diagonal array.
ma.dot(a, b[, strict, out])	Return the dot product of two arrays.
ma.identity(n[, dtype])	Return the identity array.
ma.inner(a, b, /)	Inner product of two arrays.
ma.innerproduct(a, b, /)	Inner product of two arrays.
ma.outer(a, b)	Compute the outer product of two vectors.
ma.outerproduct(a, b)	Compute the outer product of two vectors.
ma.trace(self[, offset, axis1, axis2, ...])	Return the sum along diagonals of the array.
ma.transpose(a[, axes])	Permute the dimensions of an array.
ma.MaskedArray.trace([offset, axis1, axis2, ...])	Return the sum along diagonals of the array.
ma.MaskedArray.transpose(*axes)	Returns a view of the array with axes transposed.

ma.**diag**(*v*, *k=0*)

Extract a diagonal or construct a diagonal array.

This function is the equivalent of *numpy.diag* that takes masked values into account, see *numpy.diag* for details.

See also:

numpy.diag
Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
```

Create an array with negative values masked:

```
>>> import numpy as np
>>> x = np.array([[11.2, -3.973, 18], [0.801, -1.41, 12], [7, 33, -12]])
>>> masked_x = np.ma.masked_array(x, mask=x < 0)
>>> masked_x
masked_array(
  data=[[11.2, --, 18.0],
        [0.801, --, 12.0],
        [7.0, 33.0, --]],
  mask=[[False,  True, False],
        [False,  True, False],
        [False, False,  True]],
  fill_value=1e+20)
```

Isolate the main diagonal from the masked array:

```
>>> np.ma.diag(masked_x)
masked_array(data=[11.2, --, --],
             mask=[False,  True,  True],
       fill_value=1e+20)
```

Isolate the first diagonal below the main diagonal:

```
>>> np.ma.diag(masked_x, -1)
masked_array(data=[0.801, 33.0],
             mask=[False, False],
       fill_value=1e+20)
```

ma.**dot**(*a*, *b*, *strict=False*, *out=None*)

Return the dot product of two arrays.

This function is the equivalent of *numpy.dot* that takes masked values into account. Note that *strict* and *out* are in different position than in the method version. In order to maintain compatibility with the corresponding method, it is recommended that the optional arguments be treated as keyword only. At some point that may be mandatory.

Parameters

a, b
[masked_array_like] Inputs arrays.

strict
[bool, optional] Whether masked data are propagated (True) or set to 0 (False) for the computation. Default is False. Propagating the mask means that if a masked value appears in a row or column, the whole row or column is considered masked.

out
[masked_array, optional] Output argument. This must have the exact kind that would be returned if it was not used. In particular, it must have the right type, must be C-contiguous, and its dtype must be the dtype that would be returned for *dot(a,b)*. This is a performance feature. Therefore, if these conditions are not met, an exception is raised, instead of attempting to be flexible.

See also:

numpy.dot
Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([[1, 2, 3], [4, 5, 6]], mask=[[1, 0, 0], [0, 0, 0]])
>>> b = np.ma.array([[1, 2], [3, 4], [5, 6]], mask=[[1, 0], [0, 0], [0, 0]])
>>> np.ma.dot(a, b)
masked_array(
  data=[[21, 26],
        [45, 64]],
  mask=[[False, False],
        [False, False]],
  fill_value=999999)
>>> np.ma.dot(a, b, strict=True)
masked_array(
  data=[[--, --],
        [--, 64]],
  mask=[[ True,  True],
        [ True, False]],
  fill_value=999999)
```

ma.**identity**(*n*, *dtype=None*) **= <numpy.ma.core._convert2ma object>**

Return the identity array.

The identity array is a square array with ones on the main diagonal.

Parameters

n
[int] Number of rows (and columns) in *n* x *n* output.

dtype
[data-type, optional] Data-type of the output. Defaults to `float`.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[MaskedArray] *n* x *n* array with its main diagonal set to one, and all other elements 0.

Examples

```
>>> import numpy as np
>>> np.identity(3)
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
```

`ma.`**`inner`**(*a*, *b*, */*)

Inner product of two arrays.

Ordinary inner product of vectors for 1-D arrays (without complex conjugation), in higher dimensions a sum product over the last axes.

Parameters

a, b
[array_like] If *a* and *b* are nonscalar, their last dimensions must match.

Returns

out
[ndarray] If *a* and *b* are both scalars or both 1-D arrays then a scalar is returned; otherwise an array is returned. `out.shape = (*a.shape[:-1], *b.shape[:-1])`

Raises

ValueError
If both *a* and *b* are nonscalar and their last dimensions have different sizes.

See also:

tensordot
Sum products over arbitrary axes.

dot
Generalised matrix product, using second last dimension of *b*.

vecdot
Vector dot product of two arrays.

einsum
Einstein summation convention.

Notes

Masked values are replaced by 0.

For vectors (1-D arrays) it computes the ordinary inner-product:

```
np.inner(a, b) = sum(a[:]*b[:])
```

More generally, if `ndim(a) = r > 0` and `ndim(b) = s > 0`:

```
np.inner(a, b) = np.tensordot(a, b, axes=(-1,-1))
```

or explicitly:

```
np.inner(a, b)[i0,...,ir-2,j0,...,js-2]
     = sum(a[i0,...,ir-2,:]*b[j0,...,js-2,:])
```

In addition *a* or *b* may be scalars, in which case:

```
np.inner(a,b) = a*b
```

Examples

Ordinary inner product for vectors:

```
>>> import numpy as np
>>> a = np.array([1,2,3])
>>> b = np.array([0,1,0])
>>> np.inner(a, b)
2
```

Some multidimensional examples:

```
>>> a = np.arange(24).reshape((2,3,4))
>>> b = np.arange(4)
>>> c = np.inner(a, b)
>>> c.shape
(2, 3)
>>> c
array([[ 14,  38,  62],
       [ 86, 110, 134]])
```

```
>>> a = np.arange(2).reshape((1,1,2))
>>> b = np.arange(6).reshape((3,2))
>>> c = np.inner(a, b)
>>> c.shape
(1, 1, 3)
>>> c
array([[[1, 3, 5]]])
```

An example where *b* is a scalar:

```
>>> np.inner(np.eye(2), 7)
array([[7., 0.],
       [0., 7.]])
```

ma.**innerproduct**(*a*, *b*, */*)

Inner product of two arrays.

Ordinary inner product of vectors for 1-D arrays (without complex conjugation), in higher dimensions a sum product over the last axes.

Parameters

a, b
[array_like] If *a* and *b* are nonscalar, their last dimensions must match.

Returns

out
[ndarray] If *a* and *b* are both scalars or both 1-D arrays then a scalar is returned; otherwise an array is returned. `out.shape = (*a.shape[:-1], *b.shape[:-1])`

Raises

ValueError
If both *a* and *b* are nonscalar and their last dimensions have different sizes.

See also:

tensordot
Sum products over arbitrary axes.

dot
Generalised matrix product, using second last dimension of *b*.

vecdot
Vector dot product of two arrays.

einsum
Einstein summation convention.

Notes

Masked values are replaced by 0.

For vectors (1-D arrays) it computes the ordinary inner-product:

```
np.inner(a, b) = sum(a[:]*b[:])
```

More generally, if `ndim(a) = r > 0` and `ndim(b) = s > 0`:

```
np.inner(a, b) = np.tensordot(a, b, axes=(-1,-1))
```

or explicitly:

```
np.inner(a, b)[i0,...,ir-2,j0,...,js-2]
     = sum(a[i0,...,ir-2,:]*b[j0,...,js-2,:])
```

In addition *a* or *b* may be scalars, in which case:

```
np.inner(a,b) = a*b
```

Examples

Ordinary inner product for vectors:

```
>>> import numpy as np
>>> a = np.array([1,2,3])
>>> b = np.array([0,1,0])
>>> np.inner(a, b)
2
```

Some multidimensional examples:

```
>>> a = np.arange(24).reshape((2,3,4))
>>> b = np.arange(4)
>>> c = np.inner(a, b)
>>> c.shape
(2, 3)
>>> c
array([[ 14,  38,  62],
       [ 86, 110, 134]])
```

```
>>> a = np.arange(2).reshape((1,1,2))
>>> b = np.arange(6).reshape((3,2))
>>> c = np.inner(a, b)
>>> c.shape
(1, 1, 3)
>>> c
array([[[1, 3, 5]]])
```

An example where *b* is a scalar:

```
>>> np.inner(np.eye(2), 7)
array([[7., 0.],
       [0., 7.]])
```

ma.**outer**(*a*, *b*)

Compute the outer product of two vectors.

Given two vectors *a* and *b* of length `M` and `N`, respectively, the outer product [1] is:

```
[[a_0*b_0  a_0*b_1 ... a_0*b_{N-1} ]
 [a_1*b_0    .
 [ ...          .
 [a_{M-1}*b_0            a_{M-1}*b_{N-1} ]]
```

Parameters

a

[(M,) array_like] First input vector. Input is flattened if not already 1-dimensional.

b

[(N,) array_like] Second input vector. Input is flattened if not already 1-dimensional.

out
[(M, N) ndarray, optional] A location where the result is stored

Returns

out
[(M, N) ndarray] `out[i, j] = a[i] * b[j]`

See also:

inner
einsum
`einsum('i,j->ij', a.ravel(), b.ravel())` is the equivalent.

ufunc.outer
A generalization to dimensions other than 1D and other operations. `np.multiply.outer(a.ravel(), b.ravel())` is the equivalent.

linalg.outer
An Array API compatible variation of `np.outer`, which accepts 1-dimensional inputs only.

tensordot
`np.tensordot(a.ravel(), b.ravel(), axes=((), ()))` is the equivalent.

Notes

Masked values are replaced by 0.

References

[1]

Examples

Make a (*very* coarse) grid for computing a Mandelbrot set:

```
>>> import numpy as np
>>> rl = np.outer(np.ones((5,)), np.linspace(-2, 2, 5))
>>> rl
array([[-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.]])
>>> im = np.outer(1j*np.linspace(2, -2, 5), np.ones((5,)))
>>> im
array([[0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j],
       [0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j],
       [0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j],
       [0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j],
       [0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j]])
>>> grid = rl + im
>>> grid
array([[-2.+2.j, -1.+2.j,  0.+2.j,  1.+2.j,  2.+2.j],
       [-2.+1.j, -1.+1.j,  0.+1.j,  1.+1.j,  2.+1.j],
```

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```
       [-2.+0.j, -1.+0.j,  0.+0.j,  1.+0.j,  2.+0.j],
       [-2.-1.j, -1.-1.j,  0.-1.j,  1.-1.j,  2.-1.j],
       [-2.-2.j, -1.-2.j,  0.-2.j,  1.-2.j,  2.-2.j]])
```

An example using a “vector” of letters:

```
>>> x = np.array(['a', 'b', 'c'], dtype=object)
>>> np.outer(x, [1, 2, 3])
array([['a', 'aa', 'aaa'],
       ['b', 'bb', 'bbb'],
       ['c', 'cc', 'ccc']], dtype=object)
```

ma.**outerproduct**(*a*, *b*)

Compute the outer product of two vectors.

Given two vectors *a* and *b* of length `M` and `N`, respectively, the outer product [1] is:

```
[[a_0*b_0  a_0*b_1 ... a_0*b_{N-1} ]
 [a_1*b_0    .
 [ ...          .
 [a_{M-1}*b_0            a_{M-1}*b_{N-1} ]]
```

Parameters

a
: [(M,) array_like] First input vector. Input is flattened if not already 1-dimensional.

b
: [(N,) array_like] Second input vector. Input is flattened if not already 1-dimensional.

out
: [(M, N) ndarray, optional] A location where the result is stored

Returns

out
: [(M, N) ndarray] `out[i, j] = a[i] * b[j]`

See also:

inner

einsum
: `einsum('i,j->ij', a.ravel(), b.ravel())` is the equivalent.

ufunc.outer
: A generalization to dimensions other than 1D and other operations. `np.multiply.outer(a.ravel(), b.ravel())` is the equivalent.

linalg.outer
: An Array API compatible variation of `np.outer`, which accepts 1-dimensional inputs only.

tensordot
: `np.tensordot(a.ravel(), b.ravel(), axes=((), ()))` is the equivalent.

Notes

Masked values are replaced by 0.

References

[1]

Examples

Make a (*very* coarse) grid for computing a Mandelbrot set:

```
>>> import numpy as np
>>> rl = np.outer(np.ones((5,)), np.linspace(-2, 2, 5))
>>> rl
array([[-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.],
       [-2., -1.,  0.,  1.,  2.]])
>>> im = np.outer(1j*np.linspace(2, -2, 5), np.ones((5,)))
>>> im
array([[0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j, 0.+2.j],
       [0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j, 0.+1.j],
       [0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j],
       [0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j, 0.-1.j],
       [0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j, 0.-2.j]])
>>> grid = rl + im
>>> grid
array([[-2.+2.j, -1.+2.j,  0.+2.j,  1.+2.j,  2.+2.j],
       [-2.+1.j, -1.+1.j,  0.+1.j,  1.+1.j,  2.+1.j],
       [-2.+0.j, -1.+0.j,  0.+0.j,  1.+0.j,  2.+0.j],
       [-2.-1.j, -1.-1.j,  0.-1.j,  1.-1.j,  2.-1.j],
       [-2.-2.j, -1.-2.j,  0.-2.j,  1.-2.j,  2.-2.j]])
```

An example using a “vector” of letters:

```
>>> x = np.array(['a', 'b', 'c'], dtype=object)
>>> np.outer(x, [1, 2, 3])
array([['a', 'aa', 'aaa'],
       ['b', 'bb', 'bbb'],
       ['c', 'cc', 'ccc']], dtype=object)
```

ma.**trace**(*self*, *offset=0*, *axis1=0*, *axis2=1*, *dtype=None*, *out=None*) *a.trace(offset=0, axis1=0, axis2=1, dtype=None, out=None)* **= <numpy.ma.core._frommethod object>**

Return the sum along diagonals of the array.

Refer to *numpy.trace* for full documentation.

See also:

numpy.trace
equivalent function

method

ma.MaskedArray.**trace**(*offset=0*, *axis1=0*, *axis2=1*, *dtype=None*, *out=None*)

Return the sum along diagonals of the array.

Refer to *numpy.trace* for full documentation.

See also:

numpy.trace
equivalent function

Polynomial fit

ma.vander(x[, n])	Generate a Vandermonde matrix.
ma.polyfit(x, y, deg[, rcond, full, w, cov])	Least squares polynomial fit.

ma.**vander**(*x*, *n=None*)

Generate a Vandermonde matrix.

The columns of the output matrix are powers of the input vector. The order of the powers is determined by the *increasing* boolean argument. Specifically, when *increasing* is False, the *i*-th output column is the input vector raised element-wise to the power of `N - i - 1`. Such a matrix with a geometric progression in each row is named for Alexandre- Theophile Vandermonde.

Parameters

x
[array_like] 1-D input array.

N
[int, optional] Number of columns in the output. If *N* is not specified, a square array is returned (`N = len(x)`).

increasing
[bool, optional] Order of the powers of the columns. If True, the powers increase from left to right, if False (the default) they are reversed.

Returns

out
[ndarray] Vandermonde matrix. If *increasing* is False, the first column is `x^(N-1)`, the second `x^(N-2)` and so forth. If *increasing* is True, the columns are `x^0, x^1, ..., x^(N-1)`.

See also:

polynomial.polynomial.polyvander

Notes

Masked values in the input array result in rows of zeros.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 3, 5])
>>> N = 3
>>> np.vander(x, N)
array([[ 1,  1,  1],
       [ 4,  2,  1],
       [ 9,  3,  1],
       [25,  5,  1]])
```

```
>>> np.column_stack([x**(N-1-i) for i in range(N)])
array([[ 1,  1,  1],
       [ 4,  2,  1],
       [ 9,  3,  1],
       [25,  5,  1]])
```

```
>>> x = np.array([1, 2, 3, 5])
>>> np.vander(x)
array([[  1,   1,   1,   1],
       [  8,   4,   2,   1],
       [ 27,   9,   3,   1],
       [125,  25,   5,   1]])
>>> np.vander(x, increasing=True)
array([[  1,   1,   1,   1],
       [  1,   2,   4,   8],
       [  1,   3,   9,  27],
       [  1,   5,  25, 125]])
```

The determinant of a square Vandermonde matrix is the product of the differences between the values of the input vector:

```
>>> np.linalg.det(np.vander(x))
48.000000000000043 # may vary
>>> (5-3)*(5-2)*(5-1)*(3-2)*(3-1)*(2-1)
48
```

ma.**polyfit**(*x*, *y*, *deg*, *rcond=None*, *full=False*, *w=None*, *cov=False*)

Least squares polynomial fit.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

Fit a polynomial `p(x) = p[0] * x**deg + ... + p[deg]` of degree *deg* to points *(x, y)*. Returns a vector of coefficients *p* that minimises the squared error in the order *deg*, *deg-1*, … *0*.

The *Polynomial.fit* class method is recommended for new code as it is more stable numerically. See the documentation of the method for more information.

Parameters

x
: [array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
: [array_like, shape (M,) or (M, K)] y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg
: [int] Degree of the fitting polynomial

rcond
: [float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
: [bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
: [array_like, shape (M,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

cov
: [bool or str, optional] If given and not *False*, return not just the estimate but also its covariance matrix. By default, the covariance are scaled by chi2/dof, where dof = M - (deg + 1), i.e., the weights are presumed to be unreliable except in a relative sense and everything is scaled such that the reduced chi2 is unity. This scaling is omitted if `cov='unscaled'`, as is relevant for the case that the weights are w = 1/sigma, with sigma known to be a reliable estimate of the uncertainty.

Returns

p
: [ndarray, shape (deg + 1,) or (deg + 1, K)] Polynomial coefficients, highest power first. If *y* was 2-D, the coefficients for *k*-th data set are in `p[:,k]`.

residuals, rank, singular_values, rcond
: These values are only returned if `full == True`

- residuals – sum of squared residuals of the least squares fit
- **rank – the effective rank of the scaled Vandermonde**
  coefficient matrix
- **singular_values – singular values of the scaled Vandermonde**
  coefficient matrix
- rcond – value of *rcond*.

For more details, see *numpy.linalg.lstsq*.

V
: [ndarray, shape (deg + 1, deg + 1) or (deg + 1, deg + 1, K)] Present only if `full == False` and `cov == True`. The covariance matrix of the polynomial coefficient estimates. The diagonal of this matrix are the variance estimates for each coefficient. If y is a 2-D array, then the covariance matrix for the *k*-th data set are in `V[:,:,k]`

Warns

RankWarning

The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if `full == False`.

The warnings can be turned off by

```
>>> import warnings
>>> warnings.simplefilter('ignore', np.exceptions.RankWarning)
```

See also:

polyval
Compute polynomial values.

linalg.lstsq
Computes a least-squares fit.

scipy.interpolate.UnivariateSpline
Computes spline fits.

Notes

Any masked values in x is propagated in y, and vice-versa.

The solution minimizes the squared error

$$E = \sum_{j=0}^{k} |p(x_j) - y_j|^2$$

in the equations:

```
x[0]**n * p[0] + ... + x[0] * p[n-1] + p[n] = y[0]
x[1]**n * p[0] + ... + x[1] * p[n-1] + p[n] = y[1]
...
x[k]**n * p[0] + ... + x[k] * p[n-1] + p[n] = y[k]
```

The coefficient matrix of the coefficients *p* is a Vandermonde matrix.

polyfit issues a *RankWarning* when the least-squares fit is badly conditioned. This implies that the best fit is not well-defined due to numerical error. The results may be improved by lowering the polynomial degree or by replacing *x* by *x* - *x*.mean(). The *rcond* parameter can also be set to a value smaller than its default, but the resulting fit may be spurious: including contributions from the small singular values can add numerical noise to the result.

Note that fitting polynomial coefficients is inherently badly conditioned when the degree of the polynomial is large or the interval of sample points is badly centered. The quality of the fit should always be checked in these cases. When polynomial fits are not satisfactory, splines may be a good alternative.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> import warnings
>>> x = np.array([0.0, 1.0, 2.0, 3.0,  4.0,  5.0])
>>> y = np.array([0.0, 0.8, 0.9, 0.1, -0.8, -1.0])
>>> z = np.polyfit(x, y, 3)
>>> z
array([ 0.08703704, -0.81349206,  1.69312169, -0.03968254]) # may vary
```

It is convenient to use *poly1d* objects for dealing with polynomials:

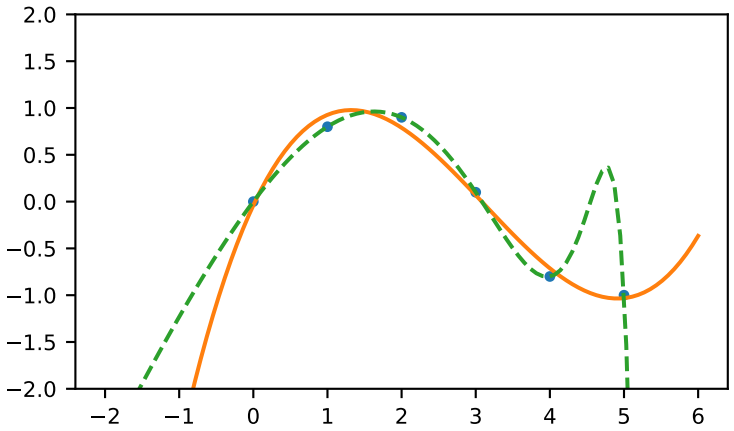
```
>>> p = np.poly1d(z)
>>> p(0.5)
0.6143849206349179 # may vary
>>> p(3.5)
-0.34732142857143039 # may vary
>>> p(10)
22.579365079365115 # may vary
```

High-order polynomials may oscillate wildly:

```
>>> with warnings.catch_warnings():
...     warnings.simplefilter('ignore', np.exceptions.RankWarning)
...     p30 = np.poly1d(np.polyfit(x, y, 30))
...
>>> p30(4)
-0.80000000000000204 # may vary
>>> p30(5)
-0.99999999999999445 # may vary
>>> p30(4.5)
-0.10547061179440398 # may vary
```

Illustration:

```
>>> import matplotlib.pyplot as plt
>>> xp = np.linspace(-2, 6, 100)
>>> _ = plt.plot(x, y, '.', xp, p(xp), '-', xp, p30(xp), '--')
>>> plt.ylim(-2,2)
(-2, 2)
>>> plt.show()
```



Clipping and rounding

ma.around	Round an array to the given number of decimals.
ma.clip	Clip (limit) the values in an array.
ma.round(a[, decimals, out])	Return a copy of a, rounded to 'decimals' places.
ma.MaskedArray.clip([min, max, out])	Return an array whose values are limited to `[min, max]`.
ma.MaskedArray.round([decimals, out])	Return each element rounded to the given number of decimals.

ma.around = <numpy.ma.core._MaskedUnaryOperation object>

Round an array to the given number of decimals.

around is an alias of *round*.

See also:

ndarray.round
equivalent method

round
alias for this function

ceil, ***fix***, ***floor***, ***rint***, ***trunc***

ma.clip = <numpy.ma.core._convert2ma object>

Clip (limit) the values in an array.

Given an interval, values outside the interval are clipped to the interval edges. For example, if an interval of `[0, 1]` is specified, values smaller than 0 become 0, and values larger than 1 become 1.

Equivalent to but faster than `np.minimum(a_max, np.maximum(a, a_min))`.

No check is performed to ensure `a_min < a_max`.

Parameters

a
: [array_like] Array containing elements to clip.

a_min, a_max
: [array_like or None] Minimum and maximum value. If `None`, clipping is not performed on the corresponding edge. If both `a_min` and `a_max` are `None`, the elements of the returned array stay the same. Both are broadcasted against `a`.

out
: [ndarray, optional] The results will be placed in this array. It may be the input array for in-place clipping. *out* must be of the right shape to hold the output. Its type is preserved.

min, max
: [array_like or None] Array API compatible alternatives for `a_min` and `a_max` arguments. Either `a_min` and `a_max` or `min` and `max` can be passed at the same time. Default: `None`.

  New in version 2.1.0.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

clipped_array
: [MaskedArray] An array with the elements of *a*, but where values < *a_min* are replaced with *a_min*, and those > *a_max* with *a_max*.

See also:

ufuncs-output-type

Notes

When *a_min* is greater than *a_max*, `clip` returns an array in which all values are equal to *a_max*, as shown in the second example.

Examples

```
>>> import numpy as np
>>> a = np.arange(10)
>>> a
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> np.clip(a, 1, 8)
array([1, 1, 2, 3, 4, 5, 6, 7, 8, 8])
>>> np.clip(a, 8, 1)
array([1, 1, 1, 1, 1, 1, 1, 1, 1, 1])
>>> np.clip(a, 3, 6, out=a)
array([3, 3, 3, 3, 4, 5, 6, 6, 6, 6])
>>> a
array([3, 3, 3, 3, 4, 5, 6, 6, 6, 6])
>>> a = np.arange(10)
>>> a
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> np.clip(a, [3, 4, 1, 1, 1, 4, 4, 4, 4, 4], 8)
array([3, 4, 2, 3, 4, 5, 6, 7, 8, 8])
```

ma.**round**(*a*, *decimals=0*, *out=None*)

Return a copy of a, rounded to 'decimals' places.

When 'decimals' is negative, it specifies the number of positions to the left of the decimal point. The real and imaginary parts of complex numbers are rounded separately. Nothing is done if the array is not of float type and 'decimals' is greater than or equal to 0.

Parameters

decimals
[int] Number of decimals to round to. May be negative.

out
[array_like] Existing array to use for output. If not given, returns a default copy of a.

Notes

If out is given and does not have a mask attribute, the mask of a is lost!

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = [11.2, -3.973, 0.801, -1.41]
>>> mask = [0, 0, 0, 1]
>>> masked_x = ma.masked_array(x, mask)
>>> masked_x
masked_array(data=[11.2, -3.973, 0.801, --],
             mask=[False, False, False, True],
    fill_value=1e+20)
>>> ma.round_(masked_x)
masked_array(data=[11.0, -4.0, 1.0, --],
             mask=[False, False, False, True],
    fill_value=1e+20)
>>> ma.round(masked_x, decimals=1)
masked_array(data=[11.2, -4.0, 0.8, --],
             mask=[False, False, False, True],
    fill_value=1e+20)
>>> ma.round_(masked_x, decimals=-1)
masked_array(data=[10.0, -0.0, 0.0, --],
             mask=[False, False, False, True],
    fill_value=1e+20)
```

method

ma.MaskedArray.**clip**(*min=None*, *max=None*, *out=None*, ***kwargs*)

Return an array whose values are limited to `[min, max]`. One of max or min must be given.

Refer to *numpy.clip* for full documentation.

See also:

numpy.clip
equivalent function

method

ma.MaskedArray.**round**(*decimals=0*, *out=None*)

Return each element rounded to the given number of decimals.

Refer to *numpy.around* for full documentation.

See also:

numpy.ndarray.round
corresponding function for ndarrays

numpy.around
equivalent function

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = ma.array([1.35, 2.5, 1.5, 1.75, 2.25, 2.75],
...              mask=[0, 0, 0, 1, 0, 0])
>>> ma.round(x)
masked_array(data=[1.0, 2.0, 2.0, --, 2.0, 3.0],
             mask=[False, False, False,  True, False, False],
       fill_value=1e+20)
```

Set operations

ma.intersect1d(ar1, ar2[, assume_unique])	Returns the unique elements common to both arrays.
ma.setdiff1d(ar1, ar2[, assume_unique])	Set difference of 1D arrays with unique elements.
ma.setxor1d(ar1, ar2[, assume_unique])	Set exclusive-or of 1-D arrays with unique elements.
ma.union1d(ar1, ar2)	Union of two arrays.

ma.**intersect1d**(*ar1*, *ar2*, *assume_unique=False*)

Returns the unique elements common to both arrays.

Masked values are considered equal one to the other. The output is always a masked array.

See *numpy.intersect1d* for more details.

See also:

numpy.intersect1d
Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([1, 3, 3, 3], mask=[0, 0, 0, 1])
>>> y = np.ma.array([3, 1, 1, 1], mask=[0, 0, 0, 1])
>>> np.ma.intersect1d(x, y)
masked_array(data=[1, 3, --],
             mask=[False, False,  True],
       fill_value=999999)
```

ma.**setdiff1d**(*ar1*, *ar2*, *assume_unique=False*)

Set difference of 1D arrays with unique elements.

The output is always a masked array. See *numpy.setdiff1d* for more details.

See also:

numpy.setdiff1d
Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([1, 2, 3, 4], mask=[0, 1, 0, 1])
>>> np.ma.setdiff1d(x, [1, 2])
masked_array(data=[3, --],
             mask=[False,  True],
       fill_value=999999)
```

ma.**setxor1d**(*ar1*, *ar2*, *assume_unique=False*)

Set exclusive-or of 1-D arrays with unique elements.

The output is always a masked array. See *numpy.setxor1d* for more details.

See also:

numpy.setxor1d
Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
>>> ar1 = np.ma.array([1, 2, 3, 2, 4])
>>> ar2 = np.ma.array([2, 3, 5, 7, 5])
>>> np.ma.setxor1d(ar1, ar2)
masked_array(data=[1, 4, 5, 7],
             mask=False,
       fill_value=999999)
```

ma.**union1d**(*ar1*, *ar2*)

Union of two arrays.

The output is always a masked array. See *numpy.union1d* for more details.

See also:

numpy.union1d
Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
>>> ar1 = np.ma.array([1, 2, 3, 4])
>>> ar2 = np.ma.array([3, 4, 5, 6])
>>> np.ma.union1d(ar1, ar2)
masked_array(data=[1, 2, 3, 4, 5, 6],
             mask=False,
       fill_value=999999)
```

Miscellanea

ma.allequal(a, b[, fill_value])	Return True if all entries of a and b are equal, using fill_value as a truth value where either or both are masked.
ma.allclose(a, b[, masked_equal, rtol, atol])	Returns True if two arrays are element-wise equal within a tolerance.
ma.amax(a[, axis, out, keepdims, initial, where])	Return the maximum of an array or maximum along an axis.
ma.amin(a[, axis, out, keepdims, initial, where])	Return the minimum of an array or minimum along an axis.
ma.apply_along_axis(func1d, axis, arr, ...)	Apply a function to 1-D slices along the given axis.
ma.apply_over_axes(func, a, axes)	Apply a function repeatedly over multiple axes.
ma.arange([start,] stop[, step,][, dtype, ...])	Return evenly spaced values within a given interval.
ma.choose(indices, choices[, out, mode])	Use an index array to construct a new array from a list of choices.
ma.compress_nd(x[, axis])	Suppress slices from multiple dimensions which contain masked values.
ma.convolve(a, v[, mode, propagate_mask])	Returns the discrete, linear convolution of two one-dimensional sequences.
ma.correlate(a, v[, mode, propagate_mask])	Cross-correlation of two 1-dimensional sequences.
ma.ediff1d(arr[, to_end, to_begin])	Compute the differences between consecutive elements of an array.
ma.flatten_mask(mask)	Returns a completely flattened version of the mask, where nested fields are collapsed.
ma.flatten_structured_array(a)	Flatten a structured array.
ma.fromflex(fxarray)	Build a masked array from a suitable flexible-type array.
ma.indices(dimensions[, dtype, sparse])	Return an array representing the indices of a grid.
ma.left_shift(a, n)	Shift the bits of an integer to the left.
ma.ndim(obj)	Return the number of dimensions of an array.
ma.put(a, indices, values[, mode])	Set storage-indexed locations to corresponding values.
ma.putmask(a, mask, values)	Changes elements of an array based on conditional and input values.
ma.right_shift(a, n)	Shift the bits of an integer to the right.
*ma.round_*(a[, decimals, out])	Return a copy of a, rounded to 'decimals' places.
ma.take(a, indices[, axis, out, mode])	
ma.where(condition[, x, y])	Return a masked array with elements from *x* or *y*, depending on condition.

ma.**allequal**(*a*, *b*, *fill_value=True*)

Return True if all entries of a and b are equal, using fill_value as a truth value where either or both are masked.

Parameters

a, b
[array_like] Input arrays to compare.

fill_value
[bool, optional] Whether masked values in a or b are considered equal (True) or not (False).

Returns

y
[bool] Returns True if the two arrays are equal within the given tolerance, False otherwise. If either array contains NaN, then False is returned.

See also:

all, *any*
numpy.ma.allclose

Examples

```
>>> import numpy as np
>>> a = np.ma.array([1e10, 1e-7, 42.0], mask=[0, 0, 1])
>>> a
masked_array(data=[10000000000.0, 1e-07, --],
             mask=[False, False,  True],
       fill_value=1e+20)
```

```
>>> b = np.array([1e10, 1e-7, -42.0])
>>> b
array([  1.00000000e+10,   1.00000000e-07,  -4.20000000e+01])
>>> np.ma.allequal(a, b, fill_value=False)
False
>>> np.ma.allequal(a, b)
True
```

ma.**allclose**(*a*, *b*, *masked_equal=True*, *rtol=1e-05*, *atol=1e-08*)

Returns True if two arrays are element-wise equal within a tolerance.

This function is equivalent to *allclose* except that masked values are treated as equal (default) or unequal, depending on the *masked_equal* argument.

Parameters

a, b
[array_like] Input arrays to compare.

masked_equal
[bool, optional] Whether masked values in *a* and *b* are considered equal (True) or not (False). They are considered equal by default.

rtol
[float, optional] Relative tolerance. The relative difference is equal to `rtol * b`. Default is 1e-5.

atol
[float, optional] Absolute tolerance. The absolute difference is equal to *atol*. Default is 1e-8.

Returns

y
[bool] Returns True if the two arrays are equal within the given tolerance, False otherwise. If either array contains NaN, then False is returned.

See also:

all*, *any
numpy.allclose
the non-masked *allclose*.

Notes

If the following equation is element-wise True, then *allclose* returns True:

```
absolute(`a` - `b`) <= (`atol` + `rtol` * absolute(`b`))
```

Return True if all elements of *a* and *b* are equal subject to given tolerances.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([1e10, 1e-7, 42.0], mask=[0, 0, 1])
>>> a
masked_array(data=[10000000000.0, 1e-07, --],
             mask=[False, False,  True],
       fill_value=1e+20)
>>> b = np.ma.array([1e10, 1e-8, -42.0], mask=[0, 0, 1])
>>> np.ma.allclose(a, b)
False
```

```
>>> a = np.ma.array([1e10, 1e-8, 42.0], mask=[0, 0, 1])
>>> b = np.ma.array([1.00001e10, 1e-9, -42.0], mask=[0, 0, 1])
>>> np.ma.allclose(a, b)
True
>>> np.ma.allclose(a, b, masked_equal=False)
False
```

Masked values are not compared directly.

```
>>> a = np.ma.array([1e10, 1e-8, 42.0], mask=[0, 0, 1])
>>> b = np.ma.array([1.00001e10, 1e-9, 42.0], mask=[0, 0, 1])
>>> np.ma.allclose(a, b)
True
>>> np.ma.allclose(a, b, masked_equal=False)
False
```

ma.**amax**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the maximum of an array or maximum along an axis.

amax is an alias of *max*.

See also:

max
alias of this function

ndarray.max
equivalent method

ma.**amin**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the minimum of an array or minimum along an axis.

amin is an alias of *min*.

See also:

min
alias of this function

ndarray.min
equivalent method

ma.**apply_along_axis**(*func1d*, *axis*, *arr*, **args*, ***kwargs*)

Apply a function to 1-D slices along the given axis.

Execute *func1d(a, *args, **kwargs)* where *func1d* operates on 1-D arrays and *a* is a 1-D slice of *arr* along *axis*.

This is equivalent to (but faster than) the following use of *ndindex* and *s_*, which sets each of `ii`, `jj`, and `kk` to a tuple of indices:

```
Ni, Nk = a.shape[:axis], a.shape[axis+1:]
for ii in ndindex(Ni):
    for kk in ndindex(Nk):
        f = func1d(arr[ii + s_[:,] + kk])
        Nj = f.shape
        for jj in ndindex(Nj):
            out[ii + jj + kk] = f[jj]
```

Equivalently, eliminating the inner loop, this can be expressed as:

```
Ni, Nk = a.shape[:axis], a.shape[axis+1:]
for ii in ndindex(Ni):
    for kk in ndindex(Nk):
        out[ii + s_[...,] + kk] = func1d(arr[ii + s_[:,] + kk])
```

Parameters

func1d
[function (M,) -> (Nj…)] This function should accept 1-D arrays. It is applied to 1-D slices of *arr* along the specified axis.

axis
[integer] Axis along which *arr* is sliced.

arr
[ndarray (Ni…, M, Nk…)] Input array.

args
[any] Additional arguments to *func1d*.

kwargs
[any] Additional named arguments to *func1d*.

Returns

out

[ndarray (Ni…, Nj…, Nk…)] The output array. The shape of *out* is identical to the shape of *arr*, except along the *axis* dimension. This axis is removed, and replaced with new dimensions equal to the shape of the return value of *func1d*. So if *func1d* returns a scalar *out* will have one fewer dimensions than *arr*.

See also:

apply_over_axes

Apply a function repeatedly over multiple axes.

Examples

```
>>> import numpy as np
>>> def my_func(a):
...     """Average first and last element of a 1-D array"""
...     return (a[0] + a[-1]) * 0.5
>>> b = np.array([[1,2,3], [4,5,6], [7,8,9]])
>>> np.apply_along_axis(my_func, 0, b)
array([4., 5., 6.])
>>> np.apply_along_axis(my_func, 1, b)
array([2.,  5.,  8.])
```

For a function that returns a 1D array, the number of dimensions in *outarr* is the same as *arr*.

```
>>> b = np.array([[8,1,7], [4,3,9], [5,2,6]])
>>> np.apply_along_axis(sorted, 1, b)
array([[1, 7, 8],
       [3, 4, 9],
       [2, 5, 6]])
```

For a function that returns a higher dimensional array, those dimensions are inserted in place of the *axis* dimension.

```
>>> b = np.array([[1,2,3], [4,5,6], [7,8,9]])
>>> np.apply_along_axis(np.diag, -1, b)
array([[[1, 0, 0],
        [0, 2, 0],
        [0, 0, 3]],
       [[4, 0, 0],
        [0, 5, 0],
        [0, 0, 6]],
       [[7, 0, 0],
        [0, 8, 0],
        [0, 0, 9]]])
```

ma.**apply_over_axes**(*func*, *a*, *axes*)

Apply a function repeatedly over multiple axes.

func is called as *res* = *func(a, axis)*, where *axis* is the first element of *axes*. The result *res* of the function call must have either the same dimensions as *a* or one less dimension. If *res* has one less dimension than *a*, a dimension is inserted before *axis*. The call to *func* is then repeated for each axis in *axes*, with *res* as the first argument.

Parameters

func
: [function] This function must take two arguments, *func(a, axis)*.

a
: [array_like] Input array.

axes
: [array_like] Axes over which *func* is applied; the elements must be integers.

Returns

apply_over_axis
: [ndarray] The output array. The number of dimensions is the same as *a*, but the shape can be different. This depends on whether *func* changes the shape of its output with respect to its input.

See also:

apply_along_axis
: Apply a function to 1-D slices of an array along the given axis.

Examples

```
>>> import numpy as np
>>> a = np.ma.arange(24).reshape(2,3,4)
>>> a[:,0,1] = np.ma.masked
>>> a[:,1,:] = np.ma.masked
>>> a
masked_array(
  data=[[[0, --, 2, 3],
         [--, --, --, --],
         [8, 9, 10, 11]],
        [[12, --, 14, 15],
         [--, --, --, --],
         [20, 21, 22, 23]]],
  mask=[[[False,  True, False, False],
         [ True,  True,  True,  True],
         [False, False, False, False]],
        [[False,  True, False, False],
         [ True,  True,  True,  True],
         [False, False, False, False]]],
  fill_value=999999)
>>> np.ma.apply_over_axes(np.ma.sum, a, [0,2])
masked_array(
  data=[[[46],
         [--],
         [124]]],
  mask=[[[False],
         [ True],
         [False]]],
  fill_value=999999)
```

Tuple axis arguments to ufuncs are equivalent:

```
>>> np.ma.sum(a, axis=(0,2)).reshape((1,-1,1))
masked_array(
  data=[[[46],
```

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```
        [--],
        [124]]],
  mask=[[[False],
        [ True],
        [False]]],
  fill_value=999999)
```

ma.**arange**([*start*,]*stop*, [*step*,]*dtype=None*, *, *device=None*, *like=None*) **= <numpy.ma.core._convert2ma object>**

Return evenly spaced values within a given interval.

`arange` can be called with a varying number of positional arguments:

- `arange(stop)`: Values are generated within the half-open interval `[0, stop)` (in other words, the interval including *start* but excluding *stop*).
- `arange(start, stop)`: Values are generated within the half-open interval `[start, stop)`.
- `arange(start, stop, step)` Values are generated within the half-open interval `[start, stop)`, with spacing between values given by `step`.

For integer arguments the function is roughly equivalent to the Python built-in `range`, but returns an ndarray rather than a `range` instance.

When using a non-integer step, such as 0.1, it is often better to use *numpy.linspace*.

See the Warning sections below for more information.

Parameters

start
: [integer or real, optional] Start of interval. The interval includes this value. The default start value is 0.

stop
: [integer or real] End of interval. The interval does not include this value, except in some cases where *step* is not an integer and floating point round-off affects the length of *out*.

step
: [integer or real, optional] Spacing between values. For any output *out*, this is the distance between two adjacent values, `out[i+1] - out[i]`. The default step size is 1. If *step* is specified as a position argument, *start* must also be given.

dtype
: [dtype, optional] The type of the output array. If *dtype* is not given, infer the data type from the other input arguments.

device
: [str, optional] The device on which to place the created array. Default: `None`. For Array-API interoperability only, so must be `"cpu"` if passed.

  New in version 2.0.0.

like
: [array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

  New in version 1.20.0.

Returns

arange

[MaskedArray] Array of evenly spaced values.

For floating point arguments, the length of the result is `ceil((stop - start)/step)`. Because of floating point overflow, this rule may result in the last element of *out* being greater than *stop*.

Warning: The length of the output might not be numerically stable.

Another stability issue is due to the internal implementation of *numpy.arange*. The actual step value used to populate the array is `dtype(start + step) - dtype(start)` and not *step*. Precision loss can occur here, due to casting or due to using floating points when *start* is much larger than *step*. This can lead to unexpected behaviour. For example:

```
>>> np.arange(0, 5, 0.5, dtype=int)
array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0])
>>> np.arange(-3, 3, 0.5, dtype=int)
array([-3, -2, -1,  0,  1,  2,  3,  4,  5,  6,  7,  8])
```

In such cases, the use of *numpy.linspace* should be preferred.

The built-in `range` generates Python built-in integers that have arbitrary size, while *numpy.arange* produces *numpy.int32* or *numpy.int64* numbers. This may result in incorrect results for large integer values:

```
>>> power = 40
>>> modulo = 10000
>>> x1 = [(n ** power) % modulo for n in range(8)]
>>> x2 = [(n ** power) % modulo for n in np.arange(8)]
>>> print(x1)
[0, 1, 7776, 8801, 6176, 625, 6576, 4001]  # correct
>>> print(x2)
[0, 1, 7776, 7185, 0, 5969, 4816, 3361]  # incorrect
```

See also:

numpy.linspace
Evenly spaced numbers with careful handling of endpoints.

numpy.ogrid
Arrays of evenly spaced numbers in N-dimensions.

numpy.mgrid
Grid-shaped arrays of evenly spaced numbers in N-dimensions.

how-to-partition

Examples

```
>>> import numpy as np
>>> np.arange(3)
array([0, 1, 2])
>>> np.arange(3.0)
array([ 0.,  1.,  2.])
>>> np.arange(3,7)
array([3, 4, 5, 6])
>>> np.arange(3,7,2)
array([3, 5])
```

ma.**choose**(*indices*, *choices*, *out=None*, *mode='raise'*)

Use an index array to construct a new array from a list of choices.

Given an array of integers and a list of n choice arrays, this method will create a new array that merges each of the choice arrays. Where a value in *index* is i, the new array will have the value that choices[i] contains in the same place.

Parameters

indices
[ndarray of ints] This array must contain integers in `[0, n-1]`, where n is the number of choices.

choices
[sequence of arrays] Choice arrays. The index array and all of the choices should be broadcastable to the same shape.

out
[array, optional] If provided, the result will be inserted into this array. It should be of the appropriate shape and *dtype*.

mode
[{'raise', 'wrap', 'clip'}, optional] Specifies how out-of-bounds indices will behave.

- 'raise' : raise an error
- 'wrap' : wrap around
- 'clip' : clip to the range

Returns

merged_array
[array]

See also:

choose
equivalent function

Examples

```
>>> import numpy as np
>>> choice = np.array([[1,1,1], [2,2,2], [3,3,3]])
>>> a = np.array([2, 1, 0])
>>> np.ma.choose(a, choice)
masked_array(data=[3, 2, 1],
             mask=False,
       fill_value=999999)
```

ma.**compress_nd**(*x*, *axis=None*)

Suppress slices from multiple dimensions which contain masked values.

Parameters

x
[array_like, MaskedArray] The array to operate on. If not a MaskedArray instance (or if no array elements are masked), *x* is interpreted as a MaskedArray with *mask* set to *nomask*.

axis
[tuple of ints or int, optional] Which dimensions to suppress slices from can be configured with this parameter. - If axis is a tuple of ints, those are the axes to suppress slices from. - If axis is an int, then that is the only axis to suppress slices from. - If axis is None, all axis are selected.

Returns

compress_array
[ndarray] The compressed array.

Examples

```
>>> import numpy as np
>>> arr = [[1, 2], [3, 4]]
>>> mask = [[0, 1], [0, 0]]
>>> x = np.ma.array(arr, mask=mask)
>>> np.ma.compress_nd(x, axis=0)
array([[3, 4]])
>>> np.ma.compress_nd(x, axis=1)
array([[1],
       [3]])
>>> np.ma.compress_nd(x)
array([[3]])
```

ma.**convolve**(*a*, *v*, *mode='full'*, *propagate_mask=True*)

Returns the discrete, linear convolution of two one-dimensional sequences.

Parameters

a, v
[array_like] Input sequences.

mode
[{'valid', 'same', 'full'}, optional] Refer to the *np.convolve* docstring.

propagate_mask
[bool] If True, then if any masked element is included in the sum for a result element, then the result is masked. If False, then the result element is only masked if no non-masked cells contribute towards it

Returns

out
[MaskedArray] Discrete, linear convolution of *a* and *v*.

See also:

numpy.convolve
Equivalent function in the top-level NumPy module.

ma.**correlate**(*a*, *v*, *mode='valid'*, *propagate_mask=True*)

Cross-correlation of two 1-dimensional sequences.

Parameters

a, v
[array_like] Input sequences.

mode
[{'valid', 'same', 'full'}, optional] Refer to the *np.convolve* docstring. Note that the default is 'valid', unlike *convolve*, which uses 'full'.

propagate_mask
[bool] If True, then a result element is masked if any masked element contributes towards it. If False, then a result element is only masked if no non-masked element contribute towards it

Returns

out
[MaskedArray] Discrete cross-correlation of *a* and *v*.

See also:

numpy.correlate
Equivalent function in the top-level NumPy module.

Examples

Basic correlation:

```
>>> a = np.ma.array([1, 2, 3])
>>> v = np.ma.array([0, 1, 0])
>>> np.ma.correlate(a, v, mode='valid')
masked_array(data=[2],
             mask=[False],
       fill_value=999999)
```

Correlation with masked elements:

```
>>> a = np.ma.array([1, 2, 3], mask=[False, True, False])
>>> v = np.ma.array([0, 1, 0])
>>> np.ma.correlate(a, v, mode='valid', propagate_mask=True)
masked_array(data=[--],
             mask=[ True],
       fill_value=999999,
            dtype=int64)
```

Correlation with different modes and mixed array types:

```
>>> a = np.ma.array([1, 2, 3])
>>> v = np.ma.array([0, 1, 0])
>>> np.ma.correlate(a, v, mode='full')
masked_array(data=[0, 1, 2, 3, 0],
             mask=[False, False, False, False, False],
       fill_value=999999)
```

ma.**ediff1d**(*arr*, *to_end=None*, *to_begin=None*)

Compute the differences between consecutive elements of an array.

This function is the equivalent of *numpy.ediff1d* that takes masked values into account, see *numpy.ediff1d* for details.

See also:

numpy.ediff1d
Equivalent function for ndarrays.

Examples

```
>>> import numpy as np
>>> arr = np.ma.array([1, 2, 4, 7, 0])
>>> np.ma.ediff1d(arr)
masked_array(data=[ 1,  2,  3, -7],
             mask=False,
       fill_value=999999)
```

ma.**flatten_mask**(*mask*)

Returns a completely flattened version of the mask, where nested fields are collapsed.

Parameters

mask
[array_like] Input array, which will be interpreted as booleans.

Returns

flattened_mask
[ndarray of bools] The flattened input.

Examples

```
>>> import numpy as np
>>> mask = np.array([0, 0, 1])
>>> np.ma.flatten_mask(mask)
array([False, False,  True])
```

```
>>> mask = np.array([(0, 0), (0, 1)], dtype=[('a', bool), ('b', bool)])
>>> np.ma.flatten_mask(mask)
array([False, False, False,  True])
```

```
>>> mdtype = [('a', bool), ('b', [('ba', bool), ('bb', bool)])]
>>> mask = np.array([(0, (0, 0)), (0, (0, 1))], dtype=mdtype)
>>> np.ma.flatten_mask(mask)
array([False, False, False, False, False,  True])
```

ma.**flatten_structured_array**(*a*)

Flatten a structured array.

The data type of the output is chosen such that it can represent all of the (nested) fields.

Parameters

a
[structured array]

Returns

output
[masked array or ndarray] A flattened masked array if the input is a masked array, otherwise a standard ndarray.

Examples

```
>>> import numpy as np
>>> ndtype = [('a', int), ('b', float)]
>>> a = np.array([(1, 1), (2, 2)], dtype=ndtype)
>>> np.ma.flatten_structured_array(a)
array([[1., 1.],
       [2., 2.]])
```

ma.**fromflex**(*fxarray*)

Build a masked array from a suitable flexible-type array.

The input array has to have a data-type with `_data` and `_mask` fields. This type of array is output by *MaskedArray.toflex*.

Parameters

fxarray
[ndarray] The structured input array, containing `_data` and `_mask` fields. If present, other fields are discarded.

Returns

result
[MaskedArray] The constructed masked array.

See also:

MaskedArray.toflex
Build a flexible-type array from a masked array.

Examples

```
>>> import numpy as np
>>> x = np.ma.array(np.arange(9).reshape(3, 3), mask=[0] + [1, 0] * 4)
>>> rec = x.toflex()
>>> rec
array([[(0, False), (1,  True), (2, False)],
       [(3,  True), (4, False), (5,  True)],
       [(6, False), (7,  True), (8, False)]],
      dtype=[('_data', '<i8'), ('_mask', '?')])
```

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```
>>> x2 = np.ma.fromflex(rec)
>>> x2
masked_array(
  data=[[0, --, 2],
        [--, 4, --],
        [6, --, 8]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
```

Extra fields can be present in the structured array but are discarded:

```
>>> dt = [('_data', '<i4'), ('_mask', '|b1'), ('field3', '<f4')]
>>> rec2 = np.zeros((2, 2), dtype=dt)
>>> rec2
array([[(0, False, 0.), (0, False, 0.)],
       [(0, False, 0.), (0, False, 0.)]],
      dtype=[('_data', '<i4'), ('_mask', '?'), ('field3', '<f4')])
>>> y = np.ma.fromflex(rec2)
>>> y
masked_array(
  data=[[0, 0],
        [0, 0]],
  mask=[[False, False],
        [False, False]],
  fill_value=np.int64(999999),
  dtype=int32)
```

ma.**indices**(*dimensions*, *dtype=<class 'int'>*, *sparse=False*) **= <numpy.ma.core._convert2ma object>**

Return an array representing the indices of a grid.

Compute an array where the subarrays contain index values 0, 1, … varying only along the corresponding axis.

Parameters

dimensions
[sequence of ints] The shape of the grid.

dtype
[dtype, optional] Data type of the result.

sparse
[boolean, optional] Return a sparse representation of the grid instead of a dense representation. Default is False.

Returns

grid
[one MaskedArray or tuple of MaskedArrays]

If sparse is False:
Returns one array of grid indices, `grid.shape = (len(dimensions),) + tuple(dimensions).`

If sparse is True:
Returns a tuple of arrays, with `grid[i].shape = (1, ..., 1, dimensions[i], 1, ..., 1)` with dimensions[i] in the ith place

See also:

mgrid, *ogrid*, *meshgrid*

Notes

The output shape in the dense case is obtained by prepending the number of dimensions in front of the tuple of dimensions, i.e. if *dimensions* is a tuple `(r0, ..., rN-1)` of length `N`, the output shape is `(N, r0, ..., rN-1)`.

The subarrays `grid[k]` contains the N-D array of indices along the `k-th` axis. Explicitly:

```
grid[k, i0, i1, ..., iN-1] = ik
```

Examples

```
>>> import numpy as np
>>> grid = np.indices((2, 3))
>>> grid.shape
(2, 2, 3)
>>> grid[0]        # row indices
array([[0, 0, 0],
       [1, 1, 1]])
>>> grid[1]        # column indices
array([[0, 1, 2],
       [0, 1, 2]])
```

The indices can be used as an index into an array.

```
>>> x = np.arange(20).reshape(5, 4)
>>> row, col = np.indices((2, 3))
>>> x[row, col]
array([[0, 1, 2],
       [4, 5, 6]])
```

Note that it would be more straightforward in the above example to extract the required elements directly with `x[:2, :3]`.

If sparse is set to true, the grid will be returned in a sparse representation.

```
>>> i, j = np.indices((2, 3), sparse=True)
>>> i.shape
(2, 1)
>>> j.shape
(1, 3)
>>> i        # row indices
array([[0],
       [1]])
>>> j        # column indices
array([[0, 1, 2]])
```

ma.**left_shift**(*a*, *n*)

Shift the bits of an integer to the left.

This is the masked array version of *numpy.left_shift*, for details see that function.

See also:

numpy.left_shift

Examples

Shift with a masked array:

```
>>> arr = np.ma.array([10, 20, 30], mask=[False, True, False])
>>> np.ma.left_shift(arr, 1)
masked_array(data=[20, --, 60],
             mask=[False,  True, False],
       fill_value=999999)
```

Large shift:

```
>>> np.ma.left_shift(10, 10)
masked_array(data=10240,
             mask=False,
       fill_value=999999)
```

Shift with a scalar and an array:

```
>>> scalar = 10
>>> arr = np.ma.array([1, 2, 3], mask=[False, True, False])
>>> np.ma.left_shift(scalar, arr)
masked_array(data=[20, --, 80],
             mask=[False,  True, False],
       fill_value=999999)
```

ma.**ndim**(*obj*)

Return the number of dimensions of an array.

Parameters

a
[array_like] Input array. If it is not already an ndarray, a conversion is attempted.

Returns

number_of_dimensions
[int] The number of dimensions in *a*. Scalars are zero-dimensional.

See also:

ndarray.ndim
equivalent method

shape
dimensions of array

ndarray.shape
dimensions of array

Examples

```
>>> import numpy as np
>>> np.ndim([[1,2,3],[4,5,6]])
2
>>> np.ndim(np.array([[1,2,3],[4,5,6]]))
2
>>> np.ndim(1)
0
```

ma.**put**(*a*, *indices*, *values*, *mode='raise'*)

Set storage-indexed locations to corresponding values.

This function is equivalent to *MaskedArray.put*, see that method for details.

See also:

MaskedArray.put

Examples

Putting values in a masked array:

```
>>> a = np.ma.array([1, 2, 3, 4], mask=[False, True, False, False])
>>> np.ma.put(a, [1, 3], [10, 30])
>>> a
masked_array(data=[ 1, 10,  3, 30],
             mask=False,
       fill_value=999999)
```

Using put with a 2D array:

```
>>> b = np.ma.array([[1, 2], [3, 4]], mask=[[False, True], [False, False]])
>>> np.ma.put(b, [[0, 1], [1, 0]], [[10, 20], [30, 40]])
>>> b
masked_array(
  data=[[40, 30],
        [ 3,  4]],
  mask=False,
  fill_value=999999)
```

ma.**putmask**(*a*, *mask*, *values*)

Changes elements of an array based on conditional and input values.

This is the masked array version of *numpy.putmask*, for details see *numpy.putmask*.

See also:

numpy.putmask

Notes

Using a masked array as *values* will **not** transform a *ndarray* into a *MaskedArray*.

Examples

```
>>> import numpy as np
>>> arr = [[1, 2], [3, 4]]
>>> mask = [[1, 0], [0, 0]]
>>> x = np.ma.array(arr, mask=mask)
>>> np.ma.putmask(x, x < 4, 10*x)
>>> x
masked_array(
  data=[[--, 20],
        [30, 4]],
  mask=[[ True, False],
        [False, False]],
  fill_value=999999)
>>> x.data
array([[10, 20],
       [30,  4]])
```

ma.**right_shift**(*a*, *n*)

Shift the bits of an integer to the right.

This is the masked array version of *numpy.right_shift*, for details see that function.

See also:

numpy.right_shift

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = [11, 3, 8, 1]
>>> mask = [0, 0, 0, 1]
>>> masked_x = ma.masked_array(x, mask)
>>> masked_x
masked_array(data=[11, 3, 8, --],
             mask=[False, False, False,  True],
       fill_value=999999)
>>> ma.right_shift(masked_x,1)
masked_array(data=[5, 1, 4, --],
             mask=[False, False, False,  True],
       fill_value=999999)
```

ma.**round_**(*a*, *decimals=0*, *out=None*)

Return a copy of a, rounded to 'decimals' places.

When 'decimals' is negative, it specifies the number of positions to the left of the decimal point. The real and imaginary parts of complex numbers are rounded separately. Nothing is done if the array is not of float type and 'decimals' is greater than or equal to 0.

Parameters

decimals
[int] Number of decimals to round to. May be negative.

out
[array_like] Existing array to use for output. If not given, returns a default copy of a.

Notes

If out is given and does not have a mask attribute, the mask of a is lost!

Examples

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = [11.2, -3.973, 0.801, -1.41]
>>> mask = [0, 0, 0, 1]
>>> masked_x = ma.masked_array(x, mask)
>>> masked_x
masked_array(data=[11.2, -3.973, 0.801, --],
             mask=[False, False, False, True],
    fill_value=1e+20)
>>> ma.round_(masked_x)
masked_array(data=[11.0, -4.0, 1.0, --],
             mask=[False, False, False, True],
    fill_value=1e+20)
>>> ma.round(masked_x, decimals=1)
masked_array(data=[11.2, -4.0, 0.8, --],
             mask=[False, False, False, True],
    fill_value=1e+20)
>>> ma.round_(masked_x, decimals=-1)
masked_array(data=[10.0, -0.0, 0.0, --],
             mask=[False, False, False, True],
    fill_value=1e+20)
```

ma.**take**(*a*, *indices*, *axis=None*, *out=None*, *mode='raise'*)

ma.**where**(*condition*, *x=<no value>*, *y=<no value>*)

Return a masked array with elements from *x* or *y*, depending on condition.

Note: When only *condition* is provided, this function is identical to `nonzero`. The rest of this documentation covers only the case where all three arguments are provided.

Parameters

condition
[array_like, bool] Where True, yield *x*, otherwise yield *y*.

x, y
[array_like, optional] Values from which to choose. *x*, *y* and *condition* need to be broadcastable to some shape.

Returns

out
[MaskedArray] An masked array with *masked* elements where the condition is masked, elements from *x* where *condition* is True, and elements from *y* elsewhere.

See also:

numpy.where
Equivalent function in the top-level NumPy module.

nonzero
The function that is called when x and y are omitted

Examples

```
>>> import numpy as np
>>> x = np.ma.array(np.arange(9.).reshape(3, 3), mask=[[0, 1, 0],
...                                                    [1, 0, 1],
...                                                    [0, 1, 0]])
>>> x
masked_array(
  data=[[0.0, --, 2.0],
        [--, 4.0, --],
        [6.0, --, 8.0]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=1e+20)
>>> np.ma.where(x > 5, x, -3.1416)
masked_array(
  data=[[-3.1416, --, -3.1416],
        [--, -3.1416, --],
        [6.0, --, 8.0]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=1e+20)
```

Matrix library (`numpy.matlib`)

This module contains all functions in the *numpy* namespace, with the following replacement functions that return *matrices* instead of *ndarrays*.

Functions that are also in the numpy namespace and return matrices

matrix(data[, dtype, copy])	Returns a matrix from an array-like object, or from a string of data.
asmatrix(data[, dtype])	Interpret the input as a matrix.
bmat(obj[, ldict, gdict])	Build a matrix object from a string, nested sequence, or array.

Replacement functions in *matlib*

empty(shape[, dtype, order])	Return a new matrix of given shape and type, without initializing entries.
zeros(shape[, dtype, order])	Return a matrix of given shape and type, filled with zeros.
ones(shape[, dtype, order])	Matrix of ones.
eye(n[, M, k, dtype, order])	Return a matrix with ones on the diagonal and zeros elsewhere.
identity(n[, dtype])	Returns the square identity matrix of given size.
repmat(a, m, n)	Repeat a 0-D to 2-D array or matrix MxN times.
rand(*args)	Return a matrix of random values with given shape.
randn(*args)	Return a random matrix with data from the "standard normal" distribution.

matlib.**empty**(*shape*, *dtype=None*, *order='C'*)

Return a new matrix of given shape and type, without initializing entries.

Parameters

shape
[int or tuple of int] Shape of the empty matrix.

dtype
[data-type, optional] Desired output data-type.

order
[{'C', 'F'}, optional] Whether to store multi-dimensional data in row-major (C-style) or column-major (Fortran-style) order in memory.

See also:

numpy.empty
Equivalent array function.

matlib.zeros
Return a matrix of zeros.

matlib.ones
Return a matrix of ones.

Notes

Unlike other matrix creation functions (e.g. *matlib.zeros*, *matlib.ones*), *matlib.empty* does not initialize the values of the matrix, and may therefore be marginally faster. However, the values stored in the newly allocated matrix are arbitrary. For reproducible behavior, be sure to set each element of the matrix before reading.

Examples

```
>>> import numpy.matlib
>>> np.matlib.empty((2, 2))    # filled with random data
matrix([[  6.76425276e-320,   9.79033856e-307], # random
        [  7.39337286e-309,   3.22135945e-309]])
>>> np.matlib.empty((2, 2), dtype=int)
matrix([[ 6600475,        0], # random
        [ 6586976, 22740995]])
```

matlib.**zeros**(*shape*, *dtype=None*, *order='C'*)

Return a matrix of given shape and type, filled with zeros.

Parameters

shape
[int or sequence of ints] Shape of the matrix

dtype
[data-type, optional] The desired data-type for the matrix, default is float.

order
[{'C', 'F'}, optional] Whether to store the result in C- or Fortran-contiguous order, default is 'C'.

Returns

out
[matrix] Zero matrix of given shape, dtype, and order.

See also:

numpy.zeros
Equivalent array function.

matlib.ones
Return a matrix of ones.

Notes

If *shape* has length one i.e. `(N,)`, or is a scalar `N`, *out* becomes a single row matrix of shape `(1,N)`.

Examples

```
>>> import numpy.matlib
>>> np.matlib.zeros((2, 3))
matrix([[0.,  0.,  0.],
        [0.,  0.,  0.]])
```

```
>>> np.matlib.zeros(2)
matrix([[0.,  0.]])
```

matlib.**ones**(*shape*, *dtype=None*, *order='C'*)

Matrix of ones.

Return a matrix of given shape and type, filled with ones.

Parameters

shape
[{sequence of ints, int}] Shape of the matrix

dtype
[data-type, optional] The desired data-type for the matrix, default is np.float64.

order
[{'C', 'F'}, optional] Whether to store matrix in C- or Fortran-contiguous order, default is 'C'.

Returns

out
[matrix] Matrix of ones of given shape, dtype, and order.

See also:

ones
Array of ones.

matlib.zeros
Zero matrix.

Notes

If *shape* has length one i.e. `(N,)`, or is a scalar `N`, *out* becomes a single row matrix of shape `(1,N)`.

Examples

```
>>> np.matlib.ones((2,3))
matrix([[1.,  1.,  1.],
        [1.,  1.,  1.]])
```

```
>>> np.matlib.ones(2)
matrix([[1.,  1.]])
```

`matlib.`**`eye`**(*n*, *M=None*, *k=0*, *dtype=<class 'float'>*, *order='C'*)

Return a matrix with ones on the diagonal and zeros elsewhere.

Parameters

n
[int] Number of rows in the output.

M
[int, optional] Number of columns in the output, defaults to *n*.

k
[int, optional] Index of the diagonal: 0 refers to the main diagonal, a positive value refers to an upper diagonal, and a negative value to a lower diagonal.

dtype
[dtype, optional] Data-type of the returned matrix.

order
[{'C', 'F'}, optional] Whether the output should be stored in row-major (C-style) or column-major (Fortran-style) order in memory.

Returns

I
[matrix] A *n* x *M* matrix where all elements are equal to zero, except for the *k*-th diagonal, whose values are equal to one.

See also:

numpy.eye
Equivalent array function.

identity
Square identity matrix.

Examples

```
>>> import numpy.matlib
>>> np.matlib.eye(3, k=1, dtype=float)
matrix([[0.,  1.,  0.],
        [0.,  0.,  1.],
        [0.,  0.,  0.]])
```

matlib.**identity**(*n*, *dtype=None*)

Returns the square identity matrix of given size.

Parameters

n
[int] Size of the returned identity matrix.

dtype
[data-type, optional] Data-type of the output. Defaults to `float`.

Returns

out
[matrix] *n* x *n* matrix with its main diagonal set to one, and all other elements zero.

See also:

numpy.identity
Equivalent array function.

matlib.eye
More general matrix identity function.

Examples

```
>>> import numpy.matlib
>>> np.matlib.identity(3, dtype=int)
matrix([[1, 0, 0],
        [0, 1, 0],
        [0, 0, 1]])
```

matlib.**repmat**(*a*, *m*, *n*)

Repeat a 0-D to 2-D array or matrix MxN times.

Parameters

a
[array_like] The array or matrix to be repeated.

m, n
[int] The number of times *a* is repeated along the first and second axes.

Returns

out
[ndarray] The result of repeating *a*.

Examples

```
>>> import numpy.matlib
>>> a0 = np.array(1)
>>> np.matlib.repmat(a0, 2, 3)
array([[1, 1, 1],
       [1, 1, 1]])
```

```
>>> a1 = np.arange(4)
>>> np.matlib.repmat(a1, 2, 2)
array([[0, 1, 2, 3, 0, 1, 2, 3],
       [0, 1, 2, 3, 0, 1, 2, 3]])
```

```
>>> a2 = np.asmatrix(np.arange(6).reshape(2, 3))
>>> np.matlib.repmat(a2, 2, 3)
matrix([[0, 1, 2, 0, 1, 2, 0, 1, 2],
        [3, 4, 5, 3, 4, 5, 3, 4, 5],
        [0, 1, 2, 0, 1, 2, 0, 1, 2],
        [3, 4, 5, 3, 4, 5, 3, 4, 5]])
```

matlib.**rand**(**args*)

Return a matrix of random values with given shape.

Create a matrix of the given shape and propagate it with random samples from a uniform distribution over `[0, 1)`.

Parameters

***args**
[Arguments] Shape of the output. If given as N integers, each integer specifies the size of one dimension. If given as a tuple, this tuple gives the complete shape.

Returns

out
[ndarray] The matrix of random values with shape given by **args*.

See also:

randn*, *numpy.random.RandomState.rand

Examples

```
>>> np.random.seed(123)
>>> import numpy.matlib
>>> np.matlib.rand(2, 3)
matrix([[0.69646919, 0.28613933, 0.22685145],
        [0.55131477, 0.71946897, 0.42310646]])
>>> np.matlib.rand((2, 3))
matrix([[0.9807642 , 0.68482974, 0.4809319 ],
        [0.39211752, 0.34317802, 0.72904971]])
```

If the first argument is a tuple, other arguments are ignored:

```
>>> np.matlib.rand((2, 3), 4)
matrix([[0.43857224, 0.0596779 , 0.39804426],
        [0.73799541, 0.18249173, 0.17545176]])
```

matlib.**randn**(**args*)

Return a random matrix with data from the "standard normal" distribution.

randn generates a matrix filled with random floats sampled from a univariate "normal" (Gaussian) distribution of mean 0 and variance 1.

Parameters

***args**
[Arguments] Shape of the output. If given as N integers, each integer specifies the size of one dimension. If given as a tuple, this tuple gives the complete shape.

Returns

Z
[matrix of floats] A matrix of floating-point samples drawn from the standard normal distribution.

See also:

rand*, *numpy.random.RandomState.randn

Notes

For random samples from the normal distribution with mean `mu` and standard deviation `sigma`, use:

```
sigma * np.matlib.randn(...) + mu
```

Examples

```
>>> np.random.seed(123)
>>> import numpy.matlib
>>> np.matlib.randn(1)
matrix([[-1.0856306]])
>>> np.matlib.randn(1, 2, 3)
matrix([[ 0.99734545,  0.2829785 , -1.50629471],
        [-0.57860025,  1.65143654, -2.42667924]])
```

Two-by-four matrix of samples from the normal distribution with mean 3 and standard deviation 2.5:

```
>>> 2.5 * np.matlib.randn((2, 4)) + 3
matrix([[1.92771843, 6.16484065, 0.83314899, 1.30278462],
        [2.76322758, 6.72847407, 1.40274501, 1.8900451 ]])
```

1.2 Array objects

NumPy provides an N-dimensional array type, the *ndarray*, which describes a collection of "items" of the same type. The items can be *indexed* using for example N integers.

All ndarrays are homogeneous: every item takes up the same size block of memory, and all blocks are interpreted in exactly the same way. How each item in the array is to be interpreted is specified by a separate *data-type object*, one of which is associated with every array. In addition to basic types (integers, floats, *etc.*), the data type objects can also represent data structures.

An item extracted from an array, *e.g.*, by indexing, is represented by a Python object whose type is one of the *array scalar types* built in NumPy. The array scalars allow easy manipulation of also more complicated arrangements of data.

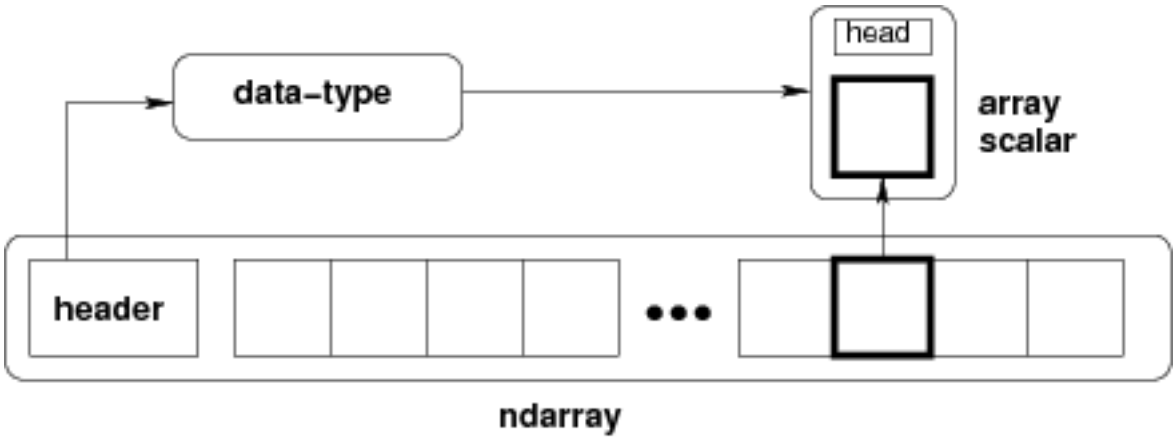

Fig. 1: **Figure** Conceptual diagram showing the relationship between the three fundamental objects used to describe the data in an array: 1) the ndarray itself, 2) the data-type object that describes the layout of a single fixed-size element of the array, 3) the array-scalar Python object that is returned when a single element of the array is accessed.

1.2.1 The N-dimensional array (`ndarray`)

An *`ndarray`* is a (usually fixed-size) multidimensional container of items of the same type and size. The number of dimensions and items in an array is defined by its *`shape`*, which is a `tuple` of *N* non-negative integers that specify the sizes of each dimension. The type of items in the array is specified by a separate *data-type object (dtype)*, one of which is associated with each ndarray.

As with other container objects in Python, the contents of an *`ndarray`* can be accessed and modified by *indexing or slicing* the array (using, for example, *N* integers), and via the methods and attributes of the *`ndarray`*.

Different *`ndarrays`* can share the same data, so that changes made in one *`ndarray`* may be visible in another. That is, an ndarray can be a *"view"* to another ndarray, and the data it is referring to is taken care of by the *"base"* ndarray. ndarrays can also be views to memory owned by Python `strings` or objects implementing the `memoryview` or *array* interfaces.

Example

A 2-dimensional array of size 2 x 3, composed of 4-byte integer elements:

```
>>> import numpy as np
```

```
>>> x = np.array([[1, 2, 3], [4, 5, 6]], np.int32)
>>> type(x)
<class 'numpy.ndarray'>
>>> x.shape
(2, 3)
>>> x.dtype
dtype('int32')
```

The array can be indexed using Python container-like syntax:

```
>>> # The element of x in the *second* row, *third* column, namely, 6.
>>> x[1, 2]
   6
```

For example *slicing* can produce views of the array:

```
>>> y = x[:,1]
>>> y
array([2, 5], dtype=int32)
>>> y[0] = 9 # this also changes the corresponding element in x
>>> y
array([9, 5], dtype=int32)
>>> x
array([[1, 9, 3],
       [4, 5, 6]], dtype=int32)
```

Constructing arrays

New arrays can be constructed using the routines detailed in *Array creation routines*, and also by using the low-level *ndarray* constructor:

ndarray(shape[, dtype, buffer, offset, ...])	An array object represents a multidimensional, homogeneous array of fixed-size items.

class numpy.**ndarray**(*shape*, *dtype=float*, *buffer=None*, *offset=0*, *strides=None*, *order=None*)

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
: [tuple of ints] Shape of created array.

dtype
: [data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
: [object exposing buffer interface, optional] Used to fill the array with data.

offset
: [int, optional] Offset of array data in buffer.

strides
: [tuple of ints, optional] Strides of data in memory.

order
: [{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] View of the transposed array.

data
[buffer] Python buffer object pointing to the start of the array's data.

dtype
[dtype object] Data-type of the array's elements.

flags
[dict] Information about the memory layout of the array.

flat
[numpy.flatiter object] A 1-D iterator over the array.

imag
[ndarray] The imaginary part of the array.

real
[ndarray] The real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] Length of one array element in bytes.

nbytes
[int] Total bytes consumed by the elements of the array.

ndim
[int] Number of array dimensions.

shape
[tuple of ints] Tuple of array dimensions.

strides
[tuple of ints] Tuple of bytes to step in each dimension when traversing an array.

ctypes
[ctypes object] An object to simplify the interaction of the array with the ctypes module.

base
[ndarray] Base object if memory is from some other object.

Methods

all([axis, out, keepdims, where])	Returns True if all elements evaluate to True.
any([axis, out, keepdims, where])	Returns True if any of the elements of *a* evaluate to True.
argmax([axis, out, keepdims])	Return indices of the maximum values along the given axis.
argmin([axis, out, keepdims])	Return indices of the minimum values along the given axis.
argpartition(kth[, axis, kind, order])	Returns the indices that would partition this array.
argsort([axis, kind, order])	Returns the indices that would sort this array.
astype(dtype[, order, casting, subok, copy])	Copy of the array, cast to a specified type.
byteswap([inplace])	Swap the bytes of the array elements
choose(choices[, out, mode])	Use an index array to construct a new array from a set of choices.
clip([min, max, out])	Return an array whose values are limited to `[min, max]`.
compress(condition[, axis, out])	Return selected slices of this array along given axis.
conj()	Complex-conjugate all elements.
conjugate()	Return the complex conjugate, element-wise.
copy([order])	Return a copy of the array.
cumprod([axis, dtype, out])	Return the cumulative product of the elements along the given axis.
cumsum([axis, dtype, out])	Return the cumulative sum of the elements along the given axis.
diagonal([offset, axis1, axis2])	Return specified diagonals.

continues on next page

Table 6 – continued from previous page

dump(file)	Dump a pickle of the array to the specified file.
dumps()	Returns the pickle of the array as a string.
fill(value)	Fill the array with a scalar value.
flatten([order])	Return a copy of the array collapsed into one dimension.
getfield(dtype[, offset])	Returns a field of the given array as a certain type.
item(*args)	Copy an element of an array to a standard Python scalar and return it.
max([axis, out, keepdims, initial, where])	Return the maximum along a given axis.
mean([axis, dtype, out, keepdims, where])	Returns the average of the array elements along given axis.
min([axis, out, keepdims, initial, where])	Return the minimum along a given axis.
nonzero()	Return the indices of the elements that are non-zero.
partition(kth[, axis, kind, order])	Partially sorts the elements in the array in such a way that the value of the element in k-th position is in the position it would be in a sorted array.
prod([axis, dtype, out, keepdims, initial, ...])	Return the product of the array elements over the given axis
put(indices, values[, mode])	Set `a.flat[n] = values[n]` for all *n* in indices.
ravel([order])	Return a flattened array.
repeat(repeats[, axis])	Repeat elements of an array.
reshape(shape, /, *[, order, copy])	Returns an array containing the same data with a new shape.
resize(new_shape[, refcheck])	Change shape and size of array in-place.
round([decimals, out])	Return *a* with each element rounded to the given number of decimals.
searchsorted(v[, side, sorter])	Find indices where elements of v should be inserted in a to maintain order.
setfield(val, dtype[, offset])	Put a value into a specified place in a field defined by a data-type.
setflags([write, align, uic])	Set array flags WRITEABLE, ALIGNED, WRITEBACKIFCOPY, respectively.
sort([axis, kind, order])	Sort an array in-place.
squeeze([axis])	Remove axes of length one from *a*.
std([axis, dtype, out, ddof, keepdims, where])	Returns the standard deviation of the array elements along given axis.
sum([axis, dtype, out, keepdims, initial, where])	Return the sum of the array elements over the given axis.
swapaxes(axis1, axis2)	Return a view of the array with *axis1* and *axis2* interchanged.
take(indices[, axis, out, mode])	Return an array formed from the elements of *a* at the given indices.
tobytes([order])	Construct Python bytes containing the raw data bytes in the array.
tofile(fid[, sep, format])	Write array to a file as text or binary (default).
tolist()	Return the array as an `a.ndim`-levels deep nested list of Python scalars.
tostring([order])	A compatibility alias for *tobytes*, with exactly the same behavior.
trace([offset, axis1, axis2, dtype, out])	Return the sum along diagonals of the array.
transpose(*axes)	Returns a view of the array with axes transposed.

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Table 6 – continued from previous page

var([axis, dtype, out, ddof, keepdims, where])	Returns the variance of the array elements, along given axis.
view([dtype][, type])	New view of array with the same data.

method

ndarray.**all**(*axis=None*, *out=None*, *keepdims=False*, *, *where=True*)

Returns True if all elements evaluate to True.

Refer to *numpy.all* for full documentation.

See also:

numpy.all
equivalent function

method

ndarray.**any**(*axis=None*, *out=None*, *keepdims=False*, *, *where=True*)

Returns True if any of the elements of *a* evaluate to True.

Refer to *numpy.any* for full documentation.

See also:

numpy.any
equivalent function

method

ndarray.**argmax**(*axis=None*, *out=None*, *, *keepdims=False*)

Return indices of the maximum values along the given axis.

Refer to *numpy.argmax* for full documentation.

See also:

numpy.argmax
equivalent function

method

ndarray.**argmin**(*axis=None*, *out=None*, *, *keepdims=False*)

Return indices of the minimum values along the given axis.

Refer to *numpy.argmin* for detailed documentation.

See also:

numpy.argmin
equivalent function

method

ndarray.**argpartition**(*kth*, *axis=-1*, *kind='introselect'*, *order=None*)

Returns the indices that would partition this array.

Refer to *numpy.argpartition* for full documentation.

See also:

numpy.argpartition
equivalent function

method

ndarray.**argsort**(*axis=-1*, *kind=None*, *order=None*)

Returns the indices that would sort this array.

Refer to *numpy.argsort* for full documentation.

See also:

numpy.argsort
equivalent function

method

ndarray.**astype**(*dtype*, *order='K'*, *casting='unsafe'*, *subok=True*, *copy=True*)

Copy of the array, cast to a specified type.

Parameters

dtype
[str or dtype] Typecode or data-type to which the array is cast.

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout order of the result. 'C' means C order, 'F' means Fortran order, 'A' means 'F' order if all the arrays are Fortran contiguous, 'C' order otherwise, and 'K' means as close to the order the array elements appear in memory as possible. Default is 'K'.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'unsafe' for backwards compatibility.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.
- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

subok
[bool, optional] If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

copy
[bool, optional] By default, astype always returns a newly allocated array. If this is set to false, and the *dtype*, *order*, and *subok* requirements are satisfied, the input array is returned instead of a copy.

Returns

arr_t
[ndarray] Unless *copy* is False and the other conditions for returning the input array are satisfied (see description for *copy* input parameter), *arr_t* is a new array of the same shape as the input array, with dtype, order given by *dtype*, *order*.

Raises

ComplexWarning
When casting from complex to float or int. To avoid this, one should use `a.real.astype(t)`.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 2.5])
>>> x
array([1. ,  2. ,  2.5])
```

```
>>> x.astype(int)
array([1, 2, 2])
```

method

ndarray.**byteswap**(*inplace=False*)

Swap the bytes of the array elements

Toggle between low-endian and big-endian data representation by returning a byteswapped array, optionally swapped in-place. Arrays of byte-strings are not swapped. The real and imaginary parts of a complex number are swapped individually.

Parameters

inplace
[bool, optional] If `True`, swap bytes in-place, default is `False`.

Returns

out
[ndarray] The byteswapped array. If *inplace* is `True`, this is a view to self.

Examples

```
>>> import numpy as np
>>> A = np.array([1, 256, 8755], dtype=np.int16)
>>> list(map(hex, A))
['0x1', '0x100', '0x2233']
>>> A.byteswap(inplace=True)
array([  256,     1, 13090], dtype=int16)
>>> list(map(hex, A))
['0x100', '0x1', '0x3322']
```

Arrays of byte-strings are not swapped

```
>>> A = np.array([b'ceg', b'fac'])
>>> A.byteswap()
array([b'ceg', b'fac'], dtype='|S3')
```

`A.view(A.dtype.newbyteorder()).byteswap()` produces an array with the same values but different representation in memory

```
>>> A = np.array([1, 2, 3],dtype=np.int64)
>>> A.view(np.uint8)
array([1, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0,
       0, 0], dtype=uint8)
>>> A.view(A.dtype.newbyteorder()).byteswap(inplace=True)
array([1, 2, 3], dtype='>i8')
>>> A.view(np.uint8)
array([0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0,
       0, 3], dtype=uint8)
```

method

`ndarray.`**`choose`**(*choices*, *out=None*, *mode='raise'*)

Use an index array to construct a new array from a set of choices.

Refer to *numpy.choose* for full documentation.

See also:

numpy.choose
equivalent function

method

`ndarray.`**`clip`**(*min=None*, *max=None*, *out=None*, ***kwargs*)

Return an array whose values are limited to `[min, max]`. One of max or min must be given.

Refer to *numpy.clip* for full documentation.

See also:

numpy.clip
equivalent function

method

`ndarray.`**`compress`**(*condition*, *axis=None*, *out=None*)

Return selected slices of this array along given axis.

Refer to *numpy.compress* for full documentation.

See also:

numpy.compress
equivalent function

method

`ndarray.`**`conj`**()

Complex-conjugate all elements.

Refer to *numpy.conjugate* for full documentation.

See also:

numpy.conjugate
equivalent function

method

ndarray.**conjugate**()

Return the complex conjugate, element-wise.

Refer to *numpy.conjugate* for full documentation.

See also:

numpy.conjugate
equivalent function

method

ndarray.**copy**(*order='C'*)

Return a copy of the array.

Parameters

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout of the copy. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible. (Note that this function and *numpy.copy* are very similar but have different default values for their order= arguments, and this function always passes sub-classes through.)

See also:

numpy.copy
Similar function with different default behavior

numpy.copyto

Notes

This function is the preferred method for creating an array copy. The function *numpy.copy* is similar, but it defaults to using order 'K', and will not pass sub-classes through by default.

Examples

```
>>> import numpy as np
>>> x = np.array([[1,2,3],[4,5,6]], order='F')
```

```
>>> y = x.copy()
```

```
>>> x.fill(0)
```

```
>>> x
array([[0, 0, 0],
       [0, 0, 0]])
```

```
>>> y
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> y.flags['C_CONTIGUOUS']
True
```

For arrays containing Python objects (e.g. dtype=object), the copy is a shallow one. The new array will contain the same object which may lead to surprises if that object can be modified (is mutable):

```
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> b = a.copy()
>>> b[2][0] = 10
>>> a
array([1, 'm', list([10, 3, 4])], dtype=object)
```

To ensure all elements within an `object` array are copied, use `copy.deepcopy`:

```
>>> import copy
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> c = copy.deepcopy(a)
>>> c[2][0] = 10
>>> c
array([1, 'm', list([10, 3, 4])], dtype=object)
>>> a
array([1, 'm', list([2, 3, 4])], dtype=object)
```

method

ndarray.**cumprod**(*axis=None*, *dtype=None*, *out=None*)

Return the cumulative product of the elements along the given axis.

Refer to *numpy.cumprod* for full documentation.

See also:

numpy.cumprod
equivalent function

method

ndarray.**cumsum**(*axis=None*, *dtype=None*, *out=None*)

Return the cumulative sum of the elements along the given axis.

Refer to *numpy.cumsum* for full documentation.

See also:

numpy.cumsum
equivalent function

method

ndarray.**diagonal**(*offset=0*, *axis1=0*, *axis2=1*)

Return specified diagonals. In NumPy 1.9 the returned array is a read-only view instead of a copy as in previous NumPy versions. In a future version the read-only restriction will be removed.

Refer to *numpy.diagonal* for full documentation.

See also:

numpy.diagonal
equivalent function

method

ndarray.**dump**(*file*)

Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

Parameters

file
[str or Path] A string naming the dump file.

method

ndarray.**dumps**()

Returns the pickle of the array as a string. pickle.loads will convert the string back to an array.

Parameters

None

method

ndarray.**fill**(*value*)

Fill the array with a scalar value.

Parameters

value
[scalar] All elements of *a* will be assigned this value.

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2])
>>> a.fill(0)
>>> a
array([0, 0])
>>> a = np.empty(2)
>>> a.fill(1)
>>> a
array([1.,  1.])
```

Fill expects a scalar value and always behaves the same as assigning to a single array element. The following is a rare example where this distinction is important:

```
>>> a = np.array([None, None], dtype=object)
>>> a[0] = np.array(3)
>>> a
array([array(3), None], dtype=object)
>>> a.fill(np.array(3))
>>> a
array([array(3), array(3)], dtype=object)
```

Where other forms of assignments will unpack the array being assigned:

```
>>> a[...] = np.array(3)
>>> a
array([3, 3], dtype=object)
```

method

ndarray.**flatten**(*order='C'*)

Return a copy of the array collapsed into one dimension.

Parameters

order
[{'C', 'F', 'A', 'K'}, optional] 'C' means to flatten in row-major (C-style) order. 'F' means to flatten in column-major (Fortran- style) order. 'A' means to flatten in column-major order if *a* is Fortran *contiguous* in memory, row-major order otherwise. 'K' means to flatten *a* in the order the elements occur in memory. The default is 'C'.

Returns

y
[ndarray] A copy of the input array, flattened to one dimension.

See also:

ravel
Return a flattened array.

flat
A 1-D flat iterator over the array.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,2], [3,4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

method

ndarray.**getfield**(*dtype*, *offset=0*)

Returns a field of the given array as a certain type.

A field is a view of the array data with a given data-type. The values in the view are determined by the given type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits in the array dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with a 32-bit integer (4 bytes), the offset needs to be between 0 and 12 bytes.

Parameters

dtype
[str or dtype] The data type of the view. The dtype size of the view can not be larger than that of the array itself.

offset
[int] Number of bytes to skip before beginning the element view.

Examples

```
>>> import numpy as np
>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[1.+1.j,  0.+0.j],
       [0.+0.j,  2.+4.j]])
>>> x.getfield(np.float64)
array([[1.,  0.],
       [0.,  2.]])
```

By choosing an offset of 8 bytes we can select the complex part of the array for our view:

```
>>> x.getfield(np.float64, offset=8)
array([[1.,  0.],
       [0.,  4.]])
```

method

ndarray.**item**(**args*)

Copy an element of an array to a standard Python scalar and return it.

Parameters

***args**

[Arguments (variable number and type)]

- none: in this case, the method only works for arrays with one element (*a.size == 1*), which element is copied into a standard Python scalar object and returned.
- int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.
- tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.

Returns

z

[Standard Python scalar object] A copy of the specified element of the array as a suitable Python scalar

Notes

When the data type of *a* is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

item is very similar to a[args], except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python's optimized math.

Examples

```
>>> import numpy as np
>>> np.random.seed(123)
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[2, 2, 6],
       [1, 3, 6],
       [1, 0, 1]])
>>> x.item(3)
1
>>> x.item(7)
0
>>> x.item((0, 1))
2
>>> x.item((2, 2))
1
```

For an array with object dtype, elements are returned as-is.

```
>>> a = np.array([np.int64(1)], dtype=object)
>>> a.item() #return np.int64
np.int64(1)
```

method

ndarray.**max**(*axis=None*, *out=None*, *keepdims=False*, *initial=<no value>*, *where=True*)

Return the maximum along a given axis.

Refer to *numpy.amax* for full documentation.

See also:

numpy.amax
equivalent function

method

ndarray.**mean**(*axis=None*, *dtype=None*, *out=None*, *keepdims=False*, ***, *where=True*)

Returns the average of the array elements along given axis.

Refer to *numpy.mean* for full documentation.

See also:

numpy.mean
equivalent function

method

ndarray.**min**(*axis=None*, *out=None*, *keepdims=False*, *initial=<no value>*, *where=True*)

Return the minimum along a given axis.

Refer to *numpy.amin* for full documentation.

See also:

numpy.amin
equivalent function

method

ndarray.**nonzero**()

Return the indices of the elements that are non-zero.

Refer to *numpy.nonzero* for full documentation.

See also:

numpy.nonzero
equivalent function

method

ndarray.**partition**(*kth*, *axis=-1*, *kind='introselect'*, *order=None*)

Partially sorts the elements in the array in such a way that the value of the element in k-th position is in the position it would be in a sorted array. In the output array, all elements smaller than the k-th element are located to the left of this element and all equal or greater are located to its right. The ordering of the elements in the two partitions on the either side of the k-th element in the output array is undefined.

Parameters

kth
[int or sequence of ints] Element index to partition by. The kth element value will be in its final sorted position and all smaller elements will be moved before it and all equal or greater elements behind it. The order of all elements in the partitions is undefined. If provided with a sequence of kth it will partition all elements indexed by kth of them into their sorted position at once.

Deprecated since version 1.22.0: Passing booleans as index is deprecated.

axis
[int, optional] Axis along which to sort. Default is -1, which means sort along the last axis.

kind
[{'introselect'}, optional] Selection algorithm. Default is 'introselect'.

order
[str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need to be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

See also:

numpy.partition
Return a partitioned copy of an array.

argpartition
Indirect partition.

sort
Full sort.

Notes

See `np.partition` for notes on the different algorithms.

Examples

```
>>> import numpy as np
>>> a = np.array([3, 4, 2, 1])
>>> a.partition(3)
>>> a
array([2, 1, 3, 4]) # may vary
```

```
>>> a.partition((1, 3))
>>> a
array([1, 2, 3, 4])
```

method

ndarray.**prod**(*axis=None*, *dtype=None*, *out=None*, *keepdims=False*, *initial=1*, *where=True*)

Return the product of the array elements over the given axis

Refer to *numpy.prod* for full documentation.

See also:

numpy.prod
equivalent function

method

ndarray.**put**(*indices*, *values*, *mode='raise'*)

Set `a.flat[n] = values[n]` for all *n* in indices.

Refer to *numpy.put* for full documentation.

See also:

numpy.put
equivalent function

method

ndarray.**ravel**([*order*])

Return a flattened array.

Refer to *numpy.ravel* for full documentation.

See also:

numpy.ravel
equivalent function

ndarray.flat
a flat iterator on the array.

method

ndarray.**repeat**(*repeats*, *axis=None*)

Repeat elements of an array.

Refer to *numpy.repeat* for full documentation.

See also:

numpy.repeat
equivalent function

method

ndarray.**reshape**(*shape*, */*, ***, *order='C'*, *copy=None*)

Returns an array containing the same data with a new shape.

Refer to *numpy.reshape* for full documentation.

See also:

numpy.reshape
equivalent function

Notes

Unlike the free function *numpy.reshape*, this method on *ndarray* allows the elements of the shape parameter to be passed in as separate arguments. For example, `a.reshape(10, 11)` is equivalent to `a.reshape((10, 11))`.

method

ndarray.**resize**(*new_shape*, *refcheck=True*)

Change shape and size of array in-place.

Parameters

new_shape
[tuple of ints, or *n* ints] Shape of resized array.

refcheck
[bool, optional] If False, reference count will not be checked. Default is True.

Returns

None

Raises

ValueError
If *a* does not own its own data or references or views to it exist, and the data memory must be changed. PyPy only: will always raise if the data memory must be changed, since there is no reliable way to determine if references or views to it exist.

SystemError
If the *order* keyword argument is specified. This behaviour is a bug in NumPy.

See also:

resize
Return a new array with the specified shape.

Notes

This reallocates space for the data area if necessary.

Only contiguous arrays (data elements consecutive in memory) can be resized.

The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set *refcheck* to False.

Examples

Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and reshaped:

```
>>> import numpy as np
```

```
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
>>> a
array([[0],
       [1]])
```

```
>>> a = np.array([[0, 1], [2, 3]], order='F')
>>> a.resize((2, 1))
>>> a
array([[0],
       [2]])
```

Enlarging an array: as above, but missing entries are filled with zeros:

```
>>> b = np.array([[0, 1], [2, 3]])
>>> b.resize(2, 3) # new_shape parameter doesn't have to be a tuple
>>> b
array([[0, 1, 2],
       [3, 0, 0]])
```

Referencing an array prevents resizing…

```
>>> c = a
>>> a.resize((1, 1))
Traceback (most recent call last):
...
ValueError: cannot resize an array that references or is referenced ...
```

Unless *refcheck* is False:

```
>>> a.resize((1, 1), refcheck=False)
>>> a
array([[0]])
>>> c
array([[0]])
```

method

ndarray.**round**(*decimals=0*, *out=None*)

Return *a* with each element rounded to the given number of decimals.

Refer to *numpy.around* for full documentation.

See also:

numpy.around
equivalent function

method

ndarray.**searchsorted**(*v*, *side='left'*, *sorter=None*)

Find indices where elements of v should be inserted in a to maintain order.

For full documentation, see *numpy.searchsorted*

See also:

numpy.searchsorted
equivalent function

method

ndarray.**setfield**(*val*, *dtype*, *offset=0*)

Put a value into a specified place in a field defined by a data-type.

Place *val* into *a*'s field defined by *dtype* and beginning *offset* bytes into the field.

Parameters

val
[object] Value to be placed in field.

dtype
[dtype object] Data-type of the field in which to place *val*.

offset
[int, optional] The number of bytes into the field at which to place *val*.

Returns

None

See also:

getfield

Examples

```
>>> import numpy as np
>>> x = np.eye(3)
>>> x.getfield(np.float64)
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
>>> x.setfield(3, np.int32)
>>> x.getfield(np.int32)
array([[3, 3, 3],
```

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```
       [3, 3, 3],
       [3, 3, 3]], dtype=int32)
>>> x
array([[1.0e+000, 1.5e-323, 1.5e-323],
       [1.5e-323, 1.0e+000, 1.5e-323],
       [1.5e-323, 1.5e-323, 1.0e+000]])
>>> x.setfield(np.eye(3), np.int32)
>>> x
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
```

method

`ndarray.`**`setflags`**(*write=None*, *align=None*, *uic=None*)

Set array flags WRITEABLE, ALIGNED, WRITEBACKIFCOPY, respectively.

These Boolean-valued flags affect how numpy interprets the memory area used by *a* (see Notes below). The ALIGNED flag can only be set to True if the data is actually aligned according to the type. The WRITEBACKIFCOPY flag can never be set to True. The flag WRITEABLE can only be set to True if the array owns its own memory, or the ultimate owner of the memory exposes a writeable buffer interface, or is a string. (The exception for string is made so that unpickling can be done without copying memory.)

Parameters

write
[bool, optional] Describes whether or not *a* can be written to.

align
[bool, optional] Describes whether or not *a* is aligned properly for its type.

uic
[bool, optional] Describes whether or not *a* is a copy of another "base" array.

Notes

Array flags provide information about how the memory area used for the array is to be interpreted. There are 7 Boolean flags in use, only three of which can be changed by the user: WRITEBACKIFCOPY, WRITEABLE, and ALIGNED.

WRITEABLE (W) the data area can be written to;

ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);

WRITEBACKIFCOPY (X) this array is a copy of some other array (referenced by .base). When the C-API function PyArray_ResolveWritebackIfCopy is called, the base array will be updated with the contents of this array.

All flags can be accessed using the single (upper case) letter as well as the full name.

Examples

```
>>> import numpy as np
>>> y = np.array([[3, 1, 7],
...               [2, 0, 0],
...               [8, 5, 9]])
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
>>> y.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
  OWNDATA : True
  WRITEABLE : True
  ALIGNED : True
  WRITEBACKIFCOPY : False
>>> y.setflags(write=0, align=0)
>>> y.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
  OWNDATA : True
  WRITEABLE : False
  ALIGNED : False
  WRITEBACKIFCOPY : False
>>> y.setflags(uic=1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set WRITEBACKIFCOPY flag to True
```

method

ndarray.**sort**(*axis=-1*, *kind=None*, *order=None*)

Sort an array in-place. Refer to *numpy.sort* for full documentation.

Parameters

axis
[int, optional] Axis along which to sort. Default is -1, which means sort along the last axis.

kind
[{'quicksort', 'mergesort', 'heapsort', 'stable'}, optional] Sorting algorithm. The default is 'quicksort'. Note that both 'stable' and 'mergesort' use timsort under the covers and, in general, the actual implementation will vary with datatype. The 'mergesort' option is retained for backwards compatibility.

order
[str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

See also:

numpy.sort
Return a sorted copy of an array.

numpy.argsort
Indirect sort.

numpy.lexsort
Indirect stable sort on multiple keys.

numpy.searchsorted
Find elements in sorted array.

numpy.partition
Partial sort.

Notes

See *numpy.sort* for notes on the different sorting algorithms.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,4], [3,1]])
>>> a.sort(axis=1)
>>> a
array([[1, 4],
       [1, 3]])
>>> a.sort(axis=0)
>>> a
array([[1, 3],
       [1, 4]])
```

Use the *order* keyword to specify a field to use when sorting a structured array:

```
>>> a = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
>>> a.sort(order='y')
>>> a
array([(b'c', 1), (b'a', 2)],
      dtype=[('x', 'S1'), ('y', '<i8')])
```

method

ndarray.**squeeze**(*axis=None*)

Remove axes of length one from *a*.

Refer to *numpy.squeeze* for full documentation.

See also:

numpy.squeeze
equivalent function

method

ndarray.**std**(*axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=False*, ***, *where=True*)

Returns the standard deviation of the array elements along given axis.

Refer to *numpy.std* for full documentation.

See also:

numpy.std
equivalent function

method

ndarray.**sum**(*axis=None*, *dtype=None*, *out=None*, *keepdims=False*, *initial=0*, *where=True*)

Return the sum of the array elements over the given axis.

Refer to *numpy.sum* for full documentation.

See also:

numpy.sum
equivalent function

method

ndarray.**swapaxes**(*axis1*, *axis2*)

Return a view of the array with *axis1* and *axis2* interchanged.

Refer to *numpy.swapaxes* for full documentation.

See also:

numpy.swapaxes
equivalent function

method

ndarray.**take**(*indices*, *axis=None*, *out=None*, *mode='raise'*)

Return an array formed from the elements of *a* at the given indices.

Refer to *numpy.take* for full documentation.

See also:

numpy.take
equivalent function

method

ndarray.**tobytes**(*order='C'*)

Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object is produced in C-order by default. This behavior is controlled by the `order` parameter.

Parameters

order
[{'C', 'F', 'A'}, optional] Controls the memory layout of the bytes object. 'C' means C-order, 'F' means F-order, 'A' (short for *Any*) means 'F' if *a* is Fortran contiguous, 'C' otherwise. Default is 'C'.

Returns

s
[bytes] Python bytes exhibiting a copy of *a*'s raw data.

See also:

frombuffer
Inverse of this operation, construct a 1-dimensional array from Python bytes.

Examples

```
>>> import numpy as np
>>> x = np.array([[0, 1], [2, 3]], dtype='<u2')
>>> x.tobytes()
b'\x00\x00\x01\x00\x02\x00\x03\x00'
>>> x.tobytes('C') == x.tobytes()
True
>>> x.tobytes('F')
b'\x00\x00\x02\x00\x01\x00\x03\x00'
```

method

ndarray.**tofile**(*fid*, *sep=''*, *format='%s'*)

Write array to a file as text or binary (default).

Data is always written in 'C' order, independent of the order of *a*. The data produced by this method can be recovered using the function fromfile().

Parameters

fid
[file or str or Path] An open file object, or a string containing a filename.

sep
[str] Separator between array items for text output. If "" (empty), a binary file is written, equivalent to `file.write(a.tobytes())`.

format
[str] Format string for text file output. Each entry in the array is formatted to text by first converting it to the closest Python type, and then using "format" % item.

Notes

This is a convenience function for quick storage of array data. Information on endianness and precision is lost, so this method is not a good choice for files intended to archive data or transport data between machines with different endianness. Some of these problems can be overcome by outputting the data as text files, at the expense of speed and file size.

When fid is a file object, array contents are directly written to the file, bypassing the file object's `write` method. As a result, tofile cannot be used with files objects supporting compression (e.g., GzipFile) or file-like objects that do not support `fileno()` (e.g., BytesIO).

method

ndarray.**tolist**()

Return the array as an `a.ndim`-levels deep nested list of Python scalars.

Return a copy of the array data as a (nested) Python list. Data items are converted to the nearest compatible builtin Python type, via the *item* function.

If `a.ndim` is 0, then since the depth of the nested list is 0, it will not be a list at all, but a simple Python scalar.

Parameters

none

Returns

y
[object, or list of object, or list of list of object, or …] The possibly nested list of array elements.

Notes

The array may be recreated via `a = np.array(a.tolist())`, although this may sometimes lose precision.

Examples

For a 1D array, `a.tolist()` is almost the same as `list(a)`, except that `tolist` changes numpy scalars to Python scalars:

```
>>> import numpy as np
>>> a = np.uint32([1, 2])
>>> a_list = list(a)
>>> a_list
[np.uint32(1), np.uint32(2)]
>>> type(a_list[0])
<class 'numpy.uint32'>
>>> a_tolist = a.tolist()
>>> a_tolist
[1, 2]
>>> type(a_tolist[0])
<class 'int'>
```

Additionally, for a 2D array, `tolist` applies recursively:

```
>>> a = np.array([[1, 2], [3, 4]])
>>> list(a)
[array([1, 2]), array([3, 4])]
>>> a.tolist()
[[1, 2], [3, 4]]
```

The base case for this recursion is a 0D array:

```
>>> a = np.array(1)
>>> list(a)
Traceback (most recent call last):
  ...
TypeError: iteration over a 0-d array
>>> a.tolist()
1
```

method

`ndarray.`**`tostring`**(*order='C'*)

A compatibility alias for *tobytes*, with exactly the same behavior.

Despite its name, it returns `bytes` not `str`s.

Deprecated since version 1.19.0.

method

ndarray.**trace**(*offset=0*, *axis1=0*, *axis2=1*, *dtype=None*, *out=None*)

Return the sum along diagonals of the array.

Refer to *numpy.trace* for full documentation.

See also:

numpy.trace
equivalent function

method

ndarray.**transpose**(**axes*)

Returns a view of the array with axes transposed.

Refer to *numpy.transpose* for full documentation.

Parameters

axes
[None, tuple of ints, or *n* ints]

- None or no argument: reverses the order of the axes.
- tuple of ints: *i* in the *j*-th place in the tuple means that the array's *i*-th axis becomes the transposed array's *j*-th axis.
- *n* ints: same as an n-tuple of the same ints (this form is intended simply as a "convenience" alternative to the tuple form).

Returns

p
[ndarray] View of the array with its axes suitably permuted.

See also:

transpose
Equivalent function.

ndarray.T
Array property returning the array transposed.

ndarray.reshape
Give a new shape to an array without changing its data.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
```

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```
array([[1, 3],
       [2, 4]])
```

```
>>> a = np.array([1, 2, 3, 4])
>>> a
array([1, 2, 3, 4])
>>> a.transpose()
array([1, 2, 3, 4])
```

method

ndarray.**var**(*axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=False*, ***, *where=True*)

Returns the variance of the array elements, along given axis.

Refer to *numpy.var* for full documentation.

See also:

numpy.var
equivalent function

method

ndarray.**view**(*[dtype][, type]*)

New view of array with the same data.

Note: Passing None for `dtype` is different from omitting the parameter, since the former invokes `dtype(None)` which is an alias for `dtype('float64')`.

Parameters

dtype
[data-type or ndarray sub-class, optional] Data-type descriptor of the returned view, e.g., float32 or int16. Omitting it results in the view having the same data-type as *a*. This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the `type` parameter).

type
[Python type, optional] Type of the returned view, e.g., ndarray or matrix. Again, omission of the parameter results in type preservation.

Notes

`a.view()` is used two different ways:

`a.view(some_dtype)` or `a.view(dtype=some_dtype)` constructs a view of the array's memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

`a.view(ndarray_subclass)` or `a.view(type=ndarray_subclass)` just returns an instance of *ndarray_subclass* that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For `a.view(some_dtype)`, if `some_dtype` has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the last axis of `a` must be contiguous. This axis will be resized in the result.

Changed in version 1.23.0: Only the last axis needs to be contiguous. Previously, the entire array had to be C-contiguous.

Examples

```
>>> import numpy as np
>>> x = np.array([(-1, 2)], dtype=[('a', np.int8), ('b', np.int8)])
```

Viewing array data using a different type and dtype:

```
>>> nonneg = np.dtype([("a", np.uint8), ("b", np.uint8)])
>>> y = x.view(dtype=nonneg, type=np.recarray)
>>> x["a"]
array([-1], dtype=int8)
>>> y.a
array([255], dtype=uint8)
```

Creating a view on a structured array so it can be used in calculations

```
>>> x = np.array([(1, 2),(3,4)], dtype=[('a', np.int8), ('b', np.int8)])
>>> xv = x.view(dtype=np.int8).reshape(-1,2)
>>> xv
array([[1, 2],
       [3, 4]], dtype=int8)
>>> xv.mean(0)
array([2.,  3.])
```

Making changes to the view changes the underlying array

```
>>> xv[0,1] = 20
>>> x
array([(1, 20), (3,  4)], dtype=[('a', 'i1'), ('b', 'i1')])
```

Using a view to convert an array to a recarray:

```
>>> z = x.view(np.recarray)
>>> z.a
array([1, 3], dtype=int8)
```

Views share data:

```
>>> x[0] = (9, 10)
>>> z[0]
np.record((9, 10), dtype=[('a', 'i1'), ('b', 'i1')])
```

Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.:

```
>>> x = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.int16)
>>> y = x[:, ::2]
>>> y
array([[1, 3],
       [4, 6]], dtype=int16)
>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
    ...
```

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```
ValueError: To change to a dtype of a different size, the last axis must be␣
↪contiguous
>>> z = y.copy()
>>> z.view(dtype=[('width', np.int16), ('length', np.int16)])
array([[(1, 3)],
       [(4, 6)]], dtype=[('width', '<i2'), ('length', '<i2')])
```

However, views that change dtype are totally fine for arrays with a contiguous last axis, even if the rest of the axes are not C-contiguous:

```
>>> x = np.arange(2 * 3 * 4, dtype=np.int8).reshape(2, 3, 4)
>>> x.transpose(1, 0, 2).view(np.int16)
array([[[ 256,  770],
        [3340, 3854]],

       [[1284, 1798],
        [4368, 4882]],

       [[2312, 2826],
        [5396, 5910]]], dtype=int16)
```

dot
to_device

Indexing arrays

Arrays can be indexed using an extended Python slicing syntax, `array[selection]`. Similar syntax is also used for accessing fields in a structured data type.

See also:

Array Indexing.

Internal memory layout of an ndarray

An instance of class *ndarray* consists of a contiguous one-dimensional segment of computer memory (owned by the array, or by some other object), combined with an indexing scheme that maps *N* integers into the location of an item in the block. The ranges in which the indices can vary is specified by the *shape* of the array. How many bytes each item takes and how the bytes are interpreted is defined by the *data-type object* associated with the array.

A segment of memory is inherently 1-dimensional, and there are many different schemes for arranging the items of an *N*-dimensional array in a 1-dimensional block. NumPy is flexible, and *ndarray* objects can accommodate any *strided indexing scheme*. In a strided scheme, the N-dimensional index $(n_0, n_1, ..., n_{N-1})$ corresponds to the offset (in bytes):

$$n_{\text{offset}} = \sum_{k=0}^{N-1} s_k n_k$$

from the beginning of the memory block associated with the array. Here, s_k are integers which specify the *strides* of the array. The column-major order (used, for example, in the Fortran language and in *Matlab*) and row-major order (used in C) schemes are just specific kinds of strided scheme, and correspond to memory that can be *addressed* by the strides:

$$s_k^{\text{column}} = \text{itemsize} \prod_{j=0}^{k-1} d_j, \quad s_k^{\text{row}} = \text{itemsize} \prod_{j=k+1}^{N-1} d_j.$$

where d_j = *self.shape[j]*.

Both the C and Fortran orders are contiguous, *i.e.,* single-segment, memory layouts, in which every part of the memory block can be accessed by some combination of the indices.

Note: *Contiguous arrays* and *single-segment arrays* are synonymous and are used interchangeably throughout the documentation.

While a C-style and Fortran-style contiguous array, which has the corresponding flags set, can be addressed with the above strides, the actual strides may be different. This can happen in two cases:

1. If `self.shape[k] == 1` then for any legal index `index[k] == 0`. This means that in the formula for the offset $n_k = 0$ and thus $s_k n_k = 0$ and the value of s_k = *self.strides[k]* is arbitrary.
2. If an array has no elements (`self.size == 0`) there is no legal index and the strides are never used. Any array with no elements may be considered C-style and Fortran-style contiguous.

Point 1. means that `self` and `self.squeeze()` always have the same contiguity and `aligned` flags value. This also means that even a high dimensional array could be C-style and Fortran-style contiguous at the same time.

An array is considered aligned if the memory offsets for all elements and the base offset itself is a multiple of *self.itemsize*. Understanding *memory-alignment* leads to better performance on most hardware.

Warning: It does *not* generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true.

Data in new *ndarrays* is in the row-major (C) order, unless otherwise specified, but, for example, *basic array slicing* often produces views in a different scheme.

Note: Several algorithms in NumPy work on arbitrarily strided arrays. However, some algorithms require single-segment arrays. When an irregularly strided array is passed in to such algorithms, a copy is automatically made.

Array attributes

Array attributes reflect information that is intrinsic to the array itself. Generally, accessing an array through its attributes allows you to get and sometimes set intrinsic properties of the array without creating a new array. The exposed attributes are the core parts of an array and only some of them can be reset meaningfully without creating a new array. Information on each attribute is given below.

Memory layout

The following attributes contain information about the memory layout of the array:

ndarray.flags	Information about the memory layout of the array.
ndarray.shape	Tuple of array dimensions.
ndarray.strides	Tuple of bytes to step in each dimension when traversing an array.
ndarray.ndim	Number of array dimensions.
ndarray.data	Python buffer object pointing to the start of the array's data.
ndarray.size	Number of elements in the array.
ndarray.itemsize	Length of one array element in bytes.
ndarray.nbytes	Total bytes consumed by the elements of the array.
ndarray.base	Base object if memory is from some other object.

attribute

ndarray.**flags**

Information about the memory layout of the array.

Notes

The *flags* object can be accessed dictionary-like (as in `a.flags['WRITEABLE']`), or by using lowercased attribute names (as in `a.flags.writeable`). Short flag names are only supported in dictionary access.

Only the WRITEBACKIFCOPY, WRITEABLE, and ALIGNED flags can be changed by the user, via direct assignment to the attribute or dictionary entry, or by calling *ndarray.setflags*.

The array flags cannot be set arbitrarily:

- WRITEBACKIFCOPY can only be set `False`.
- ALIGNED can only be set `True` if the data is truly aligned.
- WRITEABLE can only be set `True` if the array owns its own memory or the ultimate owner of the memory exposes a writeable buffer interface or is a string.

Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension `arr.strides[dim]` may be *arbitrary* if `arr.shape[dim] == 1` or the array has no elements. It does *not* generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true.

Attributes

C_CONTIGUOUS (C)
The data is in a single, C-style contiguous segment.

F_CONTIGUOUS (F)
The data is in a single, Fortran-style contiguous segment.

OWNDATA (O)
The array owns the memory it uses or borrows it from another object.

WRITEABLE (W)
The data area can be written to. Setting this to False locks the data, making it read-only. A view (slice, etc.) inherits WRITEABLE from its base array at creation time, but a view of a writeable array may be subsequently locked while the base array remains writeable. (The opposite is not true, in that a view of a locked array may not be made writeable. However,

currently, locking a base object does not lock any views that already reference it, so under that circumstance it is possible to alter the contents of a locked array via a previously created writeable view onto it.) Attempting to change a non-writeable array raises a RuntimeError exception.

ALIGNED (A)
The data and all elements are aligned appropriately for the hardware.

WRITEBACKIFCOPY (X)
This array is a copy of some other array. The C-API function PyArray_ResolveWritebackIfCopy must be called before deallocating to the base array will be updated with the contents of this array.

FNC
F_CONTIGUOUS and not C_CONTIGUOUS.

FORC
F_CONTIGUOUS or C_CONTIGUOUS (one-segment test).

BEHAVED (B)
ALIGNED and WRITEABLE.

CARRAY (CA)
BEHAVED and C_CONTIGUOUS.

FARRAY (FA)
BEHAVED and F_CONTIGUOUS and not C_CONTIGUOUS.

attribute

`ndarray.`**`shape`**

Tuple of array dimensions.

The shape property is usually used to get the current shape of an array, but may also be used to reshape the array in-place by assigning a tuple of array dimensions to it. As with *`numpy.reshape`*, one of the new shape dimensions can be -1, in which case its value is inferred from the size of the array and the remaining dimensions. Reshaping an array in-place will fail if a copy is required.

> **Warning:** Setting `arr.shape` is discouraged and may be deprecated in the future. Using *`ndarray.reshape`* is the preferred approach.

See also:

`numpy.shape`
Equivalent getter function.

`numpy.reshape`
Function similar to setting `shape`.

`ndarray.reshape`
Method similar to setting `shape`.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 3, 4])
>>> x.shape
(4,)
>>> y = np.zeros((2, 3, 4))
>>> y.shape
(2, 3, 4)
>>> y.shape = (3, 8)
>>> y
array([[ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.]])
>>> y.shape = (3, 6)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: total size of new array must be unchanged
>>> np.zeros((4,2))[::2].shape = (-1,)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: Incompatible shape for in-place modification. Use
`.reshape()` to make a copy with the desired shape.
```

attribute

ndarray.**strides**

Tuple of bytes to step in each dimension when traversing an array.

The byte offset of element `(i[0], i[1], ..., i[n])` in an array *a* is:

```
offset = sum(np.array(i) * a.strides)
```

A more detailed explanation of strides can be found in *The N-dimensional array (ndarray)*.

Warning: Setting `arr.strides` is discouraged and may be deprecated in the future. *`numpy.lib.stride_tricks.as_strided`* should be preferred to create a new view of the same data in a safer way.

See also:

numpy.lib.stride_tricks.as_strided

Notes

Imagine an array of 32-bit integers (each 4 bytes):

```
x = np.array([[0, 1, 2, 3, 4],
              [5, 6, 7, 8, 9]], dtype=np.int32)
```

This array is stored in memory as 40 bytes, one after the other (known as a contiguous block of memory). The strides of an array tell us how many bytes we have to skip in memory to move to the next position along a certain axis. For example, we have to skip 4 bytes (1 value) to move to the next column, but 20 bytes (5 values) to get to the same position in the next row. As such, the strides for the array *x* will be `(20, 4)`.

Examples

```
>>> import numpy as np
>>> y = np.reshape(np.arange(2*3*4), (2,3,4))
>>> y
array([[[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]],
       [[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]]])
>>> y.strides
(48, 16, 4)
>>> y[1,1,1]
17
>>> offset=sum(y.strides * np.array((1,1,1)))
>>> offset/y.itemsize
17
```

```
>>> x = np.reshape(np.arange(5*6*7*8), (5,6,7,8)).transpose(2,3,1,0)
>>> x.strides
(32, 4, 224, 1344)
>>> i = np.array([3,5,2,2])
>>> offset = sum(i * x.strides)
>>> x[3,5,2,2]
813
>>> offset / x.itemsize
813
```

attribute

`ndarray.`**`ndim`**

Number of array dimensions.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 3])
>>> x.ndim
1
>>> y = np.zeros((2, 3, 4))
>>> y.ndim
3
```

attribute

`ndarray.`**`data`**

Python buffer object pointing to the start of the array's data.

attribute

`ndarray.`**`size`**

Number of elements in the array.

Equal to `np.prod(a.shape)`, i.e., the product of the array's dimensions.

Notes

a.size returns a standard arbitrary precision Python integer. This may not be the case with other methods of obtaining the same value (like the suggested `np.prod(a.shape)`, which returns an instance of `np.int_`), and may be relevant if the value is used further in calculations that may overflow a fixed size integer type.

Examples

```
>>> import numpy as np
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.size
30
>>> np.prod(x.shape)
30
```

attribute

`ndarray.`**`itemsize`**

Length of one array element in bytes.

Examples

```
>>> import numpy as np
>>> x = np.array([1,2,3], dtype=np.float64)
>>> x.itemsize
8
>>> x = np.array([1,2,3], dtype=np.complex128)
>>> x.itemsize
16
```

attribute

`ndarray.`**`nbytes`**

Total bytes consumed by the elements of the array.

See also:

`sys.getsizeof`

Memory consumed by the object itself without parents in case view. This does include memory consumed by non-element attributes.

Notes

Does not include memory consumed by non-element attributes of the array object.

Examples

```
>>> import numpy as np
>>> x = np.zeros((3,5,2), dtype=np.complex128)
>>> x.nbytes
480
>>> np.prod(x.shape) * x.itemsize
480
```

attribute

ndarray.**base**

Base object if memory is from some other object.

Examples

The base of an array that owns its memory is None:

```
>>> import numpy as np
>>> x = np.array([1,2,3,4])
>>> x.base is None
True
```

Slicing creates a view, whose memory is shared with x:

```
>>> y = x[2:]
>>> y.base is x
True
```

Data type

See also:

Data type objects

The data type object associated with the array can be found in the *dtype* attribute:

ndarray.dtype	Data-type of the array's elements.

attribute

ndarray.**dtype**

Data-type of the array's elements.

> **Warning:** Setting `arr.dtype` is discouraged and may be deprecated in the future. Setting will replace the `dtype` without modifying the memory (see also *ndarray.view* and *ndarray.astype*).

Parameters

None

Returns

d

[numpy dtype object]

See also:

ndarray.astype
Cast the values contained in the array to a new data-type.

ndarray.view
Create a view of the same data but a different data-type.

numpy.dtype

Examples

```
>>> x
array([[0, 1],
       [2, 3]])
>>> x.dtype
dtype('int32')
>>> type(x.dtype)
<type 'numpy.dtype'>
```

Other attributes

ndarray.T	View of the transposed array.
ndarray.real	The real part of the array.
ndarray.imag	The imaginary part of the array.
ndarray.flat	A 1-D iterator over the array.

attribute

ndarray.**T**
View of the transposed array.

Same as `self.transpose()`.

See also:

transpose

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.T
array([[1, 3],
       [2, 4]])
```

```
>>> a = np.array([1, 2, 3, 4])
>>> a
array([1, 2, 3, 4])
>>> a.T
array([1, 2, 3, 4])
```

attribute

ndarray.**real**

The real part of the array.

See also:

numpy.real
equivalent function

Examples

```
>>> import numpy as np
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.real
array([ 1.        ,  0.70710678])
>>> x.real.dtype
dtype('float64')
```

attribute

ndarray.**imag**

The imaginary part of the array.

Examples

```
>>> import numpy as np
>>> x = np.sqrt([1+0j, 0+1j])
>>> x.imag
array([ 0.        ,  0.70710678])
>>> x.imag.dtype
dtype('float64')
```

attribute

ndarray.**flat**

A 1-D iterator over the array.

This is a *numpy.flatiter* instance, which acts similarly to, but is not a subclass of, Python's built-in iterator object.

See also:

flatten
Return a copy of the array collapsed into one dimension.

flatiter

Examples

```
>>> import numpy as np
>>> x = np.arange(1, 7).reshape(2, 3)
>>> x
array([[1, 2, 3],
       [4, 5, 6]])
>>> x.flat[3]
4
>>> x.T
array([[1, 4],
       [2, 5],
       [3, 6]])
>>> x.T.flat[3]
5
>>> type(x.flat)
<class 'numpy.flatiter'>
```

An assignment example:

```
>>> x.flat = 3; x
array([[3, 3, 3],
       [3, 3, 3]])
>>> x.flat[[1,4]] = 1; x
array([[3, 1, 3],
       [3, 1, 3]])
```

Array interface

See also:

The array interface protocol.

__array_interface__	Python-side of the array interface
__array_struct__	C-side of the array interface

`ctypes` foreign function interface

ndarray.ctypes	An object to simplify the interaction of the array with the ctypes module.

attribute

ndarray.**ctypes**

An object to simplify the interaction of the array with the ctypes module.

This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.

Parameters

None

Returns

c
: [Python object] Possessing attributes data, shape, strides, etc.

See also:

numpy.ctypeslib

Notes

Below are the public attributes of this object which were documented in "Guide to NumPy" (we have omitted undocumented public attributes, as well as documented private attributes):

`_ctypes.`**`data`**
: A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as: `self._array_interface_['data'][0]`.

  Note that unlike `data_as`, a reference won't be kept to the array: code like `ctypes.c_void_p((a + b).ctypes.data)` will result in a pointer to a deallocated array, and should be spelt `(a + b).ctypes.data_as(ctypes.c_void_p)`

`_ctypes.`**`shape`**
: (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the C-integer corresponding to `dtype('p')` on this platform (see *c_intp*). This base-type could be `ctypes.c_int`, `ctypes.c_long`, or `ctypes.c_longlong` depending on the platform. The ctypes array contains the shape of the underlying array.

`_ctypes.`**`strides`**
: (c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array. This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

`_ctypes.`**`data_as`**`(`*obj*`)`
: Return the data pointer cast to a particular c-types object. For example, calling `self._as_parameter_` is equivalent to `self.data_as(ctypes.c_void_p)`. Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: `self.data_as(ctypes.POINTER(ctypes.c_double))`.

  The returned pointer will keep a reference to the array.

`_ctypes.`**`shape_as`**`(`*obj*`)`
: Return the shape tuple as an array of some other c-types type. For example: `self.shape_as(ctypes.c_short)`.

`_ctypes.`**`strides_as`**`(`*obj*`)`
: Return the strides tuple as an array of some other c-types type. For example: `self.strides_as(ctypes.c_longlong)`.

If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the `as_parameter` attribute which will return an integer equal to the data attribute.

Examples

```
>>> import numpy as np
>>> import ctypes
>>> x = np.array([[0, 1], [2, 3]], dtype=np.int32)
>>> x
array([[0, 1],
       [2, 3]], dtype=int32)
>>> x.ctypes.data
31962608 # may vary
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_uint32))
<__main__.LP_c_uint object at 0x7ff2fc1fc200> # may vary
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_uint32)).contents
c_uint(0)
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_uint64)).contents
c_ulong(4294967296)
>>> x.ctypes.shape
<numpy._core._internal.c_long_Array_2 object at 0x7ff2fc1fce60> # may vary
>>> x.ctypes.strides
<numpy._core._internal.c_long_Array_2 object at 0x7ff2fc1ff320> # may vary
```

Array methods

An *ndarray* object has many methods which operate on or with the array in some fashion, typically returning an array result. These methods are briefly explained below. (Each method's docstring has a more complete description.)

For the following methods there are also corresponding functions in *numpy*: *all*, *any*, *argmax*, *argmin*, *argpartition*, *argsort*, *choose*, *clip*, *compress*, *copy*, *cumprod*, *cumsum*, *diagonal*, *imag*, *max*, *mean*, *min*, *nonzero*, *partition*, *prod*, *put*, *ravel*, *real*, *repeat*, *reshape*, *round*, *searchsorted*, *sort*, *squeeze*, *std*, *sum*, *swapaxes*, *take*, *trace*, *transpose*, *var*.

Array conversion

ndarray.item(*args)	Copy an element of an array to a standard Python scalar and return it.
ndarray.tolist()	Return the array as an `a.ndim`-levels deep nested list of Python scalars.
ndarray.tostring([order])	A compatibility alias for *tobytes*, with exactly the same behavior.
ndarray.tobytes([order])	Construct Python bytes containing the raw data bytes in the array.
ndarray.tofile(fid[, sep, format])	Write array to a file as text or binary (default).
ndarray.dump(file)	Dump a pickle of the array to the specified file.
ndarray.dumps()	Returns the pickle of the array as a string.
ndarray.astype(dtype[, order, casting, ...])	Copy of the array, cast to a specified type.
ndarray.byteswap([inplace])	Swap the bytes of the array elements
ndarray.copy([order])	Return a copy of the array.
ndarray.view([dtype][, type])	New view of array with the same data.
ndarray.getfield(dtype[, offset])	Returns a field of the given array as a certain type.
ndarray.setflags([write, align, uic])	Set array flags WRITEABLE, ALIGNED, WRITEBACKIFCOPY, respectively.
ndarray.fill(value)	Fill the array with a scalar value.

Shape manipulation

For reshape, resize, and transpose, the single tuple argument may be replaced with `n` integers which will be interpreted as an n-tuple.

ndarray.reshape(shape, /, *[, order, copy])	Returns an array containing the same data with a new shape.
ndarray.resize(new_shape[, refcheck])	Change shape and size of array in-place.
ndarray.transpose(*axes)	Returns a view of the array with axes transposed.
ndarray.swapaxes(axis1, axis2)	Return a view of the array with *axis1* and *axis2* interchanged.
ndarray.flatten([order])	Return a copy of the array collapsed into one dimension.
ndarray.ravel([order])	Return a flattened array.
ndarray.squeeze([axis])	Remove axes of length one from *a*.

Item selection and manipulation

For array methods that take an *axis* keyword, it defaults to *None*. If axis is *None*, then the array is treated as a 1-D array. Any other value for *axis* represents the dimension along which the operation should proceed.

ndarray.take(indices[, axis, out, mode])	Return an array formed from the elements of *a* at the given indices.
ndarray.put(indices, values[, mode])	Set `a.flat[n] = values[n]` for all *n* in indices.
ndarray.repeat(repeats[, axis])	Repeat elements of an array.
ndarray.choose(choices[, out, mode])	Use an index array to construct a new array from a set of choices.
ndarray.sort([axis, kind, order])	Sort an array in-place.
ndarray.argsort([axis, kind, order])	Returns the indices that would sort this array.
ndarray.partition(kth[, axis, kind, order])	Partially sorts the elements in the array in such a way that the value of the element in k-th position is in the position it would be in a sorted array.
ndarray.argpartition(kth[, axis, kind, order])	Returns the indices that would partition this array.
ndarray.searchsorted(v[, side, sorter])	Find indices where elements of v should be inserted in a to maintain order.
ndarray.nonzero()	Return the indices of the elements that are non-zero.
ndarray.compress(condition[, axis, out])	Return selected slices of this array along given axis.
ndarray.diagonal([offset, axis1, axis2])	Return specified diagonals.

Calculation

Many of these methods take an argument named *axis*. In such cases,

- If *axis* is *None* (the default), the array is treated as a 1-D array and the operation is performed over the entire array. This behavior is also the default if self is a 0-dimensional array or array scalar. (An array scalar is an instance of the types/classes float32, float64, etc., whereas a 0-dimensional array is an ndarray instance containing precisely one array scalar.)
- If *axis* is an integer, then the operation is done over the given axis (for each 1-D subarray that can be created along the given axis).

Example of the *axis* argument

A 3-dimensional array of size 3 x 3 x 3, summed over each of its three axes:

```
>>> import numpy as np
```

```
>>> x = np.arange(27).reshape((3,3,3))
>>> x
array([[[ 0,  1,  2],
        [ 3,  4,  5],
        [ 6,  7,  8]],
       [[ 9, 10, 11],
        [12, 13, 14],
        [15, 16, 17]],
       [[18, 19, 20],
        [21, 22, 23],
        [24, 25, 26]]])
>>> x.sum(axis=0)
array([[27, 30, 33],
       [36, 39, 42],
       [45, 48, 51]])
>>> # for sum, axis is the first keyword, so we may omit it,
>>> # specifying only its value
>>> x.sum(0), x.sum(1), x.sum(2)
(array([[27, 30, 33],
        [36, 39, 42],
        [45, 48, 51]]),
array([[ 9, 12, 15],
        [36, 39, 42],
        [63, 66, 69]]),
array([[ 3, 12, 21],
        [30, 39, 48],
        [57, 66, 75]]))
```

The parameter *dtype* specifies the data type over which a reduction operation (like summing) should take place. The default reduce data type is the same as the data type of *self*. To avoid overflow, it can be useful to perform the reduction using a larger data type.

For several methods, an optional *out* argument can also be provided and the result will be placed into the output array given. The *out* argument must be an *ndarray* and have the same number of elements. It can have a different data type in which case casting will be performed.

ndarray.max([axis, out, keepdims, initial, ...])	Return the maximum along a given axis.
ndarray.argmax([axis, out, keepdims])	Return indices of the maximum values along the given axis.
ndarray.min([axis, out, keepdims, initial, ...])	Return the minimum along a given axis.
ndarray.argmin([axis, out, keepdims])	Return indices of the minimum values along the given axis.
ndarray.clip([min, max, out])	Return an array whose values are limited to `[min, max]`.
ndarray.conj()	Complex-conjugate all elements.
ndarray.round([decimals, out])	Return *a* with each element rounded to the given number of decimals.
ndarray.trace([offset, axis1, axis2, dtype, out])	Return the sum along diagonals of the array.
ndarray.sum([axis, dtype, out, keepdims, ...])	Return the sum of the array elements over the given axis.
ndarray.cumsum([axis, dtype, out])	Return the cumulative sum of the elements along the given axis.
ndarray.mean([axis, dtype, out, keepdims, where])	Returns the average of the array elements along given axis.
ndarray.var([axis, dtype, out, ddof, ...])	Returns the variance of the array elements, along given axis.
ndarray.std([axis, dtype, out, ddof, ...])	Returns the standard deviation of the array elements along given axis.
ndarray.prod([axis, dtype, out, keepdims, ...])	Return the product of the array elements over the given axis
ndarray.cumprod([axis, dtype, out])	Return the cumulative product of the elements along the given axis.
ndarray.all([axis, out, keepdims, where])	Returns True if all elements evaluate to True.
ndarray.any([axis, out, keepdims, where])	Returns True if any of the elements of *a* evaluate to True.

Arithmetic, matrix multiplication, and comparison operations

Arithmetic and comparison operations on *ndarrays* are defined as element-wise operations, and generally yield *ndarray* objects as results.

Each of the arithmetic operations (`+`, `-`, `*`, `/`, `//`, `%`, `divmod()`, `**` or `pow()`, `<<`, `>>`, `&`, `^`, `|`, `~`) and the comparisons (`==`, `<`, `>`, `<=`, `>=`, `!=`) is equivalent to the corresponding universal function (or ufunc for short) in NumPy. For more information, see the section on *Universal Functions*.

Comparison operators:

ndarray.__lt__(value, /)	Return self<value.
ndarray.__le__(value, /)	Return self<=value.
ndarray.__gt__(value, /)	Return self>value.
ndarray.__ge__(value, /)	Return self>=value.
ndarray.__eq__(value, /)	Return self==value.
ndarray.__ne__(value, /)	Return self!=value.

method

ndarray.**__lt__**(*value*, /)

Return self<value.

method

ndarray.**__le__**(*value*, /)
Return self<=value.

method

ndarray.**__gt__**(*value*, /)
Return self>value.

method

ndarray.**__ge__**(*value*, /)
Return self>=value.

method

ndarray.**__eq__**(*value*, /)
Return self==value.

method

ndarray.**__ne__**(*value*, /)
Return self!=value.

Truth value of an array (*bool()*):

ndarray.__bool__(/)	True if self else False

method

ndarray.**__bool__**(/)
True if self else False

Note: Truth-value testing of an array invokes *ndarray.__bool__*, which raises an error if the number of elements in the array is not 1, because the truth value of such arrays is ambiguous. Use *.any()* and *.all()* instead to be clear about what is meant in such cases. (If you wish to check for whether an array is empty, use for example `.size > 0`.)

Unary operations:

ndarray.__neg__(/)	-self
ndarray.__pos__(/)	+self
ndarray.__abs__(self)	
ndarray.__invert__(/)	~self

method

ndarray.**__neg__**(/)
-self

method

ndarray.**__pos__**(/)
+self

method

ndarray.**__abs__**(*self*)

method

ndarray.**__invert__**(*/*)

~self

Arithmetic:

ndarray.__add__(value, /)	Return self+value.
ndarray.__sub__(value, /)	Return self-value.
ndarray.__mul__(value, /)	Return self*value.
ndarray.__truediv__(value, /)	Return self/value.
ndarray.__floordiv__(value, /)	Return self//value.
ndarray.__mod__(value, /)	Return self%value.
ndarray.__divmod__(value, /)	Return divmod(self, value).
ndarray.__pow__(value[, mod])	Return pow(self, value, mod).
ndarray.__lshift__(value, /)	Return self<<value.
ndarray.__rshift__(value, /)	Return self>>value.
ndarray.__and__(value, /)	Return self&value.
ndarray.__or__(value, /)	Return self|value.
ndarray.__xor__(value, /)	Return self^value.

method

ndarray.**__add__**(*value*, */*)

Return self+value.

method

ndarray.**__sub__**(*value*, */*)

Return self-value.

method

ndarray.**__mul__**(*value*, */*)

Return self*value.

method

ndarray.**__truediv__**(*value*, */*)

Return self/value.

method

ndarray.**__floordiv__**(*value*, */*)

Return self//value.

method

ndarray.**__mod__**(*value*, */*)

Return self%value.

method

ndarray.**__divmod__**(*value*, */*)

Return divmod(self, value).

method

ndarray.**__pow__**(*value*, *mod=None*, */*)
Return pow(self, value, mod).

method

ndarray.**__lshift__**(*value*, */*)
Return self<<value.

method

ndarray.**__rshift__**(*value*, */*)
Return self>>value.

method

ndarray.**__and__**(*value*, */*)
Return self&value.

method

ndarray.**__or__**(*value*, */*)
Return self|value.

method

ndarray.**__xor__**(*value*, */*)
Return self^value.

Note:

- Any third argument to *pow* is silently ignored, as the underlying *ufunc* takes only two arguments.
- Because *ndarray* is a built-in type (written in C), the __r{op}__ special methods are not directly defined.
- The functions called to implement many arithmetic special methods for arrays can be modified using *__array_ufunc__*.

Arithmetic, in-place:

ndarray.__iadd__(value, /)	Return self+=value.
ndarray.__isub__(value, /)	Return self-=value.
ndarray.__imul__(value, /)	Return self*=value.
ndarray.__itruediv__(value, /)	Return self/=value.
ndarray.__ifloordiv__(value, /)	Return self//=value.
ndarray.__imod__(value, /)	Return self%=value.
ndarray.__ipow__(value, /)	Return self**=value.
ndarray.__ilshift__(value, /)	Return self<<=value.
ndarray.__irshift__(value, /)	Return self>>=value.
ndarray.__iand__(value, /)	Return self&=value.
ndarray.__ior__(value, /)	Return self|=value.
ndarray.__ixor__(value, /)	Return self^=value.

method

ndarray.**__iadd__**(*value*, */*)
Return self+=value.

method

ndarray.**__isub__**(*value*, /)
Return self-=value.

method

ndarray.**__imul__**(*value*, /)
Return self*=value.

method

ndarray.**__itruediv__**(*value*, /)
Return self/=value.

method

ndarray.**__ifloordiv__**(*value*, /)
Return self//=value.

method

ndarray.**__imod__**(*value*, /)
Return self%=value.

method

ndarray.**__ipow__**(*value*, /)
Return self**=value.

method

ndarray.**__ilshift__**(*value*, /)
Return self<<=value.

method

ndarray.**__irshift__**(*value*, /)
Return self>>=value.

method

ndarray.**__iand__**(*value*, /)
Return self&=value.

method

ndarray.**__ior__**(*value*, /)
Return self|=value.

method

ndarray.**__ixor__**(*value*, /)
Return self^=value.

Warning: In place operations will perform the calculation using the precision decided by the data type of the two operands, but will silently downcast the result (if necessary) so it can fit back into the array. Therefore, for mixed precision calculations, `A {op}= B` can be different than `A = A {op} B`. For example, suppose `a = ones((3, 3))`. Then, `a += 3j` is different than `a = a + 3j`: while they both perform the same computation, `a += 3` casts the result to fit back in `a`, whereas `a = a + 3j` re-binds the name `a` to the result.

Matrix Multiplication:

ndarray.__matmul__(value, /)	Return self@value.

method

ndarray.**__matmul__**(*value*, /)

Return self@value.

Note: Matrix operators `@` and `@=` were introduced in Python 3.5 following **PEP 465**, and the `@` operator has been introduced in NumPy 1.10.0. Further information can be found in the *matmul* documentation.

Special methods

For standard library functions:

ndarray.__copy__()	Used if `copy.copy` is called on an array.
ndarray.__deepcopy__(memo, /)	Used if `copy.deepcopy` is called on an array.
ndarray.__reduce__()	For pickling.
ndarray.__setstate__(state, /)	For unpickling.

method

ndarray.**__copy__**()

Used if `copy.copy` is called on an array. Returns a copy of the array.

Equivalent to `a.copy(order='K')`.

method

ndarray.**__deepcopy__**(*memo*, /)

Used if `copy.deepcopy` is called on an array.

method

ndarray.**__reduce__**()

For pickling.

method

ndarray.**__setstate__**(*state*, /)

For unpickling.

The *state* argument must be a sequence that contains the following elements:

Parameters

version
[int] optional pickle version. If omitted defaults to 0.

shape
[tuple]

dtype
[data-type]

isFortran
[bool]

rawdata
[string or list] a binary string with the data (or a list if 'a' is an object array)

Basic customization:

ndarray.__new__(*args, **kwargs)	
ndarray.__array__([dtype], *[, copy])	For `dtype` parameter it returns a new reference to self if `dtype` is not given or it matches array's data type.
ndarray.__array_wrap__(array[, context], /)	Returns a view of *array* with the same type as self.

method

ndarray.**__new__**(**args*, ***kwargs*)

method

ndarray.**__array__**([*dtype*,]*, *copy=None*)

For `dtype` parameter it returns a new reference to self if `dtype` is not given or it matches array's data type. A new array of provided data type is returned if `dtype` is different from the current data type of the array. For `copy` parameter it returns a new reference to self if `copy=False` or `copy=None` and copying isn't enforced by `dtype` parameter. The method returns a new array for `copy=True`, regardless of `dtype` parameter.

A more detailed explanation of the `__array__` interface can be found in dunder_array.interface.

method

ndarray.**__array_wrap__**(*array*, [*context*,]/)

Returns a view of *array* with the same type as self.

Container customization: (see *Indexing*)

ndarray.__len__(/)	Return len(self).
ndarray.__getitem__(key, /)	Return self[key].
ndarray.__setitem__(key, value, /)	Set self[key] to value.
ndarray.__contains__(key, /)	Return key in self.

method

ndarray.**__len__**(/)

Return len(self).

method

ndarray.**__getitem__**(*key*, /)

Return self[key].

method

ndarray.**__setitem__**(*key*, *value*, /)

Set self[key] to value.

method

ndarray.**__contains__**(*key*, /)

Return key in self.

Conversion; the operations `int()`, `float()` and `complex()`. They work only on arrays that have one element in them and return the appropriate scalar.

ndarray.__int__(self)	
ndarray.__float__(self)	
ndarray.__complex__	

method

ndarray.**__int__**(*self*)

method

ndarray.**__float__**(*self*)

method

ndarray.**__complex__**()

String representations:

ndarray.__str__(/)	Return str(self).
ndarray.__repr__(/)	Return repr(self).

method

ndarray.**__str__**(/)

Return str(self).

method

ndarray.**__repr__**(/)

Return repr(self).

Utility method for typing:

ndarray.__class_getitem__(item, /)	Return a parametrized wrapper around the *ndarray* type.

method

ndarray.**__class_getitem__**(*item*, /)

Return a parametrized wrapper around the *ndarray* type.

New in version 1.22.

Returns

alias

[types.GenericAlias] A parametrized *ndarray* type.

See also:

PEP 585
Type hinting generics in standard collections.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Examples

```
>>> from typing import Any
>>> import numpy as np
```

```
>>> np.ndarray[Any, np.dtype[Any]]
numpy.ndarray[typing.Any, numpy.dtype[typing.Any]]
```

1.2.2 Scalars

Python defines only one type of a particular data class (there is only one integer type, one floating-point type, etc.). This can be convenient in applications that don't need to be concerned with all the ways data can be represented in a computer. For scientific computing, however, more control is often needed.

In NumPy, there are 24 new fundamental Python types to describe different types of scalars. These type descriptors are mostly based on the types available in the C language that CPython is written in, with several additional types compatible with Python's types.

Array scalars have the same attributes and methods as *ndarrays*.[1] This allows one to treat items of an array partly on the same footing as arrays, smoothing out rough edges that result when mixing scalar and array operations.

Array scalars live in a hierarchy (see the Figure below) of data types. They can be detected using the hierarchy: For example, `isinstance(val, np.generic)` will return `True` if *val* is an array scalar object. Alternatively, what kind of array scalar is present can be determined using other members of the data type hierarchy. Thus, for example `isinstance(val, np.complexfloating)` will return `True` if *val* is a complex valued type, while `isinstance(val, np.flexible)` will return true if *val* is one of the flexible itemsize array types (*str_*, *bytes_*, *void*).

Built-in scalar types

The built-in scalar types are shown below. The C-like names are associated with character codes, which are shown in their descriptions. Use of the character codes, however, is discouraged.

Some of the scalar types are essentially equivalent to fundamental Python types and therefore inherit from them as well as from the generic array scalar type:

[1] However, array scalars are immutable, so none of the array scalar attributes are settable.

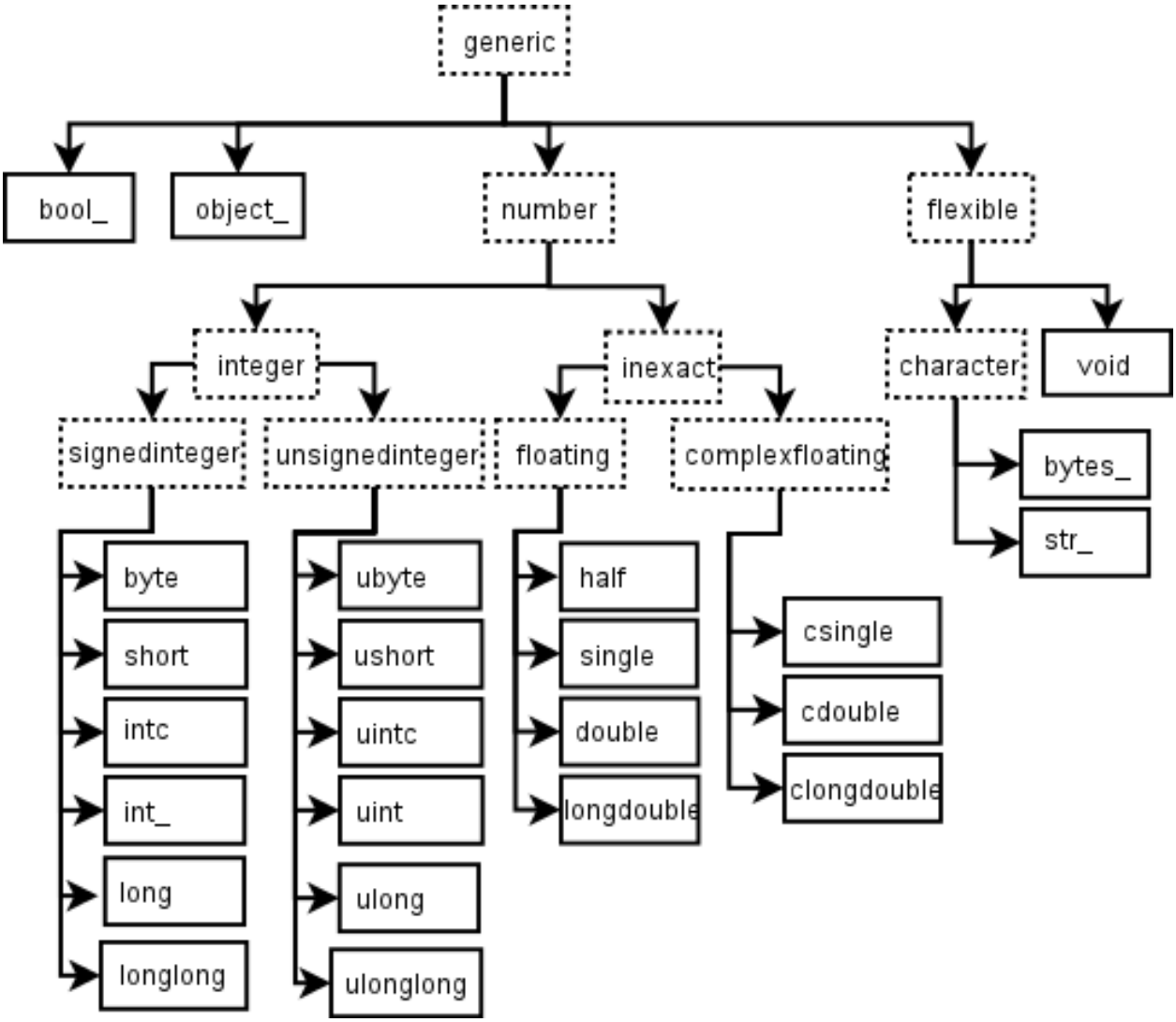

Fig. 2: **Figure:** Hierarchy of type objects representing the array data types. Not shown are the two integer types *intp* and *uintp* which are used for indexing (the same as the default integer since NumPy 2).

Array scalar type	Related Python type	Inherits?
*int_*	int	Python 2 only
double	float	yes
cdouble	complex	yes
*bytes_*	bytes	yes
*str_*	str	yes
*bool_*	*bool*	no
datetime64	datetime.datetime	no
timedelta64	datetime.timedelta	no

The *bool_* data type is very similar to the Python *bool* but does not inherit from it because Python's *bool* does not allow itself to be inherited from, and on the C-level the size of the actual bool data is not the same as a Python Boolean scalar.

Warning: The *int_* type does **not** inherit from the int built-in under Python 3, because type int is no longer a fixed-width integer type.

Tip: The default data type in NumPy is *double*.

class numpy.**generic**

Base class for numpy scalar types.

Class from which most (all?) numpy scalar types are derived. For consistency, exposes the same API as *ndarray*, despite many consequent attributes being either "get-only," or completely irrelevant. This is the class from which it is strongly suggested users should derive custom scalar types.

class numpy.**number**

Abstract base class of all numeric scalar types.

Integer types

class numpy.**integer**

Abstract base class of all integer scalar types.

Note: The numpy integer types mirror the behavior of C integers, and can therefore be subject to overflow-errors.

Signed integer types

class numpy.**signedinteger**

Abstract base class of all signed integer scalar types.

class numpy.**byte**

Signed integer type, compatible with C char.

Character code

'b'

Canonical name

numpy.byte

Alias on this platform (Linux x86_64)
numpy.int8: 8-bit signed integer (-128 to 127).

class numpy.**short**

Signed integer type, compatible with C short.

Character code
'h'

Canonical name
numpy.short

Alias on this platform (Linux x86_64)
numpy.int16: 16-bit signed integer (-32_768 to 32_767).

class numpy.**intc**

Signed integer type, compatible with C int.

Character code
'i'

Canonical name
numpy.intc

Alias on this platform (Linux x86_64)
numpy.int32: 32-bit signed integer (-2_147_483_648 to 2_147_483_647).

class numpy.**int_**

Default signed integer type, 64bit on 64bit systems and 32bit on 32bit systems.

Character code
'l'

Canonical name
*numpy.int_*

Alias on this platform (Linux x86_64)
numpy.int64: 64-bit signed integer (-9_223_372_036_854_775_808 to 9_223_372_036_854_775_807).

Alias on this platform (Linux x86_64)
numpy.intp: Signed integer large enough to fit pointer, compatible with C intptr_t.

numpy.**long**

alias of *int_*

class numpy.**longlong**

Signed integer type, compatible with C long long.

Character code
'q'

Unsigned integer types

class numpy.**unsignedinteger**

Abstract base class of all unsigned integer scalar types.

class numpy.**ubyte**

Unsigned integer type, compatible with C `unsigned char`.

Character code
`'B'`

Canonical name
numpy.ubyte

Alias on this platform (Linux x86_64)
numpy.uint8: 8-bit unsigned integer (`0` to `255`).

class numpy.**ushort**

Unsigned integer type, compatible with C `unsigned short`.

Character code
`'H'`

Canonical name
numpy.ushort

Alias on this platform (Linux x86_64)
numpy.uint16: 16-bit unsigned integer (`0` to `65_535`).

class numpy.**uintc**

Unsigned integer type, compatible with C `unsigned int`.

Character code
`'I'`

Canonical name
numpy.uintc

Alias on this platform (Linux x86_64)
numpy.uint32: 32-bit unsigned integer (`0` to `4_294_967_295`).

class numpy.**uint**

Unsigned signed integer type, 64bit on 64bit systems and 32bit on 32bit systems.

Character code
`'L'`

Canonical name
numpy.uint

Alias on this platform (Linux x86_64)
numpy.uint64: 64-bit unsigned integer (`0` to `18_446_744_073_709_551_615`).

Alias on this platform (Linux x86_64)
numpy.uintp: Unsigned integer large enough to fit pointer, compatible with C `uintptr_t`.

numpy.**ulong**

alias of *uint*

class numpy.**ulonglong**

Signed integer type, compatible with C `unsigned long long`.

Character code

`'Q'`

Inexact types

class numpy.**inexact**

Abstract base class of all numeric scalar types with a (potentially) inexact representation of the values in its range, such as floating-point numbers.

Note: Inexact scalars are printed using the fewest decimal digits needed to distinguish their value from other values of the same datatype, by judicious rounding. See the `unique` parameter of *format_float_positional* and *format_float_scientific*.

This means that variables with equal binary values but whose datatypes are of different precisions may display differently:

```
>>> import numpy as np
```

```
>>> f16 = np.float16("0.1")
>>> f32 = np.float32(f16)
>>> f64 = np.float64(f32)
>>> f16 == f32 == f64
True
>>> f16, f32, f64
(0.1, 0.099975586, 0.0999755859375)
```

Note that none of these floats hold the exact value $\frac{1}{10}$; `f16` prints as `0.1` because it is as close to that value as possible, whereas the other types do not as they have more precision and therefore have closer values.

Conversely, floating-point scalars of different precisions which approximate the same decimal value may compare unequal despite printing identically:

```
>>> f16 = np.float16("0.1")
>>> f32 = np.float32("0.1")
>>> f64 = np.float64("0.1")
>>> f16 == f32 == f64
False
>>> f16, f32, f64
(0.1, 0.1, 0.1)
```

Floating-point types

class numpy.**floating**

Abstract base class of all floating-point scalar types.

class numpy.**half**

Half-precision floating-point number type.

Character code

`'e'`

Canonical name

numpy.half

Alias on this platform (Linux x86_64)
numpy.float16: 16-bit-precision floating-point number type: sign bit, 5 bits exponent, 10 bits mantissa.

class numpy.**single**

Single-precision floating-point number type, compatible with C `float`.

Character code
`'f'`

Canonical name
numpy.single

Alias on this platform (Linux x86_64)
numpy.float32: 32-bit-precision floating-point number type: sign bit, 8 bits exponent, 23 bits mantissa.

class numpy.**double**(*x=0*, */*)

Double-precision floating-point number type, compatible with Python `float` and C `double`.

Character code
`'d'`

Canonical name
numpy.double

Alias on this platform (Linux x86_64)
numpy.float64: 64-bit precision floating-point number type: sign bit, 11 bits exponent, 52 bits mantissa.

class numpy.**longdouble**

Extended-precision floating-point number type, compatible with C `long double` but not necessarily with IEEE 754 quadruple-precision.

Character code
`'g'`

Alias on this platform (Linux x86_64)
numpy.float128: 128-bit extended-precision floating-point number type.

Complex floating-point types

class numpy.**complexfloating**

Abstract base class of all complex number scalar types that are made up of floating-point numbers.

class numpy.**csingle**

Complex number type composed of two single-precision floating-point numbers.

Character code
`'F'`

Canonical name
numpy.csingle

Alias on this platform (Linux x86_64)
numpy.complex64: Complex number type composed of 2 32-bit-precision floating-point numbers.

class numpy.**cdouble**(*real=0*, *imag=0*)

Complex number type composed of two double-precision floating-point numbers, compatible with Python `complex`.

Character code

`'D'`

Canonical name

numpy.cdouble

Alias on this platform (Linux x86_64)

numpy.complex128: Complex number type composed of 2 64-bit-precision floating-point numbers.

class numpy.**clongdouble**

Complex number type composed of two extended-precision floating-point numbers.

Character code

`'G'`

Alias on this platform (Linux x86_64)

numpy.complex256: Complex number type composed of 2 128-bit extended-precision floating-point numbers.

Other types

numpy.**bool_**

alias of *bool*

class numpy.**bool**

Boolean type (True or False), stored as a byte.

> **Warning:** The *bool* type is not a subclass of the *int_* type (the *bool* is not even a number type). This is different than Python's default implementation of *bool* as a sub-class of `int`.

Character code

`'?'`

class numpy.**datetime64**

If created from a 64-bit integer, it represents an offset from `1970-01-01T00:00:00`. If created from string, the string can be in ISO 8601 date or datetime format.

When parsing a string to create a datetime object, if the string contains a trailing timezone (A 'Z' or a timezone offset), the timezone will be dropped and a User Warning is given.

Datetime64 objects should be considered to be UTC and therefore have an offset of +0000.

```
>>> np.datetime64(10, 'Y')
np.datetime64('1980')
>>> np.datetime64('1980', 'Y')
np.datetime64('1980')
>>> np.datetime64(10, 'D')
np.datetime64('1970-01-11')
```

See *Datetimes and timedeltas* for more information.

Character code

`'M'`

class numpy.**timedelta64**

A timedelta stored as a 64-bit integer.

See *Datetimes and timedeltas* for more information.

Character code

'm'

class numpy.**object_**

Any Python object.

Character code

'O'

Note: The data actually stored in object arrays (*i.e.*, arrays having dtype *object_*) are references to Python objects, not the objects themselves. Hence, object arrays behave more like usual Python lists, in the sense that their contents need not be of the same Python type.

The object type is also special because an array containing *object_* items does not return an *object_* object on item access, but instead returns the actual object that the array item refers to.

The following data types are **flexible**: they have no predefined size and the data they describe can be of different length in different arrays. (In the character codes # is an integer denoting how many elements the data type consists of.)

class numpy.**flexible**

Abstract base class of all scalar types without predefined length. The actual size of these types depends on the specific *numpy.dtype* instantiation.

class numpy.**character**

Abstract base class of all character string scalar types.

class numpy.**bytes_**

A byte string.

When used in arrays, this type strips trailing null bytes.

Character code

'S'

class numpy.**str_**

A unicode string.

This type strips trailing null codepoints.

```
>>> s = np.str_("abc\x00")
>>> s
'abc'
```

Unlike the builtin str, this supports the Buffer Protocol, exposing its contents as UCS4:

```
>>> m = memoryview(np.str_("abc"))
>>> m.format
'3w'
>>> m.tobytes()
b'a\x00\x00\x00b\x00\x00\x00c\x00\x00\x00'
```

Character code

'U'

class numpy.**void**(*length_or_data*, */*, *dtype=None*)

Create a new structured or unstructured void scalar.

Parameters

length_or_data
[int, array-like, bytes-like, object] One of multiple meanings (see notes). The length or bytes data of an unstructured void. Or alternatively, the data to be stored in the new scalar when *dtype* is provided. This can be an array-like, in which case an array may be returned.

dtype
[dtype, optional] If provided the dtype of the new scalar. This dtype must be "void" dtype (i.e. a structured or unstructured void, see also defining-structured-types).

New in version 1.24.

Notes

For historical reasons and because void scalars can represent both arbitrary byte data and structured dtypes, the void constructor has three calling conventions:

1. `np.void(5)` creates a `dtype="V5"` scalar filled with five `\0` bytes. The 5 can be a Python or NumPy integer.
2. `np.void(b"bytes-like")` creates a void scalar from the byte string. The dtype itemsize will match the byte string length, here `"V10"`.
3. When a `dtype=` is passed the call is roughly the same as an array creation. However, a void scalar rather than array is returned.

Please see the examples which show all three different conventions.

Examples

```
>>> np.void(5)
np.void(b'\x00\x00\x00\x00\x00')
>>> np.void(b'abcd')
np.void(b'\x61\x62\x63\x64')
>>> np.void((3.2, b'eggs'), dtype="d,S5")
np.void((3.2, b'eggs'), dtype=[('f0', '<f8'), ('f1', 'S5')])
>>> np.void(3, dtype=[('x', np.int8), ('y', np.int8)])
np.void((3, 3), dtype=[('x', 'i1'), ('y', 'i1')])
```

Character code
`'V'`

Warning: See *Note on string types*.

Numeric Compatibility: If you used old typecode characters in your Numeric code (which was never recommended), you will need to change some of them to the new characters. In particular, the needed changes are `c -> S1`, `b -> B`, `1 -> b`, `s -> h`, `w -> H`, and `u -> I`. These changes make the type character convention more consistent with other Python modules such as the `struct` module.

Sized aliases

Along with their (mostly) C-derived names, the integer, float, and complex data-types are also available using a bit-width convention so that an array of the right size can always be ensured. Two aliases (*numpy.intp* and *numpy.uintp*) pointing to the integer type that is sufficiently large to hold a C pointer are also provided.

numpy.**int8**

numpy.**int16**

numpy.**int32**

numpy.**int64**

Aliases for the signed integer types (one of *numpy.byte*, *numpy.short*, *numpy.intc*, *numpy.int_*, *numpy.long* and *numpy.longlong*) with the specified number of bits.

Compatible with the C99 `int8_t`, `int16_t`, `int32_t`, and `int64_t`, respectively.

numpy.**uint8**

numpy.**uint16**

numpy.**uint32**

numpy.**uint64**

Alias for the unsigned integer types (one of *numpy.ubyte*, *numpy.ushort*, *numpy.uintc*, *numpy.uint*, *numpy.ulong* and *numpy.ulonglong*) with the specified number of bits.

Compatible with the C99 `uint8_t`, `uint16_t`, `uint32_t`, and `uint64_t`, respectively.

numpy.**intp**

Alias for the signed integer type (one of *numpy.byte*, *numpy.short*, *numpy.intc*, *numpy.int_*, *numpy.long* and *numpy.longlong*) that is used as a default integer and for indexing.

Compatible with the C `Py_ssize_t`.

Character code
`'n'`

Changed in version 2.0: Before NumPy 2, this had the same size as a pointer. In practice this is almost always identical, but the character code `'p'` maps to the C `intptr_t`. The character code `'n'` was added in NumPy 2.0.

numpy.**uintp**

Alias for the unsigned integer type that is the same size as `intp`.

Compatible with the C `size_t`.

Character code
`'N'`

Changed in version 2.0: Before NumPy 2, this had the same size as a pointer. In practice this is almost always identical, but the character code `'P'` maps to the C `uintptr_t`. The character code `'N'` was added in NumPy 2.0.

numpy.**float16**

alias of *half*

numpy.**float32**

alias of *single*

numpy.**float64**

alias of *double*

numpy.**float96**

numpy.**float128**

Alias for *numpy.longdouble*, named after its size in bits. The existence of these aliases depends on the platform.

numpy.**complex64**

alias of *csingle*

numpy.**complex128**

alias of *cdouble*

numpy.**complex192**

numpy.**complex256**

Alias for *numpy.clongdouble*, named after its size in bits. The existence of these aliases depends on the platform.

Attributes

The array scalar objects have an *array priority* of *NPY_SCALAR_PRIORITY* (-1,000,000.0). They also do not (yet) have a *ctypes* attribute. Otherwise, they share the same attributes as arrays:

generic.flags	The integer value of flags.
generic.shape	Tuple of array dimensions.
generic.strides	Tuple of bytes steps in each dimension.
generic.ndim	The number of array dimensions.
generic.data	Pointer to start of data.
generic.size	The number of elements in the gentype.
generic.itemsize	The length of one element in bytes.
generic.base	Scalar attribute identical to the corresponding array attribute.
generic.dtype	Get array data-descriptor.
generic.real	The real part of the scalar.
generic.imag	The imaginary part of the scalar.
generic.flat	A 1-D view of the scalar.
generic.T	Scalar attribute identical to the corresponding array attribute.
generic.__array_interface__	Array protocol: Python side
generic.__array_struct__	Array protocol: struct
generic.__array_priority__	Array priority.
generic.__array_wrap__	__array_wrap__ implementation for scalar types

attribute

generic.**flags**

The integer value of flags.

attribute

generic.**shape**

Tuple of array dimensions.

attribute

generic.**strides**

Tuple of bytes steps in each dimension.

attribute

generic.**ndim**

The number of array dimensions.

attribute

generic.**data**

Pointer to start of data.

attribute

generic.**size**

The number of elements in the gentype.

attribute

generic.**itemsize**

The length of one element in bytes.

attribute

generic.**base**

Scalar attribute identical to the corresponding array attribute.

Please see *ndarray.base*.

attribute

generic.**dtype**

Get array data-descriptor.

attribute

generic.**real**

The real part of the scalar.

attribute

generic.**imag**

The imaginary part of the scalar.

attribute

generic.**flat**

A 1-D view of the scalar.

attribute

generic.**T**

Scalar attribute identical to the corresponding array attribute.

Please see *ndarray.T*.

attribute

generic.**__array_interface__**

Array protocol: Python side

attribute

generic.**__array_struct__**

Array protocol: struct

attribute

generic.**__array_priority__**

Array priority.

method

generic.**__array_wrap__**()

__array_wrap__ implementation for scalar types

Indexing

See also:

Indexing routines, *Data type objects (dtype)*

Array scalars can be indexed like 0-dimensional arrays: if *x* is an array scalar,

- `x[()]` returns a copy of array scalar
- `x[...]` returns a 0-dimensional *ndarray*
- `x['field-name']` returns the array scalar in the field *field-name*. (*x* can have fields, for example, when it corresponds to a structured data type.)

Methods

Array scalars have exactly the same methods as arrays. The default behavior of these methods is to internally convert the scalar to an equivalent 0-dimensional array and to call the corresponding array method. In addition, math operations on array scalars are defined so that the same hardware flags are set and used to interpret the results as for *ufunc*, so that the error state used for ufuncs also carries over to the math on array scalars.

The exceptions to the above rules are given below:

generic.__array__	sc.__array__(dtype) return 0-dim array from scalar with specified dtype
generic.__array_wrap__	__array_wrap__ implementation for scalar types
generic.squeeze	Scalar method identical to the corresponding array attribute.
generic.byteswap	Scalar method identical to the corresponding array attribute.
generic.__reduce__	Helper for pickle.
generic.__setstate__	
generic.setflags	Scalar method identical to the corresponding array attribute.

method

generic.**__array__**()

sc.__array__(dtype) return 0-dim array from scalar with specified dtype

method

generic.**squeeze**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.squeeze*.

method

generic.**byteswap**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.byteswap*.

method

generic.**__reduce__**()

Helper for pickle.

method

generic.**__setstate__**()

method

generic.**setflags**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.setflags*.

Utility method for typing:

number.__class_getitem__(item, /)	Return a parametrized wrapper around the *number* type.

method

number.**__class_getitem__**(*item*, /)

Return a parametrized wrapper around the *number* type.

New in version 1.22.

Returns

alias

[types.GenericAlias] A parametrized *number* type.

See also:

PEP 585

Type hinting generics in standard collections.

Examples

```
>>> from typing import Any
>>> import numpy as np
```

```
>>> np.signedinteger[Any]
numpy.signedinteger[typing.Any]
```

Defining new types

There are two ways to effectively define a new array scalar type (apart from composing structured types *dtypes* from the built-in scalar types): One way is to simply subclass the `ndarray` and overwrite the methods of interest. This will work to a degree, but internally certain behaviors are fixed by the data type of the array. To fully customize the data type of an array you need to define a new data-type, and register it with NumPy. Such new types can only be defined in C, using the *NumPy C-API*.

1.2.3 Data type objects (`dtype`)

A data type object (an instance of `numpy.dtype` class) describes how the bytes in the fixed-size block of memory corresponding to an array item should be interpreted. It describes the following aspects of the data:

1. Type of the data (integer, float, Python object, etc.)
2. Size of the data (how many bytes is in *e.g.* the integer)
3. Byte order of the data (little-endian or big-endian)
4. If the data type is structured data type, an aggregate of other data types, (*e.g.*, describing an array item consisting of an integer and a float),
    1. what are the names of the "fields" of the structure, by which they can be accessed,
    2. what is the data-type of each field, and
    3. which part of the memory block each field takes.
5. If the data type is a sub-array, what is its shape and data type.

To describe the type of scalar data, there are several *built-in scalar types* in NumPy for various precision of integers, floating-point numbers, *etc.* An item extracted from an array, *e.g.*, by indexing, will be a Python object whose type is the scalar type associated with the data type of the array.

Note that the scalar types are not `dtype` objects, even though they can be used in place of one whenever a data type specification is needed in NumPy.

Structured data types are formed by creating a data type whose field contain other data types. Each field has a name by which it can be accessed. The parent data type should be of sufficient size to contain all its fields; the parent is nearly always based on the `void` type which allows an arbitrary item size. Structured data types may also contain nested structured sub-array data types in their fields.

Finally, a data type can describe items that are themselves arrays of items of another data type. These sub-arrays must, however, be of a fixed size.

If an array is created using a data-type describing a sub-array, the dimensions of the sub-array are appended to the shape of the array when the array is created. Sub-arrays in a field of a structured type behave differently, see arrays.indexing.fields.

Sub-arrays always have a C-contiguous memory layout.

Example

A simple data type containing a 32-bit big-endian integer: (see *Specifying and constructing data types* for details on construction)

```
>>> import numpy as np
```

```
>>> dt = np.dtype('>i4')
>>> dt.byteorder
'>'
>>> dt.itemsize
4
>>> dt.name
'int32'
>>> dt.type is np.int32
True
```

The corresponding array scalar type is *int32*.

Example

A structured data type containing a 16-character string (in field 'name') and a sub-array of two 64-bit floating-point number (in field 'grades'):

```
>>> import numpy as np
```

```
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> dt['name']
dtype('<U16')
>>> dt['grades']
dtype(('<f8', (2,)))
```

Items of an array of this data type are wrapped in an *array scalar* type that also has two fields:

```
>>> import numpy as np
```

```
>>> x = np.array([('Sarah', (8.0, 7.0)), ('John', (6.0, 7.0))], dtype=dt)
>>> x[1]
('John', [6., 7.])
>>> x[1]['grades']
array([6.,  7.])
>>> type(x[1])
<class 'numpy.void'>
>>> type(x[1]['grades'])
<class 'numpy.ndarray'>
```

Specifying and constructing data types

Whenever a data-type is required in a NumPy function or method, either a *dtype* object or something that can be converted to one can be supplied. Such conversions are done by the *dtype* constructor:

dtype(dtype[, align, copy])	Create a data type object.

class numpy.**dtype**(*dtype*, *align=False*, *copy=False*[, *metadata*])

Create a data type object.

A numpy array is homogeneous, and contains elements described by a dtype object. A dtype object can be constructed from different combinations of fundamental numeric types.

Parameters

dtype
Object to be converted to a data type object.

align
[bool, optional] Add padding to the fields to match what a C compiler would output for a similar C-struct. Can be `True` only if *obj* is a dictionary or a comma-separated string. If a struct dtype is being created, this also sets a sticky alignment flag `isalignedstruct`.

copy
[bool, optional] Make a new copy of the data-type object. If `False`, the result may just be a reference to a built-in data-type object.

metadata
[dict, optional] An optional dictionary with dtype metadata.

See also:

result_type

Examples

Using array-scalar type:

```
>>> import numpy as np
>>> np.dtype(np.int16)
dtype('int16')
```

Structured type, one field name 'f1', containing int16:

```
>>> np.dtype([('f1', np.int16)])
dtype([('f1', '<i2')])
```

Structured type, one field named 'f1', in itself containing a structured type with one field:

```
>>> np.dtype([('f1', [('f1', np.int16)])])
dtype([('f1', [('f1', '<i2')])])
```

Structured type, two fields: the first field contains an unsigned int, the second an int32:

```
>>> np.dtype([('f1', np.uint64), ('f2', np.int32)])
dtype([('f1', '<u8'), ('f2', '<i4')])
```

Using array-protocol type strings:

```
>>> np.dtype([('a','f8'),('b','S10')])
dtype([('a', '<f8'), ('b', 'S10')])
```

Using comma-separated field formats. The shape is (2,3):

```
>>> np.dtype("i4, (2,3)f8")
dtype([('f0', '<i4'), ('f1', '<f8', (2, 3))])
```

Using tuples. `int` is a fixed type, 3 the field's shape. `void` is a flexible type, here of size 10:

```
>>> np.dtype([('hello',(np.int64,3)),('world',np.void,10)])
dtype([('hello', '<i8', (3,)), ('world', 'V10')])
```

Subdivide `int16` into 2 `int8`'s, called x and y. 0 and 1 are the offsets in bytes:

```
>>> np.dtype((np.int16, {'x':(np.int8,0), 'y':(np.int8,1)}))
dtype((numpy.int16, [('x', 'i1'), ('y', 'i1')]))
```

Using dictionaries. Two fields named 'gender' and 'age':

```
>>> np.dtype({'names':['gender','age'], 'formats':['S1',np.uint8]})
dtype([('gender', 'S1'), ('age', 'u1')])
```

Offsets in bytes, here 0 and 25:

```
>>> np.dtype({'surname':('S25',0),'age':(np.uint8,25)})
dtype([('surname', 'S25'), ('age', 'u1')])
```

Attributes

alignment
The required alignment (bytes) of this data-type according to the compiler.

base
Returns dtype for the base element of the subarrays, regardless of their dimension or shape.

byteorder
A character indicating the byte-order of this data-type object.

char
A unique character code for each of the 21 different built-in types.

descr
__array_interface__ description of the data-type.

fields
Dictionary of named fields defined for this data type, or `None`.

flags
Bit-flags describing how this data type is to be interpreted.

hasobject
Boolean indicating whether this dtype contains any reference-counted objects in any fields or sub-dtypes.

isalignedstruct
Boolean indicating whether the dtype is a struct which maintains field alignment.

isbuiltin
Integer indicating how this dtype relates to the built-in dtypes.

isnative
Boolean indicating whether the byte order of this dtype is native to the platform.

itemsize
The element size of this data-type object.

kind
A character code (one of 'biufcmMOSUV') identifying the general kind of data.

metadata
Either `None` or a readonly dictionary of metadata (mappingproxy).

name
A bit-width name for this data-type.

names
Ordered list of field names, or `None` if there are no fields.

ndim
Number of dimensions of the sub-array if this data type describes a sub-array, and `0` otherwise.

num
A unique number for each of the 21 different built-in types.

shape
Shape tuple of the sub-array if this data type describes a sub-array, and `()` otherwise.

str
The array-protocol typestring of this data-type object.

subdtype
Tuple `(item_dtype, shape)` if this *dtype* describes a sub-array, and None otherwise.

type

Methods

newbyteorder([new_order])	Return a new dtype with a different byte order.

method

dtype.**newbyteorder**(*new_order='S'*, */*)

Return a new dtype with a different byte order.

Changes are also made in all fields and sub-arrays of the data type.

Parameters

new_order
[string, optional] Byte order to force; a value from the byte order specifications below. The default value ('S') results in swapping the current byte order. *new_order* codes can be any of:

- 'S' - swap dtype from current to opposite endian
- {'<', 'little'} - little endian
- {'>', 'big'} - big endian
- {'=', 'native'} - native order
- {'|', 'I'} - ignore (no change to byte order)

Returns

new_dtype
[dtype] New dtype object with the given change to the byte order.

Notes

Changes are also made in all fields and sub-arrays of the data type.

Examples

```
>>> import sys
>>> sys_is_le = sys.byteorder == 'little'
>>> native_code = '<' if sys_is_le else '>'
>>> swapped_code = '>' if sys_is_le else '<'
>>> import numpy as np
>>> native_dt = np.dtype(native_code+'i2')
>>> swapped_dt = np.dtype(swapped_code+'i2')
>>> native_dt.newbyteorder('S') == swapped_dt
True
>>> native_dt.newbyteorder() == swapped_dt
True
>>> native_dt == swapped_dt.newbyteorder('S')
True
>>> native_dt == swapped_dt.newbyteorder('=')
True
>>> native_dt == swapped_dt.newbyteorder('N')
True
>>> native_dt == native_dt.newbyteorder('|')
True
>>> np.dtype('<i2') == native_dt.newbyteorder('<')
True
>>> np.dtype('<i2') == native_dt.newbyteorder('L')
True
>>> np.dtype('>i2') == native_dt.newbyteorder('>')
True
>>> np.dtype('>i2') == native_dt.newbyteorder('B')
True
```

What can be converted to a data-type object is described below:

***dtype* object**
: Used as-is.

None
: The default data type: *float64*.

Array-scalar types
: The 24 built-in *array scalar type objects* all convert to an associated data-type object. This is true for their sub-classes as well.

  Note that not all data-type information can be supplied with a type-object: for example, *flexible* data-types have a default *itemsize* of 0, and require an explicitly given size to be useful.

  Example

```
>>> import numpy as np
```

```
>>> dt = np.dtype(np.int32)      # 32-bit integer
>>> dt = np.dtype(np.complex128) # 128-bit complex floating-point number
```

Generic types

The generic hierarchical type objects convert to corresponding type objects according to the associations:

number, *inexact*, *floating*	*float64*
complexfloating	*complex128*
integer, *signedinteger*	*int_*
unsignedinteger	*uint*
generic, *flexible*	*void*

Deprecated since version 1.19: This conversion of generic scalar types is deprecated. This is because it can be unexpected in a context such as `arr.astype(dtype=np.floating)`, which casts an array of `float32` to an array of `float64`, even though `float32` is a subdtype of `np.floating`.

Built-in Python types

Several python types are equivalent to a corresponding array scalar when used to generate a *dtype* object:

`int`	*int_*
bool	*bool_*
`float`	*float64*
`complex`	*complex128*
`bytes`	*bytes_*
`str`	*str_*
`memoryview`	*void*
(all others)	*object_*

Note that `str_` corresponds to UCS4 encoded unicode strings.

Example

```
>>> import numpy as np
```

```
>>> dt = np.dtype(float)   # Python-compatible floating-point number
>>> dt = np.dtype(int)     # Python-compatible integer
>>> dt = np.dtype(object)  # Python object
```

Note: All other types map to `object_` for convenience. Code should expect that such types may map to a specific (new) dtype in the future.

Types with `.dtype`

Any type object with a `dtype` attribute: The attribute will be accessed and used directly. The attribute must return something that is convertible into a dtype object.

Several kinds of strings can be converted. Recognized strings can be prepended with `'>'` (big-endian), `'<'` (little-endian), or `'='` (hardware-native, the default), to specify the byte order.

One-character strings

Each built-in data-type has a character code (the updated Numeric typecodes), that uniquely identifies it.

Example

```
>>> import numpy as np
```

```
>>> dt = np.dtype('b')  # byte, native byte order
>>> dt = np.dtype('>H') # big-endian unsigned short
>>> dt = np.dtype('<f') # little-endian single-precision float
>>> dt = np.dtype('d')  # double-precision floating-point number
```

Array-protocol type strings (see *The array interface protocol*)

The first character specifies the kind of data and the remaining characters specify the number of bytes per item, except for Unicode, where it is interpreted as the number of characters. The item size must correspond to an existing type, or an error will be raised. The supported kinds are

`'?'`	boolean
`'b'`	(signed) byte
`'B'`	unsigned byte
`'i'`	(signed) integer
`'u'`	unsigned integer
`'f'`	floating-point
`'c'`	complex-floating point
`'m'`	timedelta
`'M'`	datetime
`'O'`	(Python) objects
`'S'`, `'a'`	zero-terminated bytes (not recommended)
`'U'`	Unicode string
`'V'`	raw data (*void*)

Example

```
>>> import numpy as np
```

```
>>> dt = np.dtype('i4')   # 32-bit signed integer
>>> dt = np.dtype('f8')   # 64-bit floating-point number
>>> dt = np.dtype('c16')  # 128-bit complex floating-point number
>>> dt = np.dtype('S25')  # 25-length zero-terminated bytes
>>> dt = np.dtype('U25')  # 25-character string
```

Note on string types

For backward compatibility with existing code originally written to support Python 2, `S` and `a` typestrings are zero-terminated bytes. For unicode strings, use `U`, *`numpy.str_`*. For signed bytes that do not need zero-termination `b` or `i1` can be used.

String with comma-separated fields

A short-hand notation for specifying the format of a structured data type is a comma-separated string of basic formats.

A basic format in this context is an optional shape specifier followed by an array-protocol type string. Parenthesis are required on the shape if it has more than one dimension. NumPy allows a modification on the format in that any string that can uniquely identify the type can be used to specify the data-type in a field. The generated data-type

fields are named `'f0'`, `'f1'`, ..., `'f<N-1>'` where N (>1) is the number of comma-separated basic formats in the string. If the optional shape specifier is provided, then the data-type for the corresponding field describes a sub-array.

Example

- field named `f0` containing a 32-bit integer
- field named `f1` containing a 2 x 3 sub-array of 64-bit floating-point numbers
- field named `f2` containing a 32-bit floating-point number

```
>>> import numpy as np
>>> dt = np.dtype("i4, (2,3)f8, f4")
```

- field named `f0` containing a 3-character string
- field named `f1` containing a sub-array of shape (3,) containing 64-bit unsigned integers
- field named `f2` containing a 3 x 4 sub-array containing 10-character strings

```
>>> import numpy as np
>>> dt = np.dtype("S3, 3u8, (3,4)S10")
```

Type strings

Any string name of a NumPy dtype, e.g.:

Example

```
>>> import numpy as np
```

```
>>> dt = np.dtype('uint32')   # 32-bit unsigned integer
>>> dt = np.dtype('float64')  # 64-bit floating-point number
```

`(flexible_dtype, itemsize)`

The first argument must be an object that is converted to a zero-sized flexible data-type object, the second argument is an integer providing the desired itemsize.

Example

```
>>> import numpy as np
```

```
>>> dt = np.dtype((np.void, 10))  # 10-byte wide data block
>>> dt = np.dtype(('U', 10))   # 10-character unicode string
```

`(fixed_dtype, shape)`

The first argument is any object that can be converted into a fixed-size data-type object. The second argument is the desired shape of this type. If the shape parameter is 1, then the data-type object used to be equivalent to fixed dtype. This behaviour is deprecated since NumPy 1.17 and will raise an error in the future. If *shape* is a tuple, then the new dtype defines a sub-array of the given shape.

Example

```
>>> import numpy as np
```

```
>>> dt = np.dtype((np.int32, (2,2)))           # 2 x 2 integer sub-array
>>> dt = np.dtype(('i4, (2,3)f8, f4', (2,3))) # 2 x 3 structured sub-array
```

[(field_name, field_dtype, field_shape), ...]

obj should be a list of fields where each field is described by a tuple of length 2 or 3. (Equivalent to the `descr` item in the *__array_interface__* attribute.)

The first element, *field_name*, is the field name (if this is `''` then a standard field name, `'f#'`, is assigned). The field name may also be a 2-tuple of strings where the first string is either a "title" (which may be any string or unicode string) or meta-data for the field which can be any object, and the second string is the "name" which must be a valid Python identifier.

The second element, *field_dtype*, can be anything that can be interpreted as a data-type.

The optional third element *field_shape* contains the shape if this field represents an array of the data-type in the second element. Note that a 3-tuple with a third argument equal to 1 is equivalent to a 2-tuple.

This style does not accept *align* in the *dtype* constructor as it is assumed that all of the memory is accounted for by the array interface description.

Example

Data-type with fields `big` (big-endian 32-bit integer) and `little` (little-endian 32-bit integer):

```
>>> import numpy as np
```

```
>>> dt = np.dtype([('big', '>i4'), ('little', '<i4')])
```

Data-type with fields `R`, `G`, `B`, `A`, each being an unsigned 8-bit integer:

```
>>> dt = np.dtype([('R','u1'), ('G','u1'), ('B','u1'), ('A','u1')])
```

{'names': ..., 'formats': ..., 'offsets': ..., 'titles': ..., 'itemsize': ...}

This style has two required and three optional keys. The *names* and *formats* keys are required. Their respective values are equal-length lists with the field names and the field formats. The field names must be strings and the field formats can be any object accepted by *dtype* constructor.

When the optional keys *offsets* and *titles* are provided, their values must each be lists of the same length as the *names* and *formats* lists. The *offsets* value is a list of byte offsets (limited to `ctypes.c_int`) for each field, while the *titles* value is a list of titles for each field (`None` can be used if no title is desired for that field). The *titles* can be any object, but when a `str` object will add another entry to the fields dictionary keyed by the title and referencing the same field tuple which will contain the title as an additional tuple member.

The *itemsize* key allows the total size of the dtype to be set, and must be an integer large enough so all the fields are within the dtype. If the dtype being constructed is aligned, the *itemsize* must also be divisible by the struct alignment. Total dtype *itemsize* is limited to `ctypes.c_int`.

Example

Data type with fields `r`, `g`, `b`, `a`, each being an 8-bit unsigned integer:

```
>>> import numpy as np
```

```
>>> dt = np.dtype({'names': ['r','g','b','a'],
...                'formats': [np.uint8, np.uint8, np.uint8, np.uint8]})
```

Data type with fields `r` and `b` (with the given titles), both being 8-bit unsigned integers, the first at byte position 0 from the start of the field and the second at position 2:

```
>>> dt = np.dtype({'names': ['r','b'], 'formats': ['u1', 'u1'],
...                'offsets': [0, 2],
...                'titles': ['Red pixel', 'Blue pixel']})
```

`{'field1': ..., 'field2': ..., ...}`

This usage is discouraged, because it is ambiguous with the other dict-based construction method. If you have a field called 'names' and a field called 'formats' there will be a conflict.

This style allows passing in the *`fields`* attribute of a data-type object.

obj should contain string or unicode keys that refer to `(data-type, offset)` or `(data-type, offset, title)` tuples.

Example

Data type containing field `col1` (10-character string at byte position 0), `col2` (32-bit float at byte position 10), and `col3` (integers at byte position 14):

```
>>> import numpy as np
```

```
>>> dt = np.dtype({'col1': ('U10', 0), 'col2': (np.float32, 10),
...                'col3': (int, 14)})
```

`(base_dtype, new_dtype)`

In NumPy 1.7 and later, this form allows *base_dtype* to be interpreted as a structured dtype. Arrays created with this dtype will have underlying dtype *base_dtype* but will have fields and flags taken from *new_dtype*. This is useful for creating custom structured dtypes, as done in *record arrays*.

This form also makes it possible to specify struct dtypes with overlapping fields, functioning like the 'union' type in C. This usage is discouraged, however, and the union mechanism is preferred.

Both arguments must be convertible to data-type objects with the same total size.

Example

32-bit integer, whose first two bytes are interpreted as an integer via field `real`, and the following two bytes via field `imag`.

```
>>> import numpy as np
```

```
>>> dt = np.dtype((np.int32,{'real':(np.int16, 0),'imag':(np.int16, 2)}))
```

32-bit integer, which is interpreted as consisting of a sub-array of shape `(4,)` containing 8-bit integers:

```
>>> dt = np.dtype((np.int32, (np.int8, 4)))
```

32-bit integer, containing fields `r`, `g`, `b`, `a` that interpret the 4 bytes in the integer as four unsigned integers:

```
>>> dt = np.dtype(('i4', [('r','u1'),('g','u1'),('b','u1'),('a','u1')]))
```

Checking the data type

When checking for a specific data type, use == comparison.

Example

```
>>> import numpy as np
```

```
>>> a = np.array([1, 2], dtype=np.float32)
>>> a.dtype == np.float32
True
```

As opposed to Python types, a comparison using `is` should not be used.

First, NumPy treats data type specifications (everything that can be passed to the *dtype* constructor) as equivalent to the data type object itself. This equivalence can only be handled through ==, not through `is`.

Example

A *dtype* object is equal to all data type specifications that are equivalent to it.

```
>>> import numpy as np
```

```
>>> a = np.array([1, 2], dtype=float)
>>> a.dtype == np.dtype(np.float64)
True
>>> a.dtype == np.float64
True
>>> a.dtype == float
True
>>> a.dtype == "float64"
True
>>> a.dtype == "d"
True
```

Second, there is no guarantee that data type objects are singletons.

Example

Do not use `is` because data type objects may or may not be singletons.

```
>>> import numpy as np
```

```
>>> np.dtype(float) is np.dtype(float)
True
>>> np.dtype([('a', float)]) is np.dtype([('a', float)])
False
```

dtype

NumPy data type descriptions are instances of the *dtype* class.

Attributes

The type of the data is described by the following *dtype* attributes:

dtype.type	
dtype.kind	A character code (one of 'biufcmMOSUV') identifying the general kind of data.
dtype.char	A unique character code for each of the 21 different built-in types.
dtype.num	A unique number for each of the 21 different built-in types.
dtype.str	The array-protocol typestring of this data-type object.

attribute

dtype.**type = None**

attribute

dtype.**kind**

A character code (one of 'biufcmMOSUV') identifying the general kind of data.

b	boolean
i	signed integer
u	unsigned integer
f	floating-point
c	complex floating-point
m	timedelta
M	datetime
O	object
S	(byte-)string
U	Unicode
V	void

Examples

```
>>> import numpy as np
>>> dt = np.dtype('i4')
>>> dt.kind
'i'
>>> dt = np.dtype('f8')
>>> dt.kind
'f'
>>> dt = np.dtype([('field1', 'f8')])
```

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```
>>> dt.kind
'V'
```

attribute

dtype.**char**

A unique character code for each of the 21 different built-in types.

Examples

```
>>> import numpy as np
>>> x = np.dtype(float)
>>> x.char
'd'
```

attribute

dtype.**num**

A unique number for each of the 21 different built-in types.

These are roughly ordered from least-to-most precision.

Examples

```
>>> import numpy as np
>>> dt = np.dtype(str)
>>> dt.num
19
```

```
>>> dt = np.dtype(float)
>>> dt.num
12
```

attribute

dtype.**str**

The array-protocol typestring of this data-type object.

Size of the data is in turn described by:

dtype.name	A bit-width name for this data-type.
dtype.itemsize	The element size of this data-type object.

attribute

dtype.**name**

A bit-width name for this data-type.

Un-sized flexible data-type objects do not have this attribute.

Examples

```
>>> import numpy as np
>>> x = np.dtype(float)
>>> x.name
'float64'
>>> x = np.dtype([('a', np.int32, 8), ('b', np.float64, 6)])
>>> x.name
'void640'
```

attribute

dtype.**itemsize**

The element size of this data-type object.

For 18 of the 21 types this number is fixed by the data-type. For the flexible data-types, this number can be anything.

Examples

```
>>> import numpy as np
>>> arr = np.array([[1, 2], [3, 4]])
>>> arr.dtype
dtype('int64')
>>> arr.itemsize
8
```

```
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> dt.itemsize
80
```

Endianness of this data:

dtype.byteorder	A character indicating the byte-order of this data-type object.

attribute

dtype.**byteorder**

A character indicating the byte-order of this data-type object.

One of:

'='	native
'<'	little-endian
'>'	big-endian
'I'	not applicable

All built-in data-type objects have byteorder either '=' or 'I'.

Examples

```
>>> import numpy as np
>>> dt = np.dtype('i2')
>>> dt.byteorder
'='
>>> # endian is not relevant for 8 bit numbers
>>> np.dtype('i1').byteorder
'|'
>>> # or ASCII strings
>>> np.dtype('S2').byteorder
'|'
>>> # Even if specific code is given, and it is native
>>> # '=' is the byteorder
>>> import sys
>>> sys_is_le = sys.byteorder == 'little'
>>> native_code = '<' if sys_is_le else '>'
>>> swapped_code = '>' if sys_is_le else '<'
>>> dt = np.dtype(native_code + 'i2')
>>> dt.byteorder
'='
>>> # Swapped code shows up as itself
>>> dt = np.dtype(swapped_code + 'i2')
>>> dt.byteorder == swapped_code
True
```

Information about sub-data-types in a structured data type:

dtype.fields	Dictionary of named fields defined for this data type, or None.
dtype.names	Ordered list of field names, or None if there are no fields.

attribute

dtype.**fields**

Dictionary of named fields defined for this data type, or None.

The dictionary is indexed by keys that are the names of the fields. Each entry in the dictionary is a tuple fully describing the field:

```
(dtype, offset[, title])
```

Offset is limited to C int, which is signed and usually 32 bits. If present, the optional title can be any object (if it is a string or unicode then it will also be a key in the fields dictionary, otherwise it's meta-data). Notice also that the first two elements of the tuple can be passed directly as arguments to the ndarray.getfield and ndarray.setfield methods.

See also:

ndarray.getfield, ***ndarray.setfield***

Examples

```
>>> import numpy as np
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> print(dt.fields)
{'grades': (dtype(('float64',(2,))), 16), 'name': (dtype('|S16'), 0)}
```

attribute

`dtype.`**`names`**

Ordered list of field names, or `None` if there are no fields.

The names are ordered according to increasing byte offset. This can be used, for example, to walk through all of the named fields in offset order.

Examples

```
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> dt.names
('name', 'grades')
```

For data types that describe sub-arrays:

dtype.subdtype	Tuple `(item_dtype, shape)` if this *dtype* describes a sub-array, and None otherwise.
dtype.shape	Shape tuple of the sub-array if this data type describes a sub-array, and `()` otherwise.

attribute

`dtype.`**`subdtype`**

Tuple `(item_dtype, shape)` if this *dtype* describes a sub-array, and None otherwise.

The *shape* is the fixed shape of the sub-array described by this data type, and *item_dtype* the data type of the array.

If a field whose dtype object has this attribute is retrieved, then the extra dimensions implied by *shape* are tacked on to the end of the retrieved array.

See also:

dtype.base

Examples

```
>>> import numpy as np
>>> x = numpy.dtype('8f')
>>> x.subdtype
(dtype('float32'), (8,))
```

```
>>> x =  numpy.dtype('i2')
>>> x.subdtype
>>>
```

attribute

dtype.**shape**

Shape tuple of the sub-array if this data type describes a sub-array, and `()` otherwise.

Examples

```
>>> import numpy as np
>>> dt = np.dtype(('i4', 4))
>>> dt.shape
(4,)
```

```
>>> dt = np.dtype(('i4', (2, 3)))
>>> dt.shape
(2, 3)
```

Attributes providing additional information:

dtype.hasobject	Boolean indicating whether this dtype contains any reference-counted objects in any fields or sub-dtypes.
dtype.flags	Bit-flags describing how this data type is to be interpreted.
dtype.isbuiltin	Integer indicating how this dtype relates to the built-in dtypes.
dtype.isnative	Boolean indicating whether the byte order of this dtype is native to the platform.
dtype.descr	*__array_interface__* description of the data-type.
dtype.alignment	The required alignment (bytes) of this data-type according to the compiler.
dtype.base	Returns dtype for the base element of the subarrays, regardless of their dimension or shape.

attribute

dtype.**hasobject**

Boolean indicating whether this dtype contains any reference-counted objects in any fields or sub-dtypes.

Recall that what is actually in the ndarray memory representing the Python object is the memory address of that object (a pointer). Special handling may be required, and this attribute is useful for distinguishing data types that may contain arbitrary Python objects and data-types that won't.

attribute

dtype.**flags**

Bit-flags describing how this data type is to be interpreted.

Bit-masks are in `numpy._core.multiarray` as the constants *ITEM_HASOBJECT*, *LIST_PICKLE*, *ITEM_IS_POINTER*, *NEEDS_INIT*, *NEEDS_PYAPI*, *USE_GETITEM*, *USE_SETITEM*. A full explanation of these flags is in C-API documentation; they are largely useful for user-defined data-types.

The following example demonstrates that operations on this particular dtype requires Python C-API.

Examples

```
>>> import numpy as np
>>> x = np.dtype([('a', np.int32, 8), ('b', np.float64, 6)])
>>> x.flags
16
>>> np._core.multiarray.NEEDS_PYAPI
16
```

attribute

dtype.**isbuiltin**

Integer indicating how this dtype relates to the built-in dtypes.

Read-only.

0	if this is a structured array type, with fields
1	if this is a dtype compiled into numpy (such as ints, floats etc)
2	if the dtype is for a user-defined numpy type A user-defined type uses the numpy C-API machinery to extend numpy to handle a new array type. See user.user-defined-data-types in the NumPy manual.

Examples

```
>>> import numpy as np
>>> dt = np.dtype('i2')
>>> dt.isbuiltin
1
>>> dt = np.dtype('f8')
>>> dt.isbuiltin
1
>>> dt = np.dtype([('field1', 'f8')])
>>> dt.isbuiltin
0
```

attribute

dtype.**isnative**

Boolean indicating whether the byte order of this dtype is native to the platform.

attribute

dtype.**descr**

__array_interface__ description of the data-type.

The format is that required by the 'descr' key in the *__array_interface__* attribute.

Warning: This attribute exists specifically for *__array_interface__*, and passing it directly to *numpy.dtype* will not accurately reconstruct some dtypes (e.g., scalar and subarray dtypes).

Examples

```
>>> import numpy as np
>>> x = np.dtype(float)
>>> x.descr
[('', '<f8')]
```

```
>>> dt = np.dtype([('name', np.str_, 16), ('grades', np.float64, (2,))])
>>> dt.descr
[('name', '<U16'), ('grades', '<f8', (2,))]
```

attribute

dtype.**alignment**

The required alignment (bytes) of this data-type according to the compiler.

More information is available in the C-API section of the manual.

Examples

```
>>> import numpy as np
>>> x = np.dtype('i4')
>>> x.alignment
4
```

```
>>> x = np.dtype(float)
>>> x.alignment
8
```

attribute

dtype.**base**

Returns dtype for the base element of the subarrays, regardless of their dimension or shape.

See also:

dtype.subdtype

Examples

```
>>> import numpy as np
>>> x = numpy.dtype('8f')
>>> x.base
dtype('float32')
```

```
>>> x =  numpy.dtype('i2')
>>> x.base
dtype('int16')
```

Metadata attached by the user:

dtype.metadata	Either None or a readonly dictionary of metadata (mappingproxy).

attribute

dtype.**metadata**

Either None or a readonly dictionary of metadata (mappingproxy).

The metadata field can be set using any dictionary at data-type creation. NumPy currently has no uniform approach to propagating metadata; although some array operations preserve it, there is no guarantee that others will.

Warning: Although used in certain projects, this feature was long undocumented and is not well supported. Some aspects of metadata propagation are expected to change in the future.

Examples

```
>>> import numpy as np
>>> dt = np.dtype(float, metadata={"key": "value"})
>>> dt.metadata["key"]
'value'
>>> arr = np.array([1, 2, 3], dtype=dt)
>>> arr.dtype.metadata
mappingproxy({'key': 'value'})
```

Adding arrays with identical datatypes currently preserves the metadata:

```
>>> (arr + arr).dtype.metadata
mappingproxy({'key': 'value'})
```

But if the arrays have different dtype metadata, the metadata may be dropped:

```
>>> dt2 = np.dtype(float, metadata={"key2": "value2"})
>>> arr2 = np.array([3, 2, 1], dtype=dt2)
>>> (arr + arr2).dtype.metadata is None
True  # The metadata field is cleared so None is returned
```

Methods

Data types have the following method for changing the byte order:

dtype.newbyteorder([new_order])	Return a new dtype with a different byte order.

The following methods implement the pickle protocol:

dtype.__reduce__	Helper for pickle.
dtype.__setstate__	

method

dtype.**__reduce__**()

Helper for pickle.

method

dtype.__setstate__()

Utility method for typing:

dtype.__class_getitem__(item, /)	Return a parametrized wrapper around the *dtype* type.

method

dtype.__class_getitem__(*item*, /)

Return a parametrized wrapper around the *dtype* type.

New in version 1.22.

Returns

alias

[types.GenericAlias] A parametrized *dtype* type.

See also:

PEP 585

Type hinting generics in standard collections.

Examples

```
>>> import numpy as np
```

```
>>> np.dtype[np.int64]
numpy.dtype[numpy.int64]
```

Comparison operations:

dtype.__ge__(value, /)	Return self>=value.
dtype.__gt__(value, /)	Return self>value.
dtype.__le__(value, /)	Return self<=value.
dtype.__lt__(value, /)	Return self<value.

method

dtype.__ge__(*value*, /)

Return self>=value.

method

dtype.__gt__(*value*, /)

Return self>value.

method

dtype.__le__(*value*, /)

Return self<=value.

method

dtype.__lt__(*value*, /)

Return self<value.

1.2.4 Data type promotion in NumPy

When mixing two different data types, NumPy has to determine the appropriate dtype for the result of the operation. This step is referred to as *promotion* or *finding the common dtype*.

In typical cases, the user does not need to worry about the details of promotion, since the promotion step usually ensures that the result will either match or exceed the precision of the input.

For example, when the inputs are of the same dtype, the dtype of the result matches the dtype of the inputs:

```
>>> np.int8(1) + np.int8(1)
np.int8(2)
```

Mixing two different dtypes normally produces a result with the dtype of the higher precision input:

```
>>> np.int8(4) + np.int64(8)   # 64 > 8
np.int64(12)
>>> np.float32(3) + np.float16(3)   # 32 > 16
np.float32(6.0)
```

In typical cases, this does not lead to surprises. However, if you work with non-default dtypes like unsigned integers and low-precision floats, or if you mix NumPy integers, NumPy floats, and Python scalars, some details of NumPy promotion rules may be relevant. Note that these detailed rules do not always match those of other languages[1].

Numerical dtypes come in four "kinds" with a natural hierarchy.

1. unsigned integers (`uint`)
2. signed integers (`int`)
3. float (`float`)
4. complex (`complex`)

In addition to kind, NumPy numerical dtypes also have an associated precision, specified in bits. Together, the kind and precision specify the dtype. For example, a `uint8` is an unsigned integer stored using 8 bits.

The result of an operation will always be of an equal or higher kind of any of the inputs. Furthermore, the result will always have a precision greater than or equal to those of the inputs. Already, this can lead to some examples which may be unexpected:

1. When mixing floating point numbers and integers, the precision of the integer may force the result to a higher precision floating point. For example, the result of an operation involving `int64` and `float16` is `float64`.
2. When mixing unsigned and signed integers with the same precision, the result will have *higher* precision than either inputs. Additionally, if one of them has 64bit precision already, no higher precision integer is available and for example an operation involving `int64` and `uint64` gives `float64`.

Please see the *Numerical promotion* section and image below for details on both.

[1] To a large degree, this may just be for choices made early on in NumPy's predecessors. For more details, see NEP 50.

Detailed behavior of Python scalars

Since NumPy 2.0[2], an important point in our promotion rules is that although operations involving two NumPy dtypes never lose precision, operations involving a NumPy dtype and a Python scalar (`int`, `float`, or `complex`) *can* lose precision. For instance, it is probably intuitive that the result of an operation between a Python integer and a NumPy integer should be a NumPy integer. However, Python integers have arbitrary precision whereas all NumPy dtypes have fixed precision, so the arbitrary precision of Python integers cannot be preserved.

More generally, NumPy considers the "kind" of Python scalars, but ignores their precision when determining the result dtype. This is often convenient. For instance, when working with arrays of a low precision dtype, it is usually desirable for simple operations with Python scalars to preserve the dtype.

```
>>> arr_float32 = np.array([1, 2.5, 2.1], dtype="float32")
>>> arr_float32 + 10.0  # undesirable to promote to float64
array([11. , 12.5, 12.1], dtype=float32)
>>> arr_int16 = np.array([3, 5, 7], dtype="int16")
>>> arr_int16 + 10  # undesirable to promote to int64
array([13, 15, 17], dtype=int16)
```

In both cases, the result precision is dictated by the NumPy dtype. Because of this, `arr_float32 + 3.0` behaves the same as `arr_float32 + np.float32(3.0)`, and `arr_int16 + 10` behaves as `arr_int16 + np.int16(10.)`.

As another example, when mixing NumPy integers with a Python `float` or `complex`, the result always has type `float64` or `complex128`:

>> np.int16(1) + 1.0 np.float64(2.0)

However, these rules can also lead to surprising behavior when working with low precision dtypes.

First, since the Python value is converted to a NumPy one before the operation can by performed, operations can fail with an error when the result seems obvious. For instance, `np.int8(1) + 1000` cannot continue because `1000` exceeds the maximum value of an `int8`. When the Python scalar cannot be coerced to the NumPy dtype, an error is raised:

```
>>> np.int8(1) + 1000
Traceback (most recent call last):
  ...
OverflowError: Python integer 1000 out of bounds for int8
>>> np.int64(1) * 10**100
Traceback (most recent call last):
...
OverflowError: Python int too large to convert to C long
>>> np.float32(1) + 1e300
np.float32(inf)
... RuntimeWarning: overflow encountered in cast
```

Second, since the Python float or integer precision is always ignored, a low precision NumPy scalar will keep using its lower precision unless explicitly converted to a higher precision NumPy dtype or Python scalar (e.g. via `int()`, `float()`, or `scalar.item()`). This lower precision may be detrimental to some calculations or lead to incorrect results, especially in the case of integer overflows:

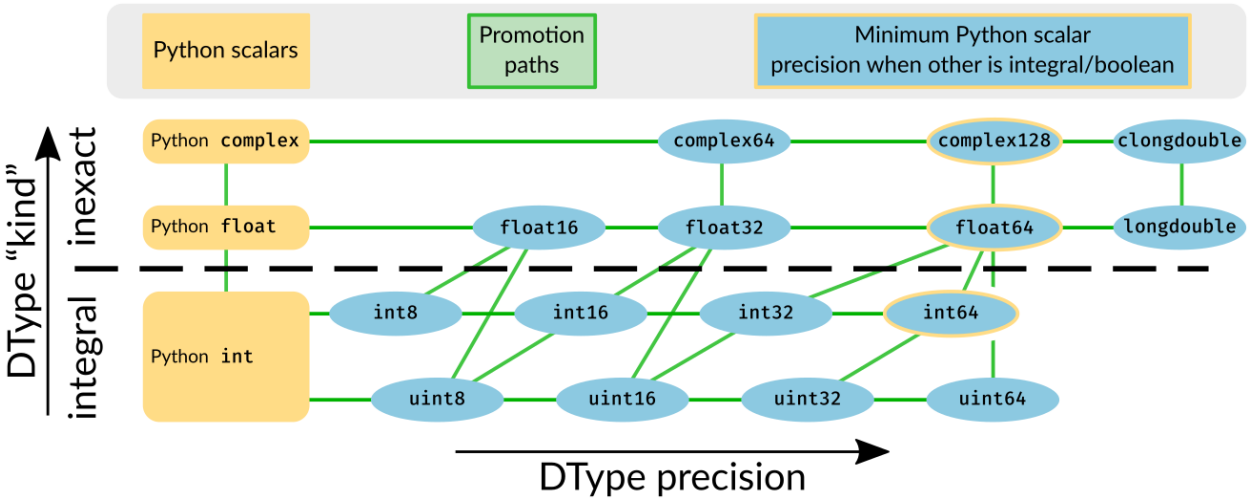
```
>>> np.int8(100) + 100  # the result exceeds the capacity of int8
np.int8(-56)
... RuntimeWarning: overflow encountered in scalar add
```

[2] See also NEP 50 which changed the rules for NumPy 2.0. Previous versions of NumPy would sometimes return higher precision results based on the input value of Python scalars. Further, previous versions of NumPy would typically ignore the higher precision of NumPy scalars or 0-D arrays for promotion purposes.

Note that NumPy warns when overflows occur for scalars, but not for arrays; e.g., `np.array(100, dtype="uint8") + 100` will *not* warn.

Numerical promotion

The following image shows the numerical promotion rules with the kinds on the vertical axis and the precision on the horizontal axis.



The input dtype with the higher kind determines the kind of the result dtype. The result dtype has a precision as low as possible without appearing to the left of either input dtype in the diagram.

Note the following specific rules and observations:

1. When a Python `float` or `complex` interacts with a NumPy integer the result will be `float64` or `complex128` (yellow border). NumPy booleans will also be cast to the default integer[3]. This is not relevant when additionally NumPy floating point values are involved.
2. The precision is drawn such that `float16 < int16 < uint16` because large `uint16` do not fit `int16` and large `int16` will lose precision when stored in a `float16`. This pattern however is broken since NumPy always considers `float64` and `complex128` to be acceptable promotion results for any integer value.
3. A special case is that NumPy promotes many combinations of signed and unsigned integers to `float64`. A higher kind is used here because no signed integer dtype is sufficiently precise to hold a `uint64`.

Exceptions to the general promotion rules

In NumPy promotion refers to what specific functions do with the result and in some cases, this means that NumPy may deviate from what the *np.result_type* would give.

[3] The default integer is marked as `int64` in the schema but is `int32` on 32bit platforms. However, normal PCs are 64bit.

Behavior of `sum` and `prod`

`np.sum` and `np.prod` will always return the default integer type when summing over integer values (or booleans). This is usually an `int64`. The reason for this is that integer summations are otherwise very likely to overflow and give confusing results. This rule also applies to the underlying `np.add.reduce` and `np.multiply.reduce`.

Notable behavior with NumPy or Python integer scalars

NumPy promotion refers to the result dtype and operation precision, but the operation will sometimes dictate that result. Division always returns floating point values and comparison always booleans.

This leads to what may appear as "exceptions" to the rules:

- NumPy comparisons with Python integers or mixed precision integers always return the correct result. The inputs will never be cast in a way which loses precision.
- Equality comparisons between types which cannot be promoted will be considered all `False` (equality) or all `True` (not-equal).
- Unary math functions like `np.sin` that always return floating point values, accept any Python integer input by converting it to `float64`.
- Division always returns floating point values and thus also allows divisions between any NumPy integer with any Python integer value by casting both to `float64`.

In principle, some of these exceptions may make sense for other functions. Please raise an issue if you feel this is the case.

Promotion of non-numerical datatypes

NumPy extends the promotion to non-numerical types, although in many cases promotion is not well defined and simply rejected.

The following rules apply:

- NumPy byte strings (`np.bytes_`) can be promoted to unicode strings (`np.str_`). However, casting the bytes to unicode will fail for non-ascii characters.
- For some purposes NumPy will promote almost any other datatype to strings. This applies to array creation or concatenation.
- The array constructors like `np.array()` will use `object` dtype when there is no viable promotion.
- Structured dtypes can promote when their field names and order matches. In that case all fields are promoted individually.
- NumPy `timedelta` can in some cases promote with integers.

Note: Some of these rules are somewhat surprising, and are being considered for change in the future. However, any backward-incompatible changes have to be weighed against the risks of breaking existing code. Please raise an issue if you have particular ideas about how promotion should work.

Details of promoted `dtype` instances

The above discussion has mainly dealt with the behavior when mixing different DType classes. A `dtype` instance attached to an array can carry additional information such as byte-order, metadata, string length, or exact structured dtype layout.

While the string length or field names of a structured dtype are important, NumPy considers byte-order, metadata, and the exact layout of a structured dtype as storage details. During promotion NumPy does *not* take these storage details into account: * Byte-order is converted to native byte-order. * Metadata attached to the dtype may or may not be preserved. * Resulting structured dtypes will be packed (but aligned if inputs were).

This behaviors is the best behavior for most programs where storage details are not relevant to the final results and where the use of incorrect byte-order could drastically slow down evaluation.

1.2.5 Iterating over arrays

Note: Arrays support the iterator protocol and can be iterated over like Python lists. See the quickstart.indexing-slicing-and-iterating section in the Quickstart guide for basic usage and examples. The remainder of this document presents the *nditer* object and covers more advanced usage.

The iterator object *nditer*, introduced in NumPy 1.6, provides many flexible ways to visit all the elements of one or more arrays in a systematic fashion. This page introduces some basic ways to use the object for computations on arrays in Python, then concludes with how one can accelerate the inner loop in Cython. Since the Python exposure of *nditer* is a relatively straightforward mapping of the C array iterator API, these ideas will also provide help working with array iteration from C or C++.

Single array iteration

The most basic task that can be done with the *nditer* is to visit every element of an array. Each element is provided one by one using the standard Python iterator interface.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a):
...     print(x, end=' ')
...
0 1 2 3 4 5
```

An important thing to be aware of for this iteration is that the order is chosen to match the memory layout of the array instead of using a standard C or Fortran ordering. This is done for access efficiency, reflecting the idea that by default one simply wants to visit each element without concern for a particular ordering. We can see this by iterating over the transpose of our previous array, compared to taking a copy of that transpose in C order.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a.T):
...     print(x, end=' ')
...
0 1 2 3 4 5
```

```
>>> for x in np.nditer(a.T.copy(order='C')):
...     print(x, end=' ')
...
0 3 1 4 2 5
```

The elements of both *a* and *a.T* get traversed in the same order, namely the order they are stored in memory, whereas the elements of *a.T.copy(order='C')* get visited in a different order because they have been put into a different memory layout.

Controlling iteration order

There are times when it is important to visit the elements of an array in a specific order, irrespective of the layout of the elements in memory. The `nditer` object provides an *order* parameter to control this aspect of iteration. The default, having the behavior described above, is order='K' to keep the existing order. This can be overridden with order='C' for C order and order='F' for Fortran order.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a, order='F'):
...     print(x, end=' ')
...
0 3 1 4 2 5
>>> for x in np.nditer(a.T, order='C'):
...     print(x, end=' ')
...
0 3 1 4 2 5
```

Modifying array values

By default, the `nditer` treats the input operand as a read-only object. To be able to modify the array elements, you must specify either read-write or write-only mode using the *'readwrite'* or *'writeonly'* per-operand flags.

The nditer will then yield writeable buffer arrays which you may modify. However, because the nditer must copy this buffer data back to the original array once iteration is finished, you must signal when the iteration is ended, by one of two methods. You may either:

- used the nditer as a context manager using the `with` statement, and the temporary data will be written back when the context is exited.
- call the iterator's `close` method once finished iterating, which will trigger the write-back.

The nditer can no longer be iterated once either `close` is called or its context is exited.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3)
>>> a
array([[0, 1, 2],
       [3, 4, 5]])
>>> with np.nditer(a, op_flags=['readwrite']) as it:
...    for x in it:
...        x[...] = 2 * x
...
>>> a
array([[ 0,  2,  4],
       [ 6,  8, 10]])
```

If you are writing code that needs to support older versions of numpy, note that prior to 1.15, *nditer* was not a context manager and did not have a *close* method. Instead it relied on the destructor to initiate the writeback of the buffer.

Using an external loop

In all the examples so far, the elements of *a* are provided by the iterator one at a time, because all the looping logic is internal to the iterator. While this is simple and convenient, it is not very efficient. A better approach is to move the one-dimensional innermost loop into your code, external to the iterator. This way, NumPy's vectorized operations can be used on larger chunks of the elements being visited.

The *nditer* will try to provide chunks that are as large as possible to the inner loop. By forcing 'C' and 'F' order, we get different external loop sizes. This mode is enabled by specifying an iterator flag.

Observe that with the default of keeping native memory order, the iterator is able to provide a single one-dimensional chunk, whereas when forcing Fortran order, it has to provide three chunks of two elements each.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a, flags=['external_loop']):
...     print(x, end=' ')
...
[0 1 2 3 4 5]
```

```
>>> for x in np.nditer(a, flags=['external_loop'], order='F'):
...     print(x, end=' ')
...
[0 3] [1 4] [2 5]
```

Tracking an index or multi-index

During iteration, you may want to use the index of the current element in a computation. For example, you may want to visit the elements of an array in memory order, but use a C-order, Fortran-order, or multidimensional index to look up values in a different array.

The index is tracked by the iterator object itself, and accessible through the *index* or *multi_index* properties, depending on what was requested. The examples below show printouts demonstrating the progression of the index:

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3)
>>> it = np.nditer(a, flags=['f_index'])
>>> for x in it:
...     print("%d <%d>" % (x, it.index), end=' ')
...
0 <0> 1 <2> 2 <4> 3 <1> 4 <3> 5 <5>
```

```
>>> it = np.nditer(a, flags=['multi_index'])
>>> for x in it:
...     print("%d <%s>" % (x, it.multi_index), end=' ')
...
0 <(0, 0)> 1 <(0, 1)> 2 <(0, 2)> 3 <(1, 0)> 4 <(1, 1)> 5 <(1, 2)>
```

```
>>> with np.nditer(a, flags=['multi_index'], op_flags=['writeonly']) as it:
...     for x in it:
...         x[...] = it.multi_index[1] - it.multi_index[0]
...
>>> a
array([[ 0,  1,  2],
       [-1,  0,  1]])
```

Tracking an index or multi-index is incompatible with using an external loop, because it requires a different index value per element. If you try to combine these flags, the *nditer* object will raise an exception.

Example

```
>>> import numpy as np
```

```
>>> a = np.zeros((2,3))
>>> it = np.nditer(a, flags=['c_index', 'external_loop'])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: Iterator flag EXTERNAL_LOOP cannot be used if an index or multi-index is␣
↪being tracked
```

Alternative looping and element access

To make its properties more readily accessible during iteration, *nditer* has an alternative syntax for iterating, which works explicitly with the iterator object itself. With this looping construct, the current value is accessible by indexing into the iterator. Other properties, such as tracked indices remain as before. The examples below produce identical results to the ones in the previous section.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3)
>>> it = np.nditer(a, flags=['f_index'])
>>> while not it.finished:
...     print("%d <%d>" % (it[0], it.index), end=' ')
...     is_not_finished = it.iternext()
...
0 <0> 1 <2> 2 <4> 3 <1> 4 <3> 5 <5>
```

```
>>> it = np.nditer(a, flags=['multi_index'])
>>> while not it.finished:
...     print("%d <%s>" % (it[0], it.multi_index), end=' ')
...     is_not_finished = it.iternext()
...
0 <(0, 0)> 1 <(0, 1)> 2 <(0, 2)> 3 <(1, 0)> 4 <(1, 1)> 5 <(1, 2)>
```

```
>>> with np.nditer(a, flags=['multi_index'], op_flags=['writeonly']) as it:
...     while not it.finished:
...         it[0] = it.multi_index[1] - it.multi_index[0]
...         is_not_finished = it.iternext()
...
>>> a
array([[ 0,  1,  2],
       [-1,  0,  1]])
```

Buffering the array elements

When forcing an iteration order, we observed that the external loop option may provide the elements in smaller chunks because the elements can't be visited in the appropriate order with a constant stride. When writing C code, this is generally fine, however in pure Python code this can cause a significant reduction in performance.

By enabling buffering mode, the chunks provided by the iterator to the inner loop can be made larger, significantly reducing the overhead of the Python interpreter. In the example forcing Fortran iteration order, the inner loop gets to see all the elements in one go when buffering is enabled.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3)
>>> for x in np.nditer(a, flags=['external_loop'], order='F'):
...     print(x, end=' ')
...
[0 3] [1 4] [2 5]
```

```
>>> for x in np.nditer(a, flags=['external_loop','buffered'], order='F'):
...     print(x, end=' ')
...
[0 3 1 4 2 5]
```

Iterating as a specific data type

There are times when it is necessary to treat an array as a different data type than it is stored as. For instance, one may want to do all computations on 64-bit floats, even if the arrays being manipulated are 32-bit floats. Except when writing low-level C code, it's generally better to let the iterator handle the copying or buffering instead of casting the data type yourself in the inner loop.

There are two mechanisms which allow this to be done, temporary copies and buffering mode. With temporary copies, a copy of the entire array is made with the new data type, then iteration is done in the copy. Write access is permitted through a mode which updates the original array after all the iteration is complete. The major drawback of temporary copies is that the temporary copy may consume a large amount of memory, particularly if the iteration data type has a larger itemsize than the original one.

Buffering mode mitigates the memory usage issue and is more cache-friendly than making temporary copies. Except for special cases, where the whole array is needed at once outside the iterator, buffering is recommended over temporary copying. Within NumPy, buffering is used by the ufuncs and other functions to support flexible inputs with minimal memory overhead.

In our examples, we will treat the input array with a complex data type, so that we can take square roots of negative numbers. Without enabling copies or buffering mode, the iterator will raise an exception if the data type doesn't match precisely.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3) - 3
>>> for x in np.nditer(a, op_dtypes=['complex128']):
...     print(np.sqrt(x), end=' ')
...
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Iterator operand required copying or buffering, but neither copying nor␣
↪buffering was enabled
```

In copying mode, 'copy' is specified as a per-operand flag. This is done to provide control in a per-operand fashion. Buffering mode is specified as an iterator flag.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6).reshape(2,3) - 3
>>> for x in np.nditer(a, op_flags=['readonly','copy'],
...                    op_dtypes=['complex128']):
...     print(np.sqrt(x), end=' ')
...
1.7320508075688772j 1.4142135623730951j 1j 0j (1+0j) (1.4142135623730951+0j)
```

```
>>> for x in np.nditer(a, flags=['buffered'], op_dtypes=['complex128']):
...     print(np.sqrt(x), end=' ')
...
1.7320508075688772j 1.4142135623730951j 1j 0j (1+0j) (1.4142135623730951+0j)
```

The iterator uses NumPy's casting rules to determine whether a specific conversion is permitted. By default, it enforces 'safe' casting. This means, for example, that it will raise an exception if you try to treat a 64-bit float array as a 32-bit float array. In many cases, the rule 'same_kind' is the most reasonable rule to use, since it will allow conversion from 64 to 32-bit float, but not from float to int or from complex to float.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6.)
>>> for x in np.nditer(a, flags=['buffered'], op_dtypes=['float32']):
...     print(x, end=' ')
...
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Iterator operand 0 dtype could not be cast from dtype('float64') to dtype(
↪'float32') according to the rule 'safe'
```

```
>>> for x in np.nditer(a, flags=['buffered'], op_dtypes=['float32'],
...                    casting='same_kind'):
...     print(x, end=' ')
...
0.0 1.0 2.0 3.0 4.0 5.0
```

```
>>> for x in np.nditer(a, flags=['buffered'], op_dtypes=['int32'], casting='same_kind
↪'):
...     print(x, end=' ')
...
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Iterator operand 0 dtype could not be cast from dtype('float64') to dtype(
↪'int32') according to the rule 'same_kind'
```

One thing to watch out for is conversions back to the original data type when using a read-write or write-only operand. A common case is to implement the inner loop in terms of 64-bit floats, and use 'same_kind' casting to allow the other floating-point types to be processed as well. While in read-only mode, an integer array could be provided, read-write mode will raise an exception because conversion back to the array would violate the casting rule.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(6)
>>> for x in np.nditer(a, flags=['buffered'], op_flags=['readwrite'],
...                    op_dtypes=['float64'], casting='same_kind'):
...     x[...] = x / 2.0
...
```

(continues on next page)

(continued from previous page)

```
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
TypeError: Iterator requested dtype could not be cast from dtype('float64') to dtype(
↪'int64'), the operand 0 dtype, according to the rule 'same_kind'
```

Broadcasting array iteration

NumPy has a set of rules for dealing with arrays that have differing shapes which are applied whenever functions take multiple operands which combine element-wise. This is called broadcasting. The *nditer* object can apply these rules for you when you need to write such a function.

As an example, we print out the result of broadcasting a one and a two dimensional array together.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(3)
>>> b = np.arange(6).reshape(2,3)
>>> for x, y in np.nditer([a,b]):
...     print("%d:%d" % (x,y), end=' ')
...
0:0 1:1 2:2 0:3 1:4 2:5
```

When a broadcasting error occurs, the iterator raises an exception which includes the input shapes to help diagnose the problem.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(2)
>>> b = np.arange(6).reshape(2,3)
>>> for x, y in np.nditer([a,b]):
...     print("%d:%d" % (x,y), end=' ')
...
Traceback (most recent call last):
...
ValueError: operands could not be broadcast together with shapes (2,) (2,3)
```

Iterator-allocated output arrays

A common case in NumPy functions is to have outputs allocated based on the broadcasting of the input, and additionally have an optional parameter called 'out' where the result will be placed when it is provided. The *nditer* object provides a convenient idiom that makes it very easy to support this mechanism.

We'll show how this works by creating a function *square* which squares its input. Let's start with a minimal function definition excluding 'out' parameter support.

Example

```
>>> import numpy as np
```

```
>>> def square(a):
...     with np.nditer([a, None]) as it:
...         for x, y in it:
...             y[...] = x*x
...         return it.operands[1]
...
>>> square([1,2,3])
array([1, 4, 9])
```

By default, the *nditer* uses the flags 'allocate' and 'writeonly' for operands that are passed in as None. This means we were able to provide just the two operands to the iterator, and it handled the rest.

When adding the 'out' parameter, we have to explicitly provide those flags, because if someone passes in an array as 'out', the iterator will default to 'readonly', and our inner loop would fail. The reason 'readonly' is the default for input arrays is to prevent confusion about unintentionally triggering a reduction operation. If the default were 'readwrite', any broadcasting operation would also trigger a reduction, a topic which is covered later in this document.

While we're at it, let's also introduce the 'no_broadcast' flag, which will prevent the output from being broadcast. This is important, because we only want one input value for each output. Aggregating more than one input value is a reduction operation which requires special handling. It would already raise an error because reductions must be explicitly enabled in an iterator flag, but the error message that results from disabling broadcasting is much more understandable for end-users. To see how to generalize the square function to a reduction, look at the sum of squares function in the section about Cython.

For completeness, we'll also add the 'external_loop' and 'buffered' flags, as these are what you will typically want for performance reasons.

Example

```
>>> import numpy as np
```

```
>>> def square(a, out=None):
...     it = np.nditer([a, out],
...             flags = ['external_loop', 'buffered'],
...             op_flags = [['readonly'],
...                         ['writeonly', 'allocate', 'no_broadcast']])
...     with it:
...         for x, y in it:
...             y[...] = x*x
...         return it.operands[1]
...
```

```
>>> square([1,2,3])
array([1, 4, 9])
```

```
>>> b = np.zeros((3,))
>>> square([1,2,3], out=b)
array([1.,  4.,  9.])
>>> b
array([1.,  4.,  9.])
```

```
>>> square(np.arange(6).reshape(2,3), out=b)
Traceback (most recent call last):
  ...
ValueError: non-broadcastable output operand with shape (3,) doesn't
match the broadcast shape (2,3)
```

Outer product iteration

Any binary operation can be extended to an array operation in an outer product fashion like in *outer*, and the *nditer* object provides a way to accomplish this by explicitly mapping the axes of the operands. It is also possible to do this with *newaxis* indexing, but we will show you how to directly use the nditer *op_axes* parameter to accomplish this with no intermediate views.

We'll do a simple outer product, placing the dimensions of the first operand before the dimensions of the second operand. The *op_axes* parameter needs one list of axes for each operand, and provides a mapping from the iterator's axes to the axes of the operand.

Suppose the first operand is one dimensional and the second operand is two dimensional. The iterator will have three dimensions, so *op_axes* will have two 3-element lists. The first list picks out the one axis of the first operand, and is -1 for the rest of the iterator axes, with a final result of [0, -1, -1]. The second list picks out the two axes of the second operand, but shouldn't overlap with the axes picked out in the first operand. Its list is [-1, 0, 1]. The output operand maps onto the iterator axes in the standard manner, so we can provide None instead of constructing another list.

The operation in the inner loop is a straightforward multiplication. Everything to do with the outer product is handled by the iterator setup.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(3)
>>> b = np.arange(8).reshape(2,4)
>>> it = np.nditer([a, b, None], flags=['external_loop'],
...             op_axes=[[0, -1, -1], [-1, 0, 1], None])
>>> with it:
...     for x, y, z in it:
...         z[...] = x*y
...     result = it.operands[2]  # same as z
...
>>> result
array([[[ 0,  0,  0,  0],
        [ 0,  0,  0,  0]],
        [[ 0,  1,  2,  3],
        [ 4,  5,  6,  7]],
        [[ 0,  2,  4,  6],
        [ 8, 10, 12, 14]]])
```

Note that once the iterator is closed we can not access `operands` and must use a reference created inside the context manager.

Reduction iteration

Whenever a writeable operand has fewer elements than the full iteration space, that operand is undergoing a reduction. The *nditer* object requires that any reduction operand be flagged as read-write, and only allows reductions when 'reduce_ok' is provided as an iterator flag.

For a simple example, consider taking the sum of all elements in an array.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(24).reshape(2,3,4)
>>> b = np.array(0)
>>> with np.nditer([a, b], flags=['reduce_ok'],
...                        op_flags=[['readonly'], ['readwrite']]) as it:
...     for x,y in it:
...         y[...] += x
...
>>> b
array(276)
>>> np.sum(a)
276
```

Things are a little bit more tricky when combining reduction and allocated operands. Before iteration is started, any reduction operand must be initialized to its starting values. Here's how we can do this, taking sums along the last axis of *a*.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(24).reshape(2,3,4)
>>> it = np.nditer([a, None], flags=['reduce_ok'],
...             op_flags=[['readonly'], ['readwrite', 'allocate']],
...             op_axes=[None, [0,1,-1]])
>>> with it:
...     it.operands[1][...] = 0
...     for x, y in it:
...         y[...] += x
...     result = it.operands[1]
...
>>> result
array([[ 6, 22, 38],
       [54, 70, 86]])
>>> np.sum(a, axis=2)
array([[ 6, 22, 38],
       [54, 70, 86]])
```

To do buffered reduction requires yet another adjustment during the setup. Normally the iterator construction involves copying the first buffer of data from the readable arrays into the buffer. Any reduction operand is readable, so it may be read into a buffer. Unfortunately, initialization of the operand after this buffering operation is complete will not be reflected in the buffer that the iteration starts with, and garbage results will be produced.

The iterator flag "delay_bufalloc" is there to allow iterator-allocated reduction operands to exist together with buffering. When this flag is set, the iterator will leave its buffers uninitialized until it receives a reset, after which it will be ready for regular iteration. Here's how the previous example looks if we also enable buffering.

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(24).reshape(2,3,4)
>>> it = np.nditer([a, None], flags=['reduce_ok',
...                                  'buffered', 'delay_bufalloc'],
...             op_flags=[['readonly'], ['readwrite', 'allocate']],
...             op_axes=[None, [0,1,-1]])
>>> with it:
...     it.operands[1][...] = 0
...     it.reset()
...     for x, y in it:
...         y[...] += x
...     result = it.operands[1]
...
>>> result
array([[ 6, 22, 38],
       [54, 70, 86]])
```

Putting the inner loop in Cython

Those who want really good performance out of their low level operations should strongly consider directly using the iteration API provided in C, but for those who are not comfortable with C or C++, Cython is a good middle ground with reasonable performance tradeoffs. For the *nditer* object, this means letting the iterator take care of broadcasting, dtype conversion, and buffering, while giving the inner loop to Cython.

For our example, we'll create a sum of squares function. To start, let's implement this function in straightforward Python. We want to support an 'axis' parameter similar to the numpy *sum* function, so we will need to construct a list for the *op_axes* parameter. Here's how this looks.

Example

```
>>> def axis_to_axeslist(axis, ndim):
...     if axis is None:
...         return [-1] * ndim
...     else:
...         if type(axis) is not tuple:
...             axis = (axis,)
...         axeslist = [1] * ndim
...         for i in axis:
...             axeslist[i] = -1
...         ax = 0
...         for i in range(ndim):
```

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```
...             if axeslist[i] != -1:
...                 axeslist[i] = ax
...                 ax += 1
...         return axeslist
...
>>> def sum_squares_py(arr, axis=None, out=None):
...     axeslist = axis_to_axeslist(axis, arr.ndim)
...     it = np.nditer([arr, out], flags=['reduce_ok',
...                                       'buffered', 'delay_bufalloc'],
...                 op_flags=[['readonly'], ['readwrite', 'allocate']],
...                 op_axes=[None, axeslist],
...                 op_dtypes=['float64', 'float64'])
...     with it:
...         it.operands[1][...] = 0
...         it.reset()
...         for x, y in it:
...             y[...] += x*x
...         return it.operands[1]
...
>>> a = np.arange(6).reshape(2,3)
>>> sum_squares_py(a)
array(55.)
>>> sum_squares_py(a, axis=-1)
array([  5.,  50.])
```

To Cython-ize this function, we replace the inner loop (y[…] += x*x) with Cython code that's specialized for the float64 dtype. With the 'external_loop' flag enabled, the arrays provided to the inner loop will always be one-dimensional, so very little checking needs to be done.

Here's the listing of sum_squares.pyx:

```
import numpy as np
cimport numpy as np
cimport cython

def axis_to_axeslist(axis, ndim):
    if axis is None:
        return [-1] * ndim
    else:
        if type(axis) is not tuple:
            axis = (axis,)
        axeslist = [1] * ndim
        for i in axis:
            axeslist[i] = -1
        ax = 0
        for i in range(ndim):
            if axeslist[i] != -1:
                axeslist[i] = ax
                ax += 1
        return axeslist

@cython.boundscheck(False)
def sum_squares_cy(arr, axis=None, out=None):
    cdef np.ndarray[double] x
    cdef np.ndarray[double] y
    cdef int size
```

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```
    cdef double value

    axeslist = axis_to_axeslist(axis, arr.ndim)
    it = np.nditer([arr, out], flags=['reduce_ok', 'external_loop',
                                      'buffered', 'delay_bufalloc'],
                op_flags=[['readonly'], ['readwrite', 'allocate']],
                op_axes=[None, axeslist],
                op_dtypes=['float64', 'float64'])
    with it:
        it.operands[1][...] = 0
        it.reset()
        for xarr, yarr in it:
            x = xarr
            y = yarr
            size = x.shape[0]
            for i in range(size):
               value = x[i]
               y[i] = y[i] + value * value
        return it.operands[1]
```

On this machine, building the .pyx file into a module looked like the following, but you may have to find some Cython tutorials to tell you the specifics for your system configuration.:

```
$ cython sum_squares.pyx
$ gcc -shared -pthread -fPIC -fwrapv -O2 -Wall -I/usr/include/python2.7 -fno-strict-
↪aliasing -o sum_squares.so sum_squares.c
```

Running this from the Python interpreter produces the same answers as our native Python/NumPy code did.

Example

```
>>> from sum_squares import sum_squares_cy
>>> a = np.arange(6).reshape(2,3)
>>> sum_squares_cy(a)
array(55.0)
>>> sum_squares_cy(a, axis=-1)
array([  5.,  50.])
```

Doing a little timing in IPython shows that the reduced overhead and memory allocation of the Cython inner loop is providing a very nice speedup over both the straightforward Python code and an expression using NumPy's built-in sum function.:

```
>>> a = np.random.rand(1000,1000)

>>> timeit sum_squares_py(a, axis=-1)
10 loops, best of 3: 37.1 ms per loop

>>> timeit np.sum(a*a, axis=-1)
10 loops, best of 3: 20.9 ms per loop

>>> timeit sum_squares_cy(a, axis=-1)
100 loops, best of 3: 11.8 ms per loop

>>> np.all(sum_squares_cy(a, axis=-1) == np.sum(a*a, axis=-1))
```

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```
True

>>> np.all(sum_squares_py(a, axis=-1) == np.sum(a*a, axis=-1))
True
```

1.2.6 Standard array subclasses

Note: Subclassing a `numpy.ndarray` is possible but if your goal is to create an array with *modified* behavior, as do dask arrays for distributed computation and cupy arrays for GPU-based computation, subclassing is discouraged. Instead, using numpy's dispatch mechanism is recommended.

The *ndarray* can be inherited from (in Python or in C) if desired. Therefore, it can form a foundation for many useful classes. Often whether to sub-class the array object or to simply use the core array component as an internal part of a new class is a difficult decision, and can be simply a matter of choice. NumPy has several tools for simplifying how your new object interacts with other array objects, and so the choice may not be significant in the end. One way to simplify the question is by asking yourself if the object you are interested in can be replaced as a single array or does it really require two or more arrays at its core.

Note that *asarray* always returns the base-class ndarray. If you are confident that your use of the array object can handle any subclass of an ndarray, then *asanyarray* can be used to allow subclasses to propagate more cleanly through your subroutine. In principal a subclass could redefine any aspect of the array and therefore, under strict guidelines, *asanyarray* would rarely be useful. However, most subclasses of the array object will not redefine certain aspects of the array object such as the buffer interface, or the attributes of the array. One important example, however, of why your subroutine may not be able to handle an arbitrary subclass of an array is that matrices redefine the "*" operator to be matrix-multiplication, rather than element-by-element multiplication.

Special attributes and methods

See also:

Subclassing ndarray

NumPy provides several hooks that classes can customize:

`class.__array_ufunc__` (*ufunc*, *method*, **inputs*, ***kwargs*)

Any class, ndarray subclass or not, can define this method or set it to None in order to override the behavior of NumPy's ufuncs. This works quite similarly to Python's `__mul__` and other binary operation routines.

- *ufunc* is the ufunc object that was called.
- *method* is a string indicating which Ufunc method was called (one of `"__call__"`, `"reduce"`, `"reduceat"`, `"accumulate"`, `"outer"`, `"inner"`).
- *inputs* is a tuple of the input arguments to the `ufunc`.
- *kwargs* is a dictionary containing the optional input arguments of the ufunc. If given, any `out` arguments, both positional and keyword, are passed as a `tuple` in *kwargs*. See the discussion in *Universal functions (ufunc)* for details.

The method should return either the result of the operation, or `NotImplemented` if the operation requested is not implemented.

If one of the input, output, or `where` arguments has a *__array_ufunc__* method, it is executed *instead* of the ufunc. If more than one of the arguments implements *__array_ufunc__*, they are tried in the order: subclasses

before superclasses, inputs before outputs, outputs before `where`, otherwise left to right. The first routine returning something other than `NotImplemented` determines the result. If all of the *`__array_ufunc__`* operations return `NotImplemented`, a `TypeError` is raised.

Note: We intend to re-implement numpy functions as (generalized) Ufunc, in which case it will become possible for them to be overridden by the `__array_ufunc__` method. A prime candidate is *`matmul`*, which currently is not a Ufunc, but could be relatively easily be rewritten as a (set of) generalized Ufuncs. The same may happen with functions such as *`median`*, *`amin`*, and *`argsort`*.

Like with some other special methods in python, such as `__hash__` and `__iter__`, it is possible to indicate that your class does *not* support ufuncs by setting `__array_ufunc__ = None`. Ufuncs always raise `TypeError` when called on an object that sets `__array_ufunc__ = None`.

The presence of *`__array_ufunc__`* also influences how *`ndarray`* handles binary operations like `arr + obj` and `arr < obj` when `arr` is an *`ndarray`* and `obj` is an instance of a custom class. There are two possibilities. If `obj.__array_ufunc__` is present and not None, then `ndarray.__add__` and friends will delegate to the ufunc machinery, meaning that `arr + obj` becomes `np.add(arr, obj)`, and then *`add`* invokes `obj.__array_ufunc__`. This is useful if you want to define an object that acts like an array.

Alternatively, if `obj.__array_ufunc__` is set to None, then as a special case, special methods like `ndarray.__add__` will notice this and *unconditionally* raise `TypeError`. This is useful if you want to create objects that interact with arrays via binary operations, but are not themselves arrays. For example, a units handling system might have an object `m` representing the "meters" unit, and want to support the syntax `arr * m` to represent that the array has units of "meters", but not want to otherwise interact with arrays via ufuncs or otherwise. This can be done by setting `__array_ufunc__ = None` and defining `__mul__` and `__rmul__` methods. (Note that this means that writing an `__array_ufunc__` that always returns `NotImplemented` is not quite the same as setting `__array_ufunc__ = None`: in the former case, `arr + obj` will raise `TypeError`, while in the latter case it is possible to define a `__radd__` method to prevent this.)

The above does not hold for in-place operators, for which *`ndarray`* never returns `NotImplemented`. Hence, `arr += obj` would always lead to a `TypeError`. This is because for arrays in-place operations cannot generically be replaced by a simple reverse operation. (For instance, by default, `arr += obj` would be translated to `arr = arr + obj`, i.e., `arr` would be replaced, contrary to what is expected for in-place array operations.)

Note: If you define `__array_ufunc__`:

- If you are not a subclass of *`ndarray`*, we recommend your class define special methods like `__add__` and `__lt__` that delegate to ufuncs just like ndarray does. An easy way to do this is to subclass from *`NDArrayOperatorsMixin`*.
- If you subclass *`ndarray`*, we recommend that you put all your override logic in `__array_ufunc__` and not also override special methods. This ensures the class hierarchy is determined in only one place rather than separately by the ufunc machinery and by the binary operation rules (which gives preference to special methods of subclasses; the alternative way to enforce a one-place only hierarchy, of setting *`__array_ufunc__`* to None, would seem very unexpected and thus confusing, as then the subclass would not work at all with ufuncs).
- *`ndarray`* defines its own *`__array_ufunc__`*, which, evaluates the ufunc if no arguments have overrides, and returns `NotImplemented` otherwise. This may be useful for subclasses for which *`__array_ufunc__`* converts any instances of its own class to *`ndarray`*: it can then pass these on to its superclass using `super().__array_ufunc__(*inputs, **kwargs)`, and finally return the results after possible back-conversion. The advantage of this practice is that it ensures that it is possible to have a hierarchy of subclasses that extend the behaviour. See Subclassing ndarray for details.

`class.`**`__array_function__`**(*func*, *types*, *args*, *kwargs*)

- `func` is an arbitrary callable exposed by NumPy's public API, which was called in the form `func(*args, **kwargs)`.
- `types` is a collection `collections.abc.Collection` of unique argument types from the original NumPy function call that implement `__array_function__`.
- The tuple `args` and dict `kwargs` are directly passed on from the original call.

As a convenience for `__array_function__` implementers, `types` provides all argument types with an `'__array_function__'` attribute. This allows implementers to quickly identify cases where they should defer to `__array_function__` implementations on other arguments. Implementations should not rely on the iteration order of `types`.

Most implementations of `__array_function__` will start with two checks:

1. Is the given function something that we know how to overload?
2. Are all arguments of a type that we know how to handle?

If these conditions hold, `__array_function__` should return the result from calling its implementation for `func(*args, **kwargs)`. Otherwise, it should return the sentinel value `NotImplemented`, indicating that the function is not implemented by these types.

There are no general requirements on the return value from `__array_function__`, although most sensible implementations should probably return array(s) with the same type as one of the function's arguments.

It may also be convenient to define a custom decorators (`implements` below) for registering `__array_function__` implementations.

```
HANDLED_FUNCTIONS = {}

class MyArray:
    def __array_function__(self, func, types, args, kwargs):
        if func not in HANDLED_FUNCTIONS:
            return NotImplemented
        # Note: this allows subclasses that don't override
        # __array_function__ to handle MyArray objects
        if not all(issubclass(t, MyArray) for t in types):
            return NotImplemented
        return HANDLED_FUNCTIONS[func](*args, **kwargs)

def implements(numpy_function):
    """Register an __array_function__ implementation for MyArray objects."""
    def decorator(func):
        HANDLED_FUNCTIONS[numpy_function] = func
        return func
    return decorator

@implements(np.concatenate)
def concatenate(arrays, axis=0, out=None):
    ...  # implementation of concatenate for MyArray objects

@implements(np.broadcast_to)
def broadcast_to(array, shape):
    ...  # implementation of broadcast_to for MyArray objects
```

Note that it is not required for `__array_function__` implementations to include *all* of the corresponding NumPy function's optional arguments (e.g., `broadcast_to` above omits the irrelevant `subok` argument). Optional arguments are only passed in to `__array_function__` if they were explicitly used in the NumPy function call.

Just like the case for builtin special methods like `__add__`, properly written `__array_function__` methods should always return `NotImplemented` when an unknown type is encountered. Otherwise, it will be impossible to correctly override NumPy functions from another object if the operation also includes one of your objects.

For the most part, the rules for dispatch with `__array_function__` match those for `__array_ufunc__`. In particular:

- NumPy will gather implementations of `__array_function__` from all specified inputs and call them in order: subclasses before superclasses, and otherwise left to right. Note that in some edge cases involving subclasses, this differs slightly from the current behavior of Python.
- Implementations of `__array_function__` indicate that they can handle the operation by returning any value other than `NotImplemented`.
- If all `__array_function__` methods return `NotImplemented`, NumPy will raise `TypeError`.

If no `__array_function__` methods exists, NumPy will default to calling its own implementation, intended for use on NumPy arrays. This case arises, for example, when all array-like arguments are Python numbers or lists. (NumPy arrays do have a `__array_function__` method, given below, but it always returns `NotImplemented` if any argument other than a NumPy array subclass implements `__array_function__`.)

One deviation from the current behavior of `__array_ufunc__` is that NumPy will only call `__array_function__` on the *first* argument of each unique type. This matches Python's rule for calling reflected methods, and this ensures that checking overloads has acceptable performance even when there are a large number of overloaded arguments.

`class.__array_finalize__`(*obj*)

This method is called whenever the system internally allocates a new array from *obj*, where *obj* is a subclass (subtype) of the *ndarray*. It can be used to change attributes of *self* after construction (so as to ensure a 2-d matrix for example), or to update meta-information from the "parent." Subclasses inherit a default implementation of this method that does nothing.

`class.__array_wrap__`(*array*, *context=None*, *return_scalar=False*)

At the end of every ufunc, this method is called on the input object with the highest array priority, or the output object if one was specified. The ufunc-computed array is passed in and whatever is returned is passed to the user. Subclasses inherit a default implementation of this method, which transforms the array into a new instance of the object's class. Subclasses may opt to use this method to transform the output array into an instance of the subclass and update metadata before returning the array to the user.

NumPy may also call this function without a context from non-ufuncs to allow preserving subclass information.

Changed in version 2.0: `return_scalar` is now passed as either `False` (usually) or `True` indicating that NumPy would return a scalar. Subclasses may ignore the value, or return `array[()]` to behave more like NumPy.

Note: It is hoped to eventually deprecate this method in favour of *__array_ufunc__* for ufuncs (and *__array_function__* for a few other functions like *numpy.squeeze*).

`class.__array_priority__`

The value of this attribute is used to determine what type of object to return in situations where there is more than one possibility for the Python type of the returned object. Subclasses inherit a default value of 0.0 for this attribute.

Note: For ufuncs, it is hoped to eventually deprecate this method in favour of *__array_ufunc__*.

`class.__array__`(*dtype=None*, *copy=None*)

If defined on an object, should return an `ndarray`. This method is called by array-coercion functions like np.array() if an object implementing this interface is passed to those functions. The third-party implementations

of `__array__` must take `dtype` and `copy` keyword arguments, as ignoring them might break third-party code or NumPy itself.

- `dtype` is a data type of the returned array.
- `copy` is an optional boolean that indicates whether a copy should be returned. For `True` a copy should always be made, for `None` only if required (e.g. due to passed `dtype` value), and for `False` a copy should never be made (if a copy is still required, an appropriate exception should be raised).

Please refer to Interoperability with NumPy for the protocol hierarchy, of which `__array__` is the oldest and least desirable.

Note: If a class (ndarray subclass or not) having the *`__array__`* method is used as the output object of an ufunc, results will *not* be written to the object returned by *`__array__`*. This practice will return `TypeError`.

Matrix objects

Note: It is strongly advised *not* to use the matrix subclass. As described below, it makes writing functions that deal consistently with matrices and regular arrays very difficult. Currently, they are mainly used for interacting with `scipy.sparse`. We hope to provide an alternative for this use, however, and eventually remove the `matrix` subclass.

`matrix` objects inherit from the ndarray and therefore, they have the same attributes and methods of ndarrays. There are six important differences of matrix objects, however, that may lead to unexpected results when you use matrices but expect them to act like arrays:

1. Matrix objects can be created using a string notation to allow Matlab-style syntax where spaces separate columns and semicolons (';') separate rows.
2. Matrix objects are always two-dimensional. This has far-reaching implications, in that m.ravel() is still two-dimensional (with a 1 in the first dimension) and item selection returns two-dimensional objects so that sequence behavior is fundamentally different than arrays.
3. Matrix objects over-ride multiplication to be matrix-multiplication. **Make sure you understand this for functions that you may want to receive matrices. Especially in light of the fact that asanyarray(m) returns a matrix when m is a matrix.**
4. Matrix objects over-ride power to be matrix raised to a power. The same warning about using power inside a function that uses asanyarray(…) to get an array object holds for this fact.
5. The default __array_priority__ of matrix objects is 10.0, and therefore mixed operations with ndarrays always produce matrices.
6. Matrices have special attributes which make calculations easier. These are

`matrix.T`	Returns the transpose of the matrix.
`matrix.H`	Returns the (complex) conjugate transpose of *self*.
`matrix.I`	Returns the (multiplicative) inverse of invertible *self*.
`matrix.A`	Return *self* as an *`ndarray`* object.

property

property matrix.**T**

Returns the transpose of the matrix.

Does *not* conjugate! For the complex conjugate transpose, use `.H`.

Parameters

None

Returns

ret
[matrix object] The (non-conjugated) transpose of the matrix.

See also:

transpose, ***getH***

Examples

```
>>> m = np.matrix('[1, 2; 3, 4]')
>>> m
matrix([[1, 2],
        [3, 4]])
>>> m.getT()
matrix([[1, 3],
        [2, 4]])
```

property

property matrix.**H**

Returns the (complex) conjugate transpose of *self*.

Equivalent to `np.transpose(self)` if *self* is real-valued.

Parameters

None

Returns

ret
[matrix object] complex conjugate transpose of *self*

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4)))
>>> z = x - 1j*x; z
matrix([[  0. +0.j,   1. -1.j,   2. -2.j,   3. -3.j],
        [  4. -4.j,   5. -5.j,   6. -6.j,   7. -7.j],
        [  8. -8.j,   9. -9.j,  10.-10.j,  11.-11.j]])
>>> z.getH()
matrix([[ 0. -0.j,  4. +4.j,  8. +8.j],
        [ 1. +1.j,  5. +5.j,  9. +9.j],
        [ 2. +2.j,  6. +6.j, 10.+10.j],
        [ 3. +3.j,  7. +7.j, 11.+11.j]])
```

property

property matrix.**I**

Returns the (multiplicative) inverse of invertible *self*.

Parameters

None

Returns

ret
[matrix object] If *self* is non-singular, *ret* is such that `ret * self` == `self * ret` == `np.matrix(np.eye(self[0,:].size))` all return `True`.

Raises

numpy.linalg.LinAlgError: Singular matrix
If *self* is singular.

See also:

linalg.inv

Examples

```
>>> m = np.matrix('[1, 2; 3, 4]'); m
matrix([[1, 2],
        [3, 4]])
>>> m.getI()
matrix([[-2. ,  1. ],
        [ 1.5, -0.5]])
>>> m.getI() * m
matrix([[ 1.,  0.], # may vary
        [ 0.,  1.]])
```

property

property matrix.**A**

Return *self* as an *ndarray* object.

Equivalent to `np.asarray(self)`.

Parameters

None

Returns

ret
[ndarray] *self* as an *ndarray*

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.getA()
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
```

Warning: Matrix objects over-ride multiplication, '*', and power, '**', to be matrix-multiplication and matrix power, respectively. If your subroutine can accept sub-classes and you do not convert to base- class arrays, then you must use the ufuncs multiply and power to be sure that you are performing the correct operation for all inputs.

The matrix class is a Python subclass of the ndarray and can be used as a reference for how to construct your own subclass of the ndarray. Matrices can be created from other matrices, strings, and anything else that can be converted to an `ndarray` . The name "mat "is an alias for "matrix "in NumPy.

matrix(data[, dtype, copy])	Returns a matrix from an array-like object, or from a string of data.
asmatrix(data[, dtype])	Interpret the input as a matrix.
bmat(obj[, ldict, gdict])	Build a matrix object from a string, nested sequence, or array.

class numpy.**matrix**(*data*, *dtype=None*, *copy=True*)

Returns a matrix from an array-like object, or from a string of data.

A matrix is a specialized 2-D array that retains its 2-D nature through operations. It has certain special operators, such as `*` (matrix multiplication) and `**` (matrix power).

Note: It is no longer recommended to use this class, even for linear algebra. Instead use regular arrays. The class may be removed in the future.

Parameters

data
[array_like or string] If `data` is a string, it is interpreted as a matrix with commas or spaces separating columns, and semicolons separating rows.

dtype
[data-type] Data-type of the output matrix.

copy
[bool] If `data` is already an *ndarray*, then this flag determines whether the data is copied (the default), or whether a view is constructed.

See also:

array

Examples

```
>>> import numpy as np
>>> a = np.matrix('1 2; 3 4')
>>> a
matrix([[1, 2],
        [3, 4]])
```

```
>>> np.matrix([[1, 2], [3, 4]])
matrix([[1, 2],
        [3, 4]])
```

Attributes

A
Return *self* as an *ndarray* object.

A1
Return *self* as a flattened *ndarray*.

H
Returns the (complex) conjugate transpose of *self*.

I
Returns the (multiplicative) inverse of invertible *self*.

T
Returns the transpose of the matrix.

base
Base object if memory is from some other object.

ctypes
An object to simplify the interaction of the array with the ctypes module.

data
Python buffer object pointing to the start of the array's data.

device

dtype
Data-type of the array's elements.

flags
Information about the memory layout of the array.

flat
A 1-D iterator over the array.

imag
The imaginary part of the array.

itemset

itemsize
Length of one array element in bytes.

mT
View of the matrix transposed array.

nbytes
Total bytes consumed by the elements of the array.

ndim
Number of array dimensions.

newbyteorder

real
The real part of the array.

shape
Tuple of array dimensions.

size
Number of elements in the array.

strides
Tuple of bytes to step in each dimension when traversing an array.

Methods

all([axis, out])	Test whether all matrix elements along a given axis evaluate to True.
any([axis, out])	Test whether any array element along a given axis evaluates to True.
argmax([axis, out])	Indexes of the maximum values along an axis.
argmin([axis, out])	Indexes of the minimum values along an axis.
argpartition(kth[, axis, kind, order])	Returns the indices that would partition this array.
argsort([axis, kind, order])	Returns the indices that would sort this array.
astype(dtype[, order, casting, subok, copy])	Copy of the array, cast to a specified type.
byteswap([inplace])	Swap the bytes of the array elements
choose(choices[, out, mode])	Use an index array to construct a new array from a set of choices.
clip([min, max, out])	Return an array whose values are limited to `[min, max]`.
compress(condition[, axis, out])	Return selected slices of this array along given axis.
conj()	Complex-conjugate all elements.
conjugate()	Return the complex conjugate, element-wise.
copy([order])	Return a copy of the array.
cumprod([axis, dtype, out])	Return the cumulative product of the elements along the given axis.
cumsum([axis, dtype, out])	Return the cumulative sum of the elements along the given axis.
diagonal([offset, axis1, axis2])	Return specified diagonals.
dump(file)	Dump a pickle of the array to the specified file.
dumps()	Returns the pickle of the array as a string.
fill(value)	Fill the array with a scalar value.
flatten([order])	Return a flattened copy of the matrix.
getA()	Return *self* as an *ndarray* object.
getA1()	Return *self* as a flattened *ndarray*.
getH()	Returns the (complex) conjugate transpose of *self*.
getI()	Returns the (multiplicative) inverse of invertible *self*.
getT()	Returns the transpose of the matrix.
getfield(dtype[, offset])	Returns a field of the given array as a certain type.
item(*args)	Copy an element of an array to a standard Python scalar and return it.
max([axis, out])	Return the maximum value along an axis.
mean([axis, dtype, out])	Returns the average of the matrix elements along the given axis.
min([axis, out])	Return the minimum value along an axis.
nonzero()	Return the indices of the elements that are non-zero.
partition(kth[, axis, kind, order])	Partially sorts the elements in the array in such a way that the value of the element in k-th position is in the position it would be in a sorted array.
prod([axis, dtype, out])	Return the product of the array elements over the given axis.
ptp([axis, out])	Peak-to-peak (maximum - minimum) value along the given axis.
put(indices, values[, mode])	Set `a.flat[n] = values[n]` for all *n* in indices.
ravel([order])	Return a flattened matrix.
repeat(repeats[, axis])	Repeat elements of an array.

continues on next page

Table 7 – continued from previous page

reshape(shape, /, *[, order, copy])	Returns an array containing the same data with a new shape.
resize(new_shape[, refcheck])	Change shape and size of array in-place.
round([decimals, out])	Return *a* with each element rounded to the given number of decimals.
searchsorted(v[, side, sorter])	Find indices where elements of v should be inserted in a to maintain order.
setfield(val, dtype[, offset])	Put a value into a specified place in a field defined by a data-type.
setflags([write, align, uic])	Set array flags WRITEABLE, ALIGNED, WRITEBACKIFCOPY, respectively.
sort([axis, kind, order])	Sort an array in-place.
squeeze([axis])	Return a possibly reshaped matrix.
std([axis, dtype, out, ddof])	Return the standard deviation of the array elements along the given axis.
sum([axis, dtype, out])	Returns the sum of the matrix elements, along the given axis.
swapaxes(axis1, axis2)	Return a view of the array with *axis1* and *axis2* interchanged.
take(indices[, axis, out, mode])	Return an array formed from the elements of *a* at the given indices.
tobytes([order])	Construct Python bytes containing the raw data bytes in the array.
tofile(fid[, sep, format])	Write array to a file as text or binary (default).
tolist()	Return the matrix as a (possibly nested) list.
tostring([order])	A compatibility alias for *tobytes*, with exactly the same behavior.
trace([offset, axis1, axis2, dtype, out])	Return the sum along diagonals of the array.
transpose(*axes)	Returns a view of the array with axes transposed.
var([axis, dtype, out, ddof])	Returns the variance of the matrix elements, along the given axis.
view([dtype][, type])	New view of array with the same data.

method

matrix.**all**(*axis=None*, *out=None*)

Test whether all matrix elements along a given axis evaluate to True.

Parameters

See `numpy.all` for complete descriptions

See also:

numpy.all

Notes

This is the same as *ndarray.all*, but it returns a *matrix* object.

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> y = x[0]; y
matrix([[0, 1, 2, 3]])
>>> (x == y)
matrix([[ True,  True,  True,  True],
        [False, False, False, False],
        [False, False, False, False]])
>>> (x == y).all()
False
>>> (x == y).all(0)
matrix([[False, False, False, False]])
>>> (x == y).all(1)
matrix([[ True],
        [False],
        [False]])
```

method

matrix.**any**(*axis=None*, *out=None*)

Test whether any array element along a given axis evaluates to True.

Refer to *numpy.any* for full documentation.

Parameters

axis
[int, optional] Axis along which logical OR is performed

out
[ndarray, optional] Output to existing array instead of creating new one, must have same shape as expected output

Returns

any
[bool, ndarray] Returns a single bool if *axis* is `None`; otherwise, returns *ndarray*

method

matrix.**argmax**(*axis=None*, *out=None*)

Indexes of the maximum values along an axis.

Return the indexes of the first occurrences of the maximum values along the specified axis. If axis is None, the index is for the flattened matrix.

Parameters

See `numpy.argmax` for complete descriptions

See also:

numpy.argmax

Notes

This is the same as *ndarray.argmax*, but returns a *matrix* object where *ndarray.argmax* would return an *ndarray*.

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.argmax()
11
>>> x.argmax(0)
matrix([[2, 2, 2, 2]])
>>> x.argmax(1)
matrix([[3],
        [3],
        [3]])
```

method

`matrix.`**`argmin`**(*axis=None*, *out=None*)

Indexes of the minimum values along an axis.

Return the indexes of the first occurrences of the minimum values along the specified axis. If axis is None, the index is for the flattened matrix.

Parameters

See `numpy.argmin` for complete descriptions.

See also:

numpy.argmin

Notes

This is the same as *ndarray.argmin*, but returns a *matrix* object where *ndarray.argmin* would return an *ndarray*.

Examples

```
>>> x = -np.matrix(np.arange(12).reshape((3,4))); x
matrix([[  0,  -1,  -2,  -3],
        [ -4,  -5,  -6,  -7],
        [ -8,  -9, -10, -11]])
>>> x.argmin()
11
>>> x.argmin(0)
matrix([[2, 2, 2, 2]])
>>> x.argmin(1)
matrix([[3],
        [3],
        [3]])
```

method

matrix.**argpartition**(*kth*, *axis=-1*, *kind='introselect'*, *order=None*)

Returns the indices that would partition this array.

Refer to *numpy.argpartition* for full documentation.

See also:

numpy.argpartition
equivalent function

method

matrix.**argsort**(*axis=-1*, *kind=None*, *order=None*)

Returns the indices that would sort this array.

Refer to *numpy.argsort* for full documentation.

See also:

numpy.argsort
equivalent function

method

matrix.**astype**(*dtype*, *order='K'*, *casting='unsafe'*, *subok=True*, *copy=True*)

Copy of the array, cast to a specified type.

Parameters

dtype
[str or dtype] Typecode or data-type to which the array is cast.

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout order of the result. 'C' means C order, 'F' means Fortran order, 'A' means 'F' order if all the arrays are Fortran contiguous, 'C' order otherwise, and 'K' means as close to the order the array elements appear in memory as possible. Default is 'K'.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'unsafe' for backwards compatibility.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.
- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

subok
[bool, optional] If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

copy
[bool, optional] By default, astype always returns a newly allocated array. If this is set to false, and the *dtype*, *order*, and *subok* requirements are satisfied, the input array is returned instead of a copy.

Returns

arr_t
[ndarray] Unless *copy* is False and the other conditions for returning the input array are satisfied (see description for *copy* input parameter), *arr_t* is a new array of the same shape as the input array, with dtype, order given by *dtype*, *order*.

Raises

ComplexWarning
When casting from complex to float or int. To avoid this, one should use `a.real.astype(t)`.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 2.5])
>>> x
array([1. ,  2. ,  2.5])
```

```
>>> x.astype(int)
array([1, 2, 2])
```

method

`matrix.`**`byteswap`**(*inplace=False*)

Swap the bytes of the array elements

Toggle between low-endian and big-endian data representation by returning a byteswapped array, optionally swapped in-place. Arrays of byte-strings are not swapped. The real and imaginary parts of a complex number are swapped individually.

Parameters

inplace
[bool, optional] If `True`, swap bytes in-place, default is `False`.

Returns

out
[ndarray] The byteswapped array. If *inplace* is `True`, this is a view to self.

Examples

```
>>> import numpy as np
>>> A = np.array([1, 256, 8755], dtype=np.int16)
>>> list(map(hex, A))
['0x1', '0x100', '0x2233']
>>> A.byteswap(inplace=True)
array([  256,     1, 13090], dtype=int16)
>>> list(map(hex, A))
['0x100', '0x1', '0x3322']
```

Arrays of byte-strings are not swapped

```
>>> A = np.array([b'ceg', b'fac'])
>>> A.byteswap()
array([b'ceg', b'fac'], dtype='|S3')
```

`A.view(A.dtype.newbyteorder()).byteswap()` produces an array with the same values but different representation in memory

```
>>> A = np.array([1, 2, 3],dtype=np.int64)
>>> A.view(np.uint8)
array([1, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0,
       0, 0], dtype=uint8)
>>> A.view(A.dtype.newbyteorder()).byteswap(inplace=True)
array([1, 2, 3], dtype='>i8')
>>> A.view(np.uint8)
array([0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0,
       0, 3], dtype=uint8)
```

method

`matrix.`**`choose`**(*choices*, *out=None*, *mode='raise'*)

Use an index array to construct a new array from a set of choices.

Refer to *`numpy.choose`* for full documentation.

See also:

`numpy.choose`
equivalent function

method

`matrix.`**`clip`**(*min=None*, *max=None*, *out=None*, ***kwargs*)

Return an array whose values are limited to `[min, max]`. One of max or min must be given.

Refer to *`numpy.clip`* for full documentation.

See also:

`numpy.clip`
equivalent function

method

`matrix.`**`compress`**(*condition*, *axis=None*, *out=None*)

Return selected slices of this array along given axis.

Refer to *`numpy.compress`* for full documentation.

See also:

`numpy.compress`
equivalent function

method

matrix.**conj**()

Complex-conjugate all elements.

Refer to *numpy.conjugate* for full documentation.

See also:

numpy.conjugate
equivalent function

method

matrix.**conjugate**()

Return the complex conjugate, element-wise.

Refer to *numpy.conjugate* for full documentation.

See also:

numpy.conjugate
equivalent function

method

matrix.**copy**(*order='C'*)

Return a copy of the array.

Parameters

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout of the copy. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible. (Note that this function and *numpy.copy* are very similar but have different default values for their order= arguments, and this function always passes sub-classes through.)

See also:

numpy.copy
Similar function with different default behavior

numpy.copyto

Notes

This function is the preferred method for creating an array copy. The function *numpy.copy* is similar, but it defaults to using order 'K', and will not pass sub-classes through by default.

Examples

```
>>> import numpy as np
>>> x = np.array([[1,2,3],[4,5,6]], order='F')
```

```
>>> y = x.copy()
```

```
>>> x.fill(0)
```

```
>>> x
array([[0, 0, 0],
       [0, 0, 0]])
```

```
>>> y
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> y.flags['C_CONTIGUOUS']
True
```

For arrays containing Python objects (e.g. dtype=object), the copy is a shallow one. The new array will contain the same object which may lead to surprises if that object can be modified (is mutable):

```
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> b = a.copy()
>>> b[2][0] = 10
>>> a
array([1, 'm', list([10, 3, 4])], dtype=object)
```

To ensure all elements within an `object` array are copied, use `copy.deepcopy`:

```
>>> import copy
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> c = copy.deepcopy(a)
>>> c[2][0] = 10
>>> c
array([1, 'm', list([10, 3, 4])], dtype=object)
>>> a
array([1, 'm', list([2, 3, 4])], dtype=object)
```

method

`matrix.`**`cumprod`**(*axis=None*, *dtype=None*, *out=None*)

Return the cumulative product of the elements along the given axis.

Refer to *`numpy.cumprod`* for full documentation.

See also:

`numpy.cumprod`
equivalent function

method

matrix.**cumsum**(*axis=None*, *dtype=None*, *out=None*)

Return the cumulative sum of the elements along the given axis.

Refer to *numpy.cumsum* for full documentation.

See also:

numpy.cumsum
equivalent function

method

matrix.**diagonal**(*offset=0*, *axis1=0*, *axis2=1*)

Return specified diagonals. In NumPy 1.9 the returned array is a read-only view instead of a copy as in previous NumPy versions. In a future version the read-only restriction will be removed.

Refer to *numpy.diagonal* for full documentation.

See also:

numpy.diagonal
equivalent function

method

matrix.**dump**(*file*)

Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

Parameters

file
[str or Path] A string naming the dump file.

method

matrix.**dumps**()

Returns the pickle of the array as a string. pickle.loads will convert the string back to an array.

Parameters

None

method

matrix.**fill**(*value*)

Fill the array with a scalar value.

Parameters

value
[scalar] All elements of *a* will be assigned this value.

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2])
>>> a.fill(0)
>>> a
array([0, 0])
>>> a = np.empty(2)
>>> a.fill(1)
>>> a
array([1.,  1.])
```

Fill expects a scalar value and always behaves the same as assigning to a single array element. The following is a rare example where this distinction is important:

```
>>> a = np.array([None, None], dtype=object)
>>> a[0] = np.array(3)
>>> a
array([array(3), None], dtype=object)
>>> a.fill(np.array(3))
>>> a
array([array(3), array(3)], dtype=object)
```

Where other forms of assignments will unpack the array being assigned:

```
>>> a[...] = np.array(3)
>>> a
array([3, 3], dtype=object)
```

method

`matrix.`**`flatten`**(*order='C'*)

Return a flattened copy of the matrix.

All *N* elements of the matrix are placed into a single row.

Parameters

order
[{'C', 'F', 'A', 'K'}, optional] 'C' means to flatten in row-major (C-style) order. 'F' means to flatten in column-major (Fortran-style) order. 'A' means to flatten in column-major order if *m* is Fortran *contiguous* in memory, row-major order otherwise. 'K' means to flatten *m* in the order the elements occur in memory. The default is 'C'.

Returns

y
[matrix] A copy of the matrix, flattened to a *(1, N)* matrix where *N* is the number of elements in the original matrix.

See also:

ravel
Return a flattened array.

flat
A 1-D flat iterator over the matrix.

Examples

```
>>> m = np.matrix([[1,2], [3,4]])
>>> m.flatten()
matrix([[1, 2, 3, 4]])
>>> m.flatten('F')
matrix([[1, 3, 2, 4]])
```

method

`matrix.`**`getA`**`()`

Return *self* as an *ndarray* object.

Equivalent to `np.asarray(self)`.

Parameters

None

Returns

ret
[ndarray] *self* as an *ndarray*

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.getA()
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
```

method

`matrix.`**`getA1`**`()`

Return *self* as a flattened *ndarray*.

Equivalent to `np.asarray(x).ravel()`

Parameters

None

Returns

ret
[ndarray] *self*, 1-D, as an *ndarray*

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.getA1()
array([ 0,  1,  2, ...,  9, 10, 11])
```

method

`matrix.`**`getH`**`()`

Returns the (complex) conjugate transpose of *self*.

Equivalent to `np.transpose(self)` if *self* is real-valued.

Parameters

None

Returns

ret
[matrix object] complex conjugate transpose of *self*

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4)))
>>> z = x - 1j*x; z
matrix([[  0. +0.j,   1. -1.j,   2. -2.j,   3. -3.j],
        [  4. -4.j,   5. -5.j,   6. -6.j,   7. -7.j],
        [  8. -8.j,   9. -9.j,  10.-10.j,  11.-11.j]])
>>> z.getH()
matrix([[ 0. -0.j,  4. +4.j,  8. +8.j],
        [ 1. +1.j,  5. +5.j,  9. +9.j],
        [ 2. +2.j,  6. +6.j, 10.+10.j],
        [ 3. +3.j,  7. +7.j, 11.+11.j]])
```

method

`matrix.`**`getI`**`()`

Returns the (multiplicative) inverse of invertible *self*.

Parameters

None

Returns

ret
[matrix object] If *self* is non-singular, *ret* is such that `ret * self` == `self * ret` == `np.matrix(np.eye(self[0,:].size))` all return `True`.

Raises

numpy.linalg.LinAlgError: Singular matrix
If *self* is singular.

See also:

`linalg.inv`

Examples

```
>>> m = np.matrix('[1, 2; 3, 4]'); m
matrix([[1, 2],
        [3, 4]])
>>> m.getI()
matrix([[-2. ,  1. ],
        [ 1.5, -0.5]])
>>> m.getI() * m
matrix([[ 1.,  0.], # may vary
        [ 0.,  1.]])
```

method

matrix.**getT**()

Returns the transpose of the matrix.

Does *not* conjugate! For the complex conjugate transpose, use `.H`.

Parameters

None

Returns

ret
[matrix object] The (non-conjugated) transpose of the matrix.

See also:

transpose*, *getH

Examples

```
>>> m = np.matrix('[1, 2; 3, 4]')
>>> m
matrix([[1, 2],
        [3, 4]])
>>> m.getT()
matrix([[1, 3],
        [2, 4]])
```

method

matrix.**getfield**(*dtype*, *offset=0*)

Returns a field of the given array as a certain type.

A field is a view of the array data with a given data-type. The values in the view are determined by the given type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits in the array dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with a 32-bit integer (4 bytes), the offset needs to be between 0 and 12 bytes.

Parameters

dtype
[str or dtype] The data type of the view. The dtype size of the view can not be larger than that of the array itself.

offset
[int] Number of bytes to skip before beginning the element view.

Examples

```
>>> import numpy as np
>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[1.+1.j,  0.+0.j],
       [0.+0.j,  2.+4.j]])
>>> x.getfield(np.float64)
array([[1.,  0.],
       [0.,  2.]])
```

By choosing an offset of 8 bytes we can select the complex part of the array for our view:

```
>>> x.getfield(np.float64, offset=8)
array([[1.,  0.],
       [0.,  4.]])
```

method

`matrix.item(*args)`

Copy an element of an array to a standard Python scalar and return it.

Parameters

***args**
[Arguments (variable number and type)]

- none: in this case, the method only works for arrays with one element (*a.size == 1*), which element is copied into a standard Python scalar object and returned.
- int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.
- tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.

Returns

z
[Standard Python scalar object] A copy of the specified element of the array as a suitable Python scalar

Notes

When the data type of *a* is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

item is very similar to a[args], except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python's optimized math.

Examples

```
>>> import numpy as np
>>> np.random.seed(123)
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[2, 2, 6],
       [1, 3, 6],
       [1, 0, 1]])
>>> x.item(3)
1
>>> x.item(7)
0
>>> x.item((0, 1))
2
>>> x.item((2, 2))
1
```

For an array with object dtype, elements are returned as-is.

```
>>> a = np.array([np.int64(1)], dtype=object)
>>> a.item() #return np.int64
np.int64(1)
```

method

matrix.**max**(*axis=None*, *out=None*)

Return the maximum value along an axis.

Parameters

See `amax` for complete descriptions

See also:

amax*, *ndarray.max

Notes

This is the same as *ndarray.max*, but returns a *matrix* object where *ndarray.max* would return an ndarray.

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.max()
11
>>> x.max(0)
matrix([[ 8,  9, 10, 11]])
>>> x.max(1)
matrix([[ 3],
        [ 7],
        [11]])
```

method

matrix.**mean**(*axis=None*, *dtype=None*, *out=None*)

Returns the average of the matrix elements along the given axis.

Refer to *numpy.mean* for full documentation.

See also:

numpy.mean

Notes

Same as *ndarray.mean* except that, where that returns an *ndarray*, this returns a *matrix* object.

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3, 4)))
>>> x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.mean()
5.5
>>> x.mean(0)
matrix([[4., 5., 6., 7.]])
>>> x.mean(1)
matrix([[ 1.5],
        [ 5.5],
        [ 9.5]])
```

method

matrix.**min**(*axis=None*, *out=None*)

Return the minimum value along an axis.

Parameters

See `amin` for complete descriptions.

See also:

amin*, *ndarray.min

Notes

This is the same as *ndarray.min*, but returns a *matrix* object where *ndarray.min* would return an ndarray.

Examples

```
>>> x = -np.matrix(np.arange(12).reshape((3,4))); x
matrix([[  0,  -1,  -2,  -3],
        [ -4,  -5,  -6,  -7],
        [ -8,  -9, -10, -11]])
>>> x.min()
-11
>>> x.min(0)
matrix([[ -8,  -9, -10, -11]])
>>> x.min(1)
matrix([[ -3],
        [ -7],
        [-11]])
```

method

matrix.**nonzero**()

Return the indices of the elements that are non-zero.

Refer to *numpy.nonzero* for full documentation.

See also:

numpy.nonzero
equivalent function

method

matrix.**partition**(*kth*, *axis=-1*, *kind='introselect'*, *order=None*)

Partially sorts the elements in the array in such a way that the value of the element in k-th position is in the position it would be in a sorted array. In the output array, all elements smaller than the k-th element are located to the left of this element and all equal or greater are located to its right. The ordering of the elements in the two partitions on the either side of the k-th element in the output array is undefined.

Parameters

kth
[int or sequence of ints] Element index to partition by. The kth element value will be in its final sorted position and all smaller elements will be moved before it and all equal or greater elements behind it. The order of all elements in the partitions is undefined. If provided with a sequence of kth it will partition all elements indexed by kth of them into their sorted position at once.

Deprecated since version 1.22.0: Passing booleans as index is deprecated.

axis
[int, optional] Axis along which to sort. Default is -1, which means sort along the last axis.

kind
[{'introselect'}, optional] Selection algorithm. Default is 'introselect'.

order
[str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need to be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

See also:

numpy.partition
Return a partitioned copy of an array.

argpartition
Indirect partition.

sort
Full sort.

Notes

See `np.partition` for notes on the different algorithms.

Examples

```
>>> import numpy as np
>>> a = np.array([3, 4, 2, 1])
>>> a.partition(3)
>>> a
array([2, 1, 3, 4]) # may vary
```

```
>>> a.partition((1, 3))
>>> a
array([1, 2, 3, 4])
```

method

`matrix.`**`prod`**(*axis=None*, *dtype=None*, *out=None*)

Return the product of the array elements over the given axis.

Refer to *prod* for full documentation.

See also:

prod*, *ndarray.prod

Notes

Same as *ndarray.prod*, except, where that returns an *ndarray*, this returns a *matrix* object instead.

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.prod()
0
>>> x.prod(0)
matrix([[  0,  45, 120, 231]])
>>> x.prod(1)
matrix([[   0],
        [ 840],
        [7920]])
```

method

matrix.**ptp**(*axis=None*, *out=None*)

Peak-to-peak (maximum - minimum) value along the given axis.

Refer to *numpy.ptp* for full documentation.

See also:

numpy.ptp

Notes

Same as ndarray.ptp, except, where that would return an *ndarray* object, this returns a *matrix* object.

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.ptp()
11
>>> x.ptp(0)
matrix([[8, 8, 8, 8]])
>>> x.ptp(1)
matrix([[3],
        [3],
        [3]])
```

method

matrix.**put**(*indices*, *values*, *mode='raise'*)

Set `a.flat[n] = values[n]` for all *n* in indices.

Refer to *numpy.put* for full documentation.

See also:

numpy.put
equivalent function

method

matrix.**ravel**(*order='C'*)

Return a flattened matrix.

Refer to *numpy.ravel* for more documentation.

Parameters

order
[{'C', 'F', 'A', 'K'}, optional] The elements of *m* are read using this index order. 'C' means to index the elements in C-like order, with the last axis index changing fastest, back to the first axis index changing slowest. 'F' means to index the elements in Fortran-like index order, with the first index changing fastest, and the last index changing slowest. Note that the 'C'

and 'F' options take no account of the memory layout of the underlying array, and only refer to the order of axis indexing. 'A' means to read the elements in Fortran-like index order if *m* is Fortran *contiguous* in memory, C-like order otherwise. 'K' means to read the elements in the order they occur in memory, except for reversing the data when strides are negative. By default, 'C' index order is used.

Returns

ret
[matrix] Return the matrix flattened to shape *(1, N)* where *N* is the number of elements in the original matrix. A copy is made only if necessary.

See also:

matrix.flatten
returns a similar output matrix but always a copy

matrix.flat
a flat iterator on the array.

numpy.ravel
related function which returns an ndarray

method

`matrix.`**`repeat`**(*repeats*, *axis=None*)

Repeat elements of an array.

Refer to *numpy.repeat* for full documentation.

See also:

numpy.repeat
equivalent function

method

`matrix.`**`reshape`**(*shape*, */*, *, *order='C'*, *copy=None*)

Returns an array containing the same data with a new shape.

Refer to *numpy.reshape* for full documentation.

See also:

numpy.reshape
equivalent function

Notes

Unlike the free function *numpy.reshape*, this method on *ndarray* allows the elements of the shape parameter to be passed in as separate arguments. For example, `a.reshape(10, 11)` is equivalent to `a.reshape((10, 11))`.

method

`matrix.`**`resize`**(*new_shape*, *refcheck=True*)

Change shape and size of array in-place.

Parameters

new_shape
[tuple of ints, or *n* ints] Shape of resized array.

refcheck
[bool, optional] If False, reference count will not be checked. Default is True.

Returns

None

Raises

ValueError
If *a* does not own its own data or references or views to it exist, and the data memory must be changed. PyPy only: will always raise if the data memory must be changed, since there is no reliable way to determine if references or views to it exist.

SystemError
If the *order* keyword argument is specified. This behaviour is a bug in NumPy.

See also:

resize
Return a new array with the specified shape.

Notes

This reallocates space for the data area if necessary.

Only contiguous arrays (data elements consecutive in memory) can be resized.

The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set *refcheck* to False.

Examples

Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and reshaped:

```
>>> import numpy as np
```

```
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
>>> a
array([[0],
       [1]])
```

```
>>> a = np.array([[0, 1], [2, 3]], order='F')
>>> a.resize((2, 1))
>>> a
array([[0],
       [2]])
```

Enlarging an array: as above, but missing entries are filled with zeros:

```
>>> b = np.array([[0, 1], [2, 3]])
>>> b.resize(2, 3) # new_shape parameter doesn't have to be a tuple
>>> b
array([[0, 1, 2],
       [3, 0, 0]])
```

Referencing an array prevents resizing…

```
>>> c = a
>>> a.resize((1, 1))
Traceback (most recent call last):
...
ValueError: cannot resize an array that references or is referenced ...
```

Unless *refcheck* is False:

```
>>> a.resize((1, 1), refcheck=False)
>>> a
array([[0]])
>>> c
array([[0]])
```

method

`matrix.`**`round`**(*decimals=0*, *out=None*)

Return *a* with each element rounded to the given number of decimals.

Refer to *numpy.around* for full documentation.

See also:

numpy.around
equivalent function

method

`matrix.`**`searchsorted`**(*v*, *side='left'*, *sorter=None*)

Find indices where elements of v should be inserted in a to maintain order.

For full documentation, see *numpy.searchsorted*

See also:

numpy.searchsorted
equivalent function

method

`matrix.`**`setfield`**(*val*, *dtype*, *offset=0*)

Put a value into a specified place in a field defined by a data-type.

Place *val* into *a*'s field defined by *dtype* and beginning *offset* bytes into the field.

Parameters

val
[object] Value to be placed in field.

dtype
[dtype object] Data-type of the field in which to place *val*.

offset
[int, optional] The number of bytes into the field at which to place *val*.

Returns

None

See also:

getfield

Examples

```
>>> import numpy as np
>>> x = np.eye(3)
>>> x.getfield(np.float64)
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
>>> x.setfield(3, np.int32)
>>> x.getfield(np.int32)
array([[3, 3, 3],
       [3, 3, 3],
       [3, 3, 3]], dtype=int32)
>>> x
array([[1.0e+000, 1.5e-323, 1.5e-323],
       [1.5e-323, 1.0e+000, 1.5e-323],
       [1.5e-323, 1.5e-323, 1.0e+000]])
>>> x.setfield(np.eye(3), np.int32)
>>> x
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
```

method

`matrix.`**`setflags`**(*write=None*, *align=None*, *uic=None*)

Set array flags WRITEABLE, ALIGNED, WRITEBACKIFCOPY, respectively.

These Boolean-valued flags affect how numpy interprets the memory area used by *a* (see Notes below). The ALIGNED flag can only be set to True if the data is actually aligned according to the type. The WRITEBACKIFCOPY flag can never be set to True. The flag WRITEABLE can only be set to True if the array owns its own memory, or the ultimate owner of the memory exposes a writeable buffer interface, or is a string. (The exception for string is made so that unpickling can be done without copying memory.)

Parameters

write
[bool, optional] Describes whether or not *a* can be written to.

align
[bool, optional] Describes whether or not *a* is aligned properly for its type.

uic
[bool, optional] Describes whether or not *a* is a copy of another "base" array.

Notes

Array flags provide information about how the memory area used for the array is to be interpreted. There are 7 Boolean flags in use, only three of which can be changed by the user: WRITEBACKIFCOPY, WRITEABLE, and ALIGNED.

WRITEABLE (W) the data area can be written to;

ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);

WRITEBACKIFCOPY (X) this array is a copy of some other array (referenced by .base). When the C-API function PyArray_ResolveWritebackIfCopy is called, the base array will be updated with the contents of this array.

All flags can be accessed using the single (upper case) letter as well as the full name.

Examples

```
>>> import numpy as np
>>> y = np.array([[3, 1, 7],
...               [2, 0, 0],
...               [8, 5, 9]])
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
>>> y.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
  OWNDATA : True
  WRITEABLE : True
  ALIGNED : True
  WRITEBACKIFCOPY : False
>>> y.setflags(write=0, align=0)
>>> y.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
  OWNDATA : True
  WRITEABLE : False
  ALIGNED : False
  WRITEBACKIFCOPY : False
>>> y.setflags(uic=1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set WRITEBACKIFCOPY flag to True
```

method

`matrix.sort`(*axis=-1*, *kind=None*, *order=None*)

Sort an array in-place. Refer to *numpy.sort* for full documentation.

Parameters

axis
[int, optional] Axis along which to sort. Default is -1, which means sort along the last axis.

kind
[{'quicksort', 'mergesort', 'heapsort', 'stable'}, optional] Sorting algorithm. The default is

'quicksort'. Note that both 'stable' and 'mergesort' use timsort under the covers and, in general, the actual implementation will vary with datatype. The 'mergesort' option is retained for backwards compatibility.

order
[str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

See also:

numpy.sort
Return a sorted copy of an array.

numpy.argsort
Indirect sort.

numpy.lexsort
Indirect stable sort on multiple keys.

numpy.searchsorted
Find elements in sorted array.

numpy.partition
Partial sort.

Notes

See *numpy.sort* for notes on the different sorting algorithms.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,4], [3,1]])
>>> a.sort(axis=1)
>>> a
array([[1, 4],
       [1, 3]])
>>> a.sort(axis=0)
>>> a
array([[1, 3],
       [1, 4]])
```

Use the *order* keyword to specify a field to use when sorting a structured array:

```
>>> a = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
>>> a.sort(order='y')
>>> a
array([(b'c', 1), (b'a', 2)],
      dtype=[('x', 'S1'), ('y', '<i8')])
```

method

matrix.**squeeze**(*axis=None*)

Return a possibly reshaped matrix.

Refer to *numpy.squeeze* for more documentation.

Parameters

axis
[None or int or tuple of ints, optional] Selects a subset of the axes of length one in the shape. If an axis is selected with shape entry greater than one, an error is raised.

Returns

squeezed
[matrix] The matrix, but as a (1, N) matrix if it had shape (N, 1).

See also:

numpy.squeeze
related function

Notes

If *m* has a single column then that column is returned as the single row of a matrix. Otherwise *m* is returned. The returned matrix is always either *m* itself or a view into *m*. Supplying an axis keyword argument will not affect the returned matrix but it may cause an error to be raised.

Examples

```
>>> c = np.matrix([[1], [2]])
>>> c
matrix([[1],
        [2]])
>>> c.squeeze()
matrix([[1, 2]])
>>> r = c.T
>>> r
matrix([[1, 2]])
>>> r.squeeze()
matrix([[1, 2]])
>>> m = np.matrix([[1, 2], [3, 4]])
>>> m.squeeze()
matrix([[1, 2],
        [3, 4]])
```

method

matrix.**std**(*axis=None*, *dtype=None*, *out=None*, *ddof=0*)

Return the standard deviation of the array elements along the given axis.

Refer to *numpy.std* for full documentation.

See also:

numpy.std

Notes

This is the same as *ndarray.std*, except that where an *ndarray* would be returned, a *matrix* object is returned instead.

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3, 4)))
>>> x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.std()
3.4520525295346629 # may vary
>>> x.std(0)
matrix([[ 3.26598632,  3.26598632,  3.26598632,  3.26598632]]) # may vary
>>> x.std(1)
matrix([[ 1.11803399],
        [ 1.11803399],
        [ 1.11803399]])
```

method

matrix.**sum**(*axis=None*, *dtype=None*, *out=None*)

Returns the sum of the matrix elements, along the given axis.

Refer to *numpy.sum* for full documentation.

See also:

numpy.sum

Notes

This is the same as *ndarray.sum*, except that where an *ndarray* would be returned, a *matrix* object is returned instead.

Examples

```
>>> x = np.matrix([[1, 2], [4, 3]])
>>> x.sum()
10
>>> x.sum(axis=1)
matrix([[3],
        [7]])
>>> x.sum(axis=1, dtype='float')
matrix([[3.],
        [7.]])
>>> out = np.zeros((2, 1), dtype='float')
>>> x.sum(axis=1, dtype='float', out=np.asmatrix(out))
matrix([[3.],
        [7.]])
```

method

matrix.**swapaxes**(*axis1*, *axis2*)

Return a view of the array with *axis1* and *axis2* interchanged.

Refer to *numpy.swapaxes* for full documentation.

See also:

numpy.swapaxes
equivalent function

method

matrix.**take**(*indices*, *axis=None*, *out=None*, *mode='raise'*)

Return an array formed from the elements of *a* at the given indices.

Refer to *numpy.take* for full documentation.

See also:

numpy.take
equivalent function

method

matrix.**tobytes**(*order='C'*)

Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object is produced in C-order by default. This behavior is controlled by the `order` parameter.

Parameters

order
[{'C', 'F', 'A'}, optional] Controls the memory layout of the bytes object. 'C' means C-order, 'F' means F-order, 'A' (short for *Any*) means 'F' if *a* is Fortran contiguous, 'C' otherwise. Default is 'C'.

Returns

s
[bytes] Python bytes exhibiting a copy of *a*'s raw data.

See also:

frombuffer
Inverse of this operation, construct a 1-dimensional array from Python bytes.

Examples

```
>>> import numpy as np
>>> x = np.array([[0, 1], [2, 3]], dtype='<u2')
>>> x.tobytes()
b'\x00\x00\x01\x00\x02\x00\x03\x00'
>>> x.tobytes('C') == x.tobytes()
True
>>> x.tobytes('F')
b'\x00\x00\x02\x00\x01\x00\x03\x00'
```

method

matrix.**tofile**(*fid*, *sep=''*, *format='%s'*)

Write array to a file as text or binary (default).

Data is always written in 'C' order, independent of the order of *a*. The data produced by this method can be recovered using the function fromfile().

Parameters

fid
[file or str or Path] An open file object, or a string containing a filename.

sep
[str] Separator between array items for text output. If "" (empty), a binary file is written, equivalent to `file.write(a.tobytes())`.

format
[str] Format string for text file output. Each entry in the array is formatted to text by first converting it to the closest Python type, and then using "format" % item.

Notes

This is a convenience function for quick storage of array data. Information on endianness and precision is lost, so this method is not a good choice for files intended to archive data or transport data between machines with different endianness. Some of these problems can be overcome by outputting the data as text files, at the expense of speed and file size.

When fid is a file object, array contents are directly written to the file, bypassing the file object's `write` method. As a result, tofile cannot be used with files objects supporting compression (e.g., GzipFile) or file-like objects that do not support `fileno()` (e.g., BytesIO).

method

matrix.**tolist**()

Return the matrix as a (possibly nested) list.

See *ndarray.tolist* for full documentation.

See also:

ndarray.tolist

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3,4))); x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.tolist()
[[0, 1, 2, 3], [4, 5, 6, 7], [8, 9, 10, 11]]
```

method

matrix.**tostring**(*order='C'*)

A compatibility alias for *tobytes*, with exactly the same behavior.

Despite its name, it returns `bytes` not `str`s.

Deprecated since version 1.19.0.

method

matrix.**trace**(*offset=0*, *axis1=0*, *axis2=1*, *dtype=None*, *out=None*)

Return the sum along diagonals of the array.

Refer to *numpy.trace* for full documentation.

See also:

numpy.trace
equivalent function

method

matrix.**transpose**(**axes*)

Returns a view of the array with axes transposed.

Refer to *numpy.transpose* for full documentation.

Parameters

axes
[None, tuple of ints, or *n* ints]

- None or no argument: reverses the order of the axes.
- tuple of ints: *i* in the *j*-th place in the tuple means that the array's *i*-th axis becomes the transposed array's *j*-th axis.
- *n* ints: same as an n-tuple of the same ints (this form is intended simply as a "convenience" alternative to the tuple form).

Returns

p
[ndarray] View of the array with its axes suitably permuted.

See also:

transpose
Equivalent function.

ndarray.T
Array property returning the array transposed.

ndarray.reshape
Give a new shape to an array without changing its data.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
```

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```
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

```
>>> a = np.array([1, 2, 3, 4])
>>> a
array([1, 2, 3, 4])
>>> a.transpose()
array([1, 2, 3, 4])
```

method

`matrix.`**`var`**(*axis=None*, *dtype=None*, *out=None*, *ddof=0*)

Returns the variance of the matrix elements, along the given axis.

Refer to *numpy.var* for full documentation.

See also:

numpy.var

Notes

This is the same as *ndarray.var*, except that where an *ndarray* would be returned, a *matrix* object is returned instead.

Examples

```
>>> x = np.matrix(np.arange(12).reshape((3, 4)))
>>> x
matrix([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]])
>>> x.var()
11.916666666666666
>>> x.var(0)
matrix([[ 10.66666667,  10.66666667,  10.66666667,  10.66666667]]) # may vary
>>> x.var(1)
matrix([[1.25],
        [1.25],
        [1.25]])
```

method

`matrix.`**`view`**(*[dtype][, type]*)

New view of array with the same data.

Note: Passing None for `dtype` is different from omitting the parameter, since the former invokes `dtype(None)` which is an alias for `dtype('float64')`.

Parameters

dtype
: [data-type or ndarray sub-class, optional] Data-type descriptor of the returned view, e.g., float32 or int16. Omitting it results in the view having the same data-type as *a*. This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the `type` parameter).

type
: [Python type, optional] Type of the returned view, e.g., ndarray or matrix. Again, omission of the parameter results in type preservation.

Notes

`a.view()` is used two different ways:

`a.view(some_dtype)` or `a.view(dtype=some_dtype)` constructs a view of the array's memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

`a.view(ndarray_subclass)` or `a.view(type=ndarray_subclass)` just returns an instance of *ndarray_subclass* that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For `a.view(some_dtype)`, if `some_dtype` has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the last axis of `a` must be contiguous. This axis will be resized in the result.

Changed in version 1.23.0: Only the last axis needs to be contiguous. Previously, the entire array had to be C-contiguous.

Examples

```
>>> import numpy as np
>>> x = np.array([(-1, 2)], dtype=[('a', np.int8), ('b', np.int8)])
```

Viewing array data using a different type and dtype:

```
>>> nonneg = np.dtype([("a", np.uint8), ("b", np.uint8)])
>>> y = x.view(dtype=nonneg, type=np.recarray)
>>> x["a"]
array([-1], dtype=int8)
>>> y.a
array([255], dtype=uint8)
```

Creating a view on a structured array so it can be used in calculations

```
>>> x = np.array([(1, 2),(3,4)], dtype=[('a', np.int8), ('b', np.int8)])
>>> xv = x.view(dtype=np.int8).reshape(-1,2)
>>> xv
array([[1, 2],
       [3, 4]], dtype=int8)
>>> xv.mean(0)
array([2.,  3.])
```

Making changes to the view changes the underlying array

```
>>> xv[0,1] = 20
>>> x
array([(1, 20), (3,  4)], dtype=[('a', 'i1'), ('b', 'i1')])
```

Using a view to convert an array to a recarray:

```
>>> z = x.view(np.recarray)
>>> z.a
array([1, 3], dtype=int8)
```

Views share data:

```
>>> x[0] = (9, 10)
>>> z[0]
np.record((9, 10), dtype=[('a', 'i1'), ('b', 'i1')])
```

Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.:

```
>>> x = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.int16)
>>> y = x[:, ::2]
>>> y
array([[1, 3],
       [4, 6]], dtype=int16)
>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
    ...
ValueError: To change to a dtype of a different size, the last axis must be␣
↪contiguous
>>> z = y.copy()
>>> z.view(dtype=[('width', np.int16), ('length', np.int16)])
array([[(1, 3)],
       [(4, 6)]], dtype=[('width', '<i2'), ('length', '<i2')])
```

However, views that change dtype are totally fine for arrays with a contiguous last axis, even if the rest of the axes are not C-contiguous:

```
>>> x = np.arange(2 * 3 * 4, dtype=np.int8).reshape(2, 3, 4)
>>> x.transpose(1, 0, 2).view(np.int16)
array([[[ 256,  770],
        [3340, 3854]],

       [[1284, 1798],
        [4368, 4882]],

       [[2312, 2826],
        [5396, 5910]]], dtype=int16)
```

dot
to_device

numpy.**asmatrix**(*data*, *dtype=None*)

Interpret the input as a matrix.

Unlike *matrix*, *asmatrix* does not make a copy if the input is already a matrix or an ndarray. Equivalent to `matrix(data, copy=False)`.

Parameters

data
[array_like] Input data.

dtype
[data-type] Data-type of the output matrix.

Returns

mat
[matrix] *data* interpreted as a matrix.

Examples

```
>>> import numpy as np
>>> x = np.array([[1, 2], [3, 4]])
```

```
>>> m = np.asmatrix(x)
```

```
>>> x[0,0] = 5
```

```
>>> m
matrix([[5, 2],
        [3, 4]])
```

numpy.**bmat**(*obj*, *ldict=None*, *gdict=None*)

Build a matrix object from a string, nested sequence, or array.

Parameters

obj
[str or array_like] Input data. If a string, variables in the current scope may be referenced by name.

ldict
[dict, optional] A dictionary that replaces local operands in current frame. Ignored if *obj* is not a string or *gdict* is None.

gdict
[dict, optional] A dictionary that replaces global operands in current frame. Ignored if *obj* is not a string.

Returns

out
[matrix] Returns a matrix object, which is a specialized 2-D array.

See also:

block
A generalization of this function for N-d arrays, that returns normal ndarrays.

Examples

```
>>> import numpy as np
>>> A = np.asmatrix('1 1; 1 1')
>>> B = np.asmatrix('2 2; 2 2')
>>> C = np.asmatrix('3 4; 5 6')
>>> D = np.asmatrix('7 8; 9 0')
```

All the following expressions construct the same block matrix:

```
>>> np.bmat([[A, B], [C, D]])
matrix([[1, 1, 2, 2],
        [1, 1, 2, 2],
        [3, 4, 7, 8],
        [5, 6, 9, 0]])
>>> np.bmat(np.r_[np.c_[A, B], np.c_[C, D]])
matrix([[1, 1, 2, 2],
        [1, 1, 2, 2],
        [3, 4, 7, 8],
        [5, 6, 9, 0]])
>>> np.bmat('A,B; C,D')
matrix([[1, 1, 2, 2],
        [1, 1, 2, 2],
        [3, 4, 7, 8],
        [5, 6, 9, 0]])
```

Example 1: Matrix creation from a string

```
>>> import numpy as np
>>> a = np.asmatrix('1 2 3; 4 5 3')
>>> print((a*a.T).I)
  [[ 0.29239766 -0.13450292]
   [-0.13450292  0.08187135]]
```

Example 2: Matrix creation from a nested sequence

```
>>> import numpy as np
>>> np.asmatrix([[1,5,10],[1.0,3,4j]])
matrix([[  1.+0.j,   5.+0.j,  10.+0.j],
        [  1.+0.j,   3.+0.j,   0.+4.j]])
```

Example 3: Matrix creation from an array

```
>>> import numpy as np
>>> np.asmatrix(np.random.rand(3,3)).T
matrix([[4.17022005e-01, 3.02332573e-01, 1.86260211e-01],
        [7.20324493e-01, 1.46755891e-01, 3.45560727e-01],
        [1.14374817e-04, 9.23385948e-02, 3.96767474e-01]])
```

Memory-mapped file arrays

Memory-mapped files are useful for reading and/or modifying small segments of a large file with regular layout, without reading the entire file into memory. A simple subclass of the ndarray uses a memory-mapped file for the data buffer of the array. For small files, the over-head of reading the entire file into memory is typically not significant, however for large files using memory mapping can save considerable resources.

Memory-mapped-file arrays have one additional method (besides those they inherit from the ndarray): *.flush()* which must be called manually by the user to ensure that any changes to the array actually get written to disk.

memmap(filename[, dtype, mode, offset, ...])	Create a memory-map to an array stored in a *binary* file on disk.
memmap.flush()	Write any changes in the array to the file on disk.

class numpy.**memmap**(*filename*, *dtype=<class 'numpy.ubyte'>*, *mode='r+'*, *offset=0*, *shape=None*, *order='C'*)

Create a memory-map to an array stored in a *binary* file on disk.

Memory-mapped files are used for accessing small segments of large files on disk, without reading the entire file into memory. NumPy's memmap's are array-like objects. This differs from Python's `mmap` module, which uses file-like objects.

This subclass of ndarray has some unpleasant interactions with some operations, because it doesn't quite fit properly as a subclass. An alternative to using this subclass is to create the `mmap` object yourself, then create an ndarray with ndarray.__new__ directly, passing the object created in its 'buffer=' parameter.

This class may at some point be turned into a factory function which returns a view into an mmap buffer.

Flush the memmap instance to write the changes to the file. Currently there is no API to close the underlying `mmap`. It is tricky to ensure the resource is actually closed, since it may be shared between different memmap instances.

Parameters

filename
[str, file-like object, or pathlib.Path instance] The file name or file object to be used as the array data buffer.

dtype
[data-type, optional] The data-type used to interpret the file contents. Default is *uint8*.

mode
[{'r+', 'r', 'w+', 'c'}, optional] The file is opened in this mode:

'r'	Open existing file for reading only.
'r+'	Open existing file for reading and writing.
'w+'	Create or overwrite existing file for reading and writing. If `mode == 'w+'` then *shape* must also be specified.
'c'	Copy-on-write: assignments affect data in memory, but changes are not saved to disk. The file on disk is read-only.

Default is 'r+'.

offset
[int, optional] In the file, array data starts at this offset. Since *offset* is measured in bytes, it should normally be a multiple of the byte-size of *dtype*. When `mode != 'r'`, even positive offsets beyond end of file are valid; The file will be extended to accommodate the additional data. By default, `memmap` will start at the beginning of the file, even if `filename` is a file pointer `fp` and `fp.tell() != 0`.

shape
: [int or sequence of ints, optional] The desired shape of the array. If `mode == 'r'` and the number of remaining bytes after *offset* is not a multiple of the byte-size of *dtype*, you must specify *shape*. By default, the returned array will be 1-D with the number of elements determined by file size and data-type.

  Changed in version 2.0: The shape parameter can now be any integer sequence type, previously types were limited to tuple and int.

order
: [{'C', 'F'}, optional] Specify the order of the ndarray memory layout: row-major, C-style or column-major, Fortran-style. This only has an effect if the shape is greater than 1-D. The default order is 'C'.

See also:

lib.format.open_memmap
: Create or load a memory-mapped `.npy` file.

Notes

The memmap object can be used anywhere an ndarray is accepted. Given a memmap `fp`, `isinstance(fp, numpy.ndarray)` returns `True`.

Memory-mapped files cannot be larger than 2GB on 32-bit systems.

When a memmap causes a file to be created or extended beyond its current size in the filesystem, the contents of the new part are unspecified. On systems with POSIX filesystem semantics, the extended part will be filled with zero bytes.

Examples

```
>>> import numpy as np
>>> data = np.arange(12, dtype='float32')
>>> data.resize((3,4))
```

This example uses a temporary file so that doctest doesn't write files to your directory. You would use a 'normal' filename.

```
>>> from tempfile import mkdtemp
>>> import os.path as path
>>> filename = path.join(mkdtemp(), 'newfile.dat')
```

Create a memmap with dtype and shape that matches our data:

```
>>> fp = np.memmap(filename, dtype='float32', mode='w+', shape=(3,4))
>>> fp
memmap([[0., 0., 0., 0.],
        [0., 0., 0., 0.],
        [0., 0., 0., 0.]], dtype=float32)
```

Write data to memmap array:

```
>>> fp[:] = data[:]
>>> fp
memmap([[  0.,   1.,   2.,   3.],
```

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```
        [  4.,   5.,   6.,   7.],
        [  8.,   9.,  10.,  11.]], dtype=float32)
```

```
>>> fp.filename == path.abspath(filename)
True
```

Flushes memory changes to disk in order to read them back

```
>>> fp.flush()
```

Load the memmap and verify data was stored:

```
>>> newfp = np.memmap(filename, dtype='float32', mode='r', shape=(3,4))
>>> newfp
memmap([[  0.,   1.,   2.,   3.],
        [  4.,   5.,   6.,   7.],
        [  8.,   9.,  10.,  11.]], dtype=float32)
```

Read-only memmap:

```
>>> fpr = np.memmap(filename, dtype='float32', mode='r', shape=(3,4))
>>> fpr.flags.writeable
False
```

Copy-on-write memmap:

```
>>> fpc = np.memmap(filename, dtype='float32', mode='c', shape=(3,4))
>>> fpc.flags.writeable
True
```

It's possible to assign to copy-on-write array, but values are only written into the memory copy of the array, and not written to disk:

```
>>> fpc
memmap([[  0.,   1.,   2.,   3.],
        [  4.,   5.,   6.,   7.],
        [  8.,   9.,  10.,  11.]], dtype=float32)
>>> fpc[0,:] = 0
>>> fpc
memmap([[  0.,   0.,   0.,   0.],
        [  4.,   5.,   6.,   7.],
        [  8.,   9.,  10.,  11.]], dtype=float32)
```

File on disk is unchanged:

```
>>> fpr
memmap([[  0.,   1.,   2.,   3.],
        [  4.,   5.,   6.,   7.],
        [  8.,   9.,  10.,  11.]], dtype=float32)
```

Offset into a memmap:

```
>>> fpo = np.memmap(filename, dtype='float32', mode='r', offset=16)
>>> fpo
memmap([  4.,   5.,   6.,   7.,   8.,   9.,  10.,  11.], dtype=float32)
```

Attributes

filename
[str or pathlib.Path instance] Path to the mapped file.

offset
[int] Offset position in the file.

mode
[str] File mode.

Methods

flush()	Write any changes in the array to the file on disk.

method

memmap.**flush**()

Write any changes in the array to the file on disk.

For further information, see *memmap*.

Parameters

None

See also:

memmap

Example:

```
>>> import numpy as np
```

```
>>> a = np.memmap('newfile.dat', dtype=float, mode='w+', shape=1000)
>>> a[10] = 10.0
>>> a[30] = 30.0
>>> del a
```

```
>>> b = np.fromfile('newfile.dat', dtype=float)
>>> print(b[10], b[30])
10.0 30.0
```

```
>>> a = np.memmap('newfile.dat', dtype=float)
>>> print(a[10], a[30])
10.0 30.0
```

Character arrays (`numpy.char`)

See also:

Creating character arrays (numpy.char)

Note: The `chararray` class exists for backwards compatibility with Numarray, it is not recommended for new development. Starting from numpy 1.4, if one needs arrays of strings, it is recommended to use arrays of `dtype object_`, `bytes_` or `str_`, and use the free functions in the `numpy.char` module for fast vectorized string operations.

These are enhanced arrays of either `str_` type or `bytes_` type. These arrays inherit from the `ndarray`, but specially-define the operations `+`, `*`, and `%` on a (broadcasting) element-by-element basis. These operations are not available on the standard `ndarray` of character type. In addition, the `chararray` has all of the standard `str` (and `bytes`) methods, executing them on an element-by-element basis. Perhaps the easiest way to create a chararray is to use `self.view(chararray)` where *self* is an ndarray of str or unicode data-type. However, a chararray can also be created using the `chararray` constructor, or via the `numpy.char.array` function:

`char.chararray`(shape[, itemsize, unicode, ...])	Provides a convenient view on arrays of string and unicode values.
`char.array`(obj[, itemsize, copy, unicode, order])	Create a `chararray`.

Another difference with the standard ndarray of str data-type is that the chararray inherits the feature introduced by Numarray that white-space at the end of any element in the array will be ignored on item retrieval and comparison operations.

Record arrays

See also:

Creating record arrays, *Data type routines*, *Data type objects (dtype)*.

NumPy provides the `recarray` class which allows accessing the fields of a structured array as attributes, and a corresponding scalar data type object `record`.

`recarray`(shape[, dtype, buf, offset, ...])	Construct an ndarray that allows field access using attributes.
`record`	A data-type scalar that allows field access as attribute lookup.

class numpy.**recarray**(*shape*, *dtype=None*, *buf=None*, *offset=0*, *strides=None*, *formats=None*, *names=None*, *titles=None*, *byteorder=None*, *aligned=False*, *order='C'*)

Construct an ndarray that allows field access using attributes.

Arrays may have a data-types containing fields, analogous to columns in a spread sheet. An example is `[(x, int), (y, float)]`, where each entry in the array is a pair of `(int, float)`. Normally, these attributes are accessed using dictionary lookups such as `arr['x']` and `arr['y']`. Record arrays allow the fields to be accessed as members of the array, using `arr.x` and `arr.y`.

Parameters

shape
[tuple] Shape of output array.

dtype
: [data-type, optional] The desired data-type. By default, the data-type is determined from *formats*, *names*, *titles*, *aligned* and *byteorder*.

formats
: [list of data-types, optional] A list containing the data-types for the different columns, e.g. `['i4', 'f8', 'i4']`. *formats* does *not* support the new convention of using types directly, i.e. `(int, float, int)`. Note that *formats* must be a list, not a tuple. Given that *formats* is somewhat limited, we recommend specifying *dtype* instead.

names
: [tuple of str, optional] The name of each column, e.g. `('x', 'y', 'z')`.

buf
: [buffer, optional] By default, a new array is created of the given shape and data-type. If *buf* is specified and is an object exposing the buffer interface, the array will use the memory from the existing buffer. In this case, the *offset* and `strides` keywords are available.

Returns

rec
: [recarray] Empty array of the given shape and type.

Other Parameters

titles
: [tuple of str, optional] Aliases for column names. For example, if *names* were `('x', 'y', 'z')` and *titles* is `('x_coordinate', 'y_coordinate', 'z_coordinate')`, then `arr['x']` is equivalent to both `arr.x` and `arr.x_coordinate`.

byteorder
: [{'<', '>', '='}, optional] Byte-order for all fields.

aligned
: [bool, optional] Align the fields in memory as the C-compiler would.

strides
: [tuple of ints, optional] Buffer (*buf*) is interpreted according to these strides (strides define how many bytes each array element, row, column, etc. occupy in memory).

offset
: [int, optional] Start reading buffer (*buf*) from this offset onwards.

order
: [{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

numpy.rec.fromrecords
: Construct a record array from data.

numpy.record
: fundamental data-type for *recarray*.

numpy.rec.format_parser
: determine data-type from formats, names, titles.

Notes

This constructor can be compared to `empty`: it creates a new record array but does not fill it with data. To create a record array from data, use one of the following methods:

1. Create a standard ndarray and convert it to a record array, using `arr.view(np.recarray)`
2. Use the *buf* keyword.
3. Use *np.rec.fromrecords*.

Examples

Create an array with two fields, `x` and `y`:

```
>>> import numpy as np
>>> x = np.array([(1.0, 2), (3.0, 4)], dtype=[('x', '<f8'), ('y', '<i8')])
>>> x
array([(1., 2), (3., 4)], dtype=[('x', '<f8'), ('y', '<i8')])
```

```
>>> x['x']
array([1., 3.])
```

View the array as a record array:

```
>>> x = x.view(np.recarray)
```

```
>>> x.x
array([1., 3.])
```

```
>>> x.y
array([2, 4])
```

Create a new, empty record array:

```
>>> np.recarray((2,),
... dtype=[('x', int), ('y', float), ('z', int)])
rec.array([(-1073741821, 1.2249118382103472e-301, 24547520),
       (3471280, 1.2134086255804012e-316, 0)],
      dtype=[('x', '<i4'), ('y', '<f8'), ('z', '<i4')])
```

Attributes

T
View of the transposed array.

base
Base object if memory is from some other object.

ctypes
An object to simplify the interaction of the array with the ctypes module.

data
Python buffer object pointing to the start of the array's data.

device

dtype
Data-type of the array's elements.

flags
Information about the memory layout of the array.

flat
A 1-D iterator over the array.

imag
The imaginary part of the array.

itemset
itemsize
Length of one array element in bytes.

mT
View of the matrix transposed array.

nbytes
Total bytes consumed by the elements of the array.

ndim
Number of array dimensions.

newbyteorder
ptp
real
The real part of the array.

shape
Tuple of array dimensions.

size
Number of elements in the array.

strides
Tuple of bytes to step in each dimension when traversing an array.

Methods

all([axis, out, keepdims, where])	Returns True if all elements evaluate to True.
any([axis, out, keepdims, where])	Returns True if any of the elements of *a* evaluate to True.
argmax([axis, out, keepdims])	Return indices of the maximum values along the given axis.
argmin([axis, out, keepdims])	Return indices of the minimum values along the given axis.
argpartition(kth[, axis, kind, order])	Returns the indices that would partition this array.
argsort([axis, kind, order])	Returns the indices that would sort this array.
astype(dtype[, order, casting, subok, copy])	Copy of the array, cast to a specified type.
byteswap([inplace])	Swap the bytes of the array elements
choose(choices[, out, mode])	Use an index array to construct a new array from a set of choices.
clip([min, max, out])	Return an array whose values are limited to `[min, max]`.
compress(condition[, axis, out])	Return selected slices of this array along given axis.
conj()	Complex-conjugate all elements.
conjugate()	Return the complex conjugate, element-wise.

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`copy`([order])	Return a copy of the array.
`cumprod`([axis, dtype, out])	Return the cumulative product of the elements along the given axis.
`cumsum`([axis, dtype, out])	Return the cumulative sum of the elements along the given axis.
`diagonal`([offset, axis1, axis2])	Return specified diagonals.
`dump`(file)	Dump a pickle of the array to the specified file.
`dumps`()	Returns the pickle of the array as a string.
`fill`(value)	Fill the array with a scalar value.
`flatten`([order])	Return a copy of the array collapsed into one dimension.
`getfield`(dtype[, offset])	Returns a field of the given array as a certain type.
`item`(*args)	Copy an element of an array to a standard Python scalar and return it.
`max`([axis, out, keepdims, initial, where])	Return the maximum along a given axis.
`mean`([axis, dtype, out, keepdims, where])	Returns the average of the array elements along given axis.
`min`([axis, out, keepdims, initial, where])	Return the minimum along a given axis.
`nonzero`()	Return the indices of the elements that are non-zero.
`partition`(kth[, axis, kind, order])	Partially sorts the elements in the array in such a way that the value of the element in k-th position is in the position it would be in a sorted array.
`prod`([axis, dtype, out, keepdims, initial, ...])	Return the product of the array elements over the given axis
`put`(indices, values[, mode])	Set `a.flat[n] = values[n]` for all *n* in indices.
`ravel`([order])	Return a flattened array.
`repeat`(repeats[, axis])	Repeat elements of an array.
`reshape`(shape, /, *[, order, copy])	Returns an array containing the same data with a new shape.
`resize`(new_shape[, refcheck])	Change shape and size of array in-place.
`round`([decimals, out])	Return *a* with each element rounded to the given number of decimals.
`searchsorted`(v[, side, sorter])	Find indices where elements of v should be inserted in a to maintain order.
`setfield`(val, dtype[, offset])	Put a value into a specified place in a field defined by a data-type.
`setflags`([write, align, uic])	Set array flags WRITEABLE, ALIGNED, WRITEBACKIFCOPY, respectively.
`sort`([axis, kind, order])	Sort an array in-place.
`squeeze`([axis])	Remove axes of length one from *a*.
`std`([axis, dtype, out, ddof, keepdims, where])	Returns the standard deviation of the array elements along given axis.
`sum`([axis, dtype, out, keepdims, initial, where])	Return the sum of the array elements over the given axis.
`swapaxes`(axis1, axis2)	Return a view of the array with *axis1* and *axis2* interchanged.
`take`(indices[, axis, out, mode])	Return an array formed from the elements of *a* at the given indices.
`tobytes`([order])	Construct Python bytes containing the raw data bytes in the array.
`tofile`(fid[, sep, format])	Write array to a file as text or binary (default).

continues on next page

Table 8 – continued from previous page

tolist()	Return the array as an `a.ndim`-levels deep nested list of Python scalars.
tostring([order])	A compatibility alias for *tobytes*, with exactly the same behavior.
trace([offset, axis1, axis2, dtype, out])	Return the sum along diagonals of the array.
transpose(*axes)	Returns a view of the array with axes transposed.
var([axis, dtype, out, ddof, keepdims, where])	Returns the variance of the array elements, along given axis.
view([dtype][, type])	New view of array with the same data.

method

recarray.**all**(*axis=None*, *out=None*, *keepdims=False*, ***, *where=True*)

Returns True if all elements evaluate to True.

Refer to *numpy.all* for full documentation.

See also:

numpy.all
equivalent function

method

recarray.**any**(*axis=None*, *out=None*, *keepdims=False*, ***, *where=True*)

Returns True if any of the elements of *a* evaluate to True.

Refer to *numpy.any* for full documentation.

See also:

numpy.any
equivalent function

method

recarray.**argmax**(*axis=None*, *out=None*, ***, *keepdims=False*)

Return indices of the maximum values along the given axis.

Refer to *numpy.argmax* for full documentation.

See also:

numpy.argmax
equivalent function

method

recarray.**argmin**(*axis=None*, *out=None*, ***, *keepdims=False*)

Return indices of the minimum values along the given axis.

Refer to *numpy.argmin* for detailed documentation.

See also:

numpy.argmin
equivalent function

method

recarray.**argpartition**(*kth*, *axis=-1*, *kind='introselect'*, *order=None*)

Returns the indices that would partition this array.

Refer to *numpy.argpartition* for full documentation.

See also:

numpy.argpartition
equivalent function

method

recarray.**argsort**(*axis=-1*, *kind=None*, *order=None*)

Returns the indices that would sort this array.

Refer to *numpy.argsort* for full documentation.

See also:

numpy.argsort
equivalent function

method

recarray.**astype**(*dtype*, *order='K'*, *casting='unsafe'*, *subok=True*, *copy=True*)

Copy of the array, cast to a specified type.

Parameters

dtype
[str or dtype] Typecode or data-type to which the array is cast.

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout order of the result. 'C' means C order, 'F' means Fortran order, 'A' means 'F' order if all the arrays are Fortran contiguous, 'C' order otherwise, and 'K' means as close to the order the array elements appear in memory as possible. Default is 'K'.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'unsafe' for backwards compatibility.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.
- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

subok
[bool, optional] If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

copy
[bool, optional] By default, astype always returns a newly allocated array. If this is set to false, and the *dtype*, *order*, and *subok* requirements are satisfied, the input array is returned instead of a copy.

Returns

arr_t
[ndarray] Unless *copy* is False and the other conditions for returning the input array are satisfied (see description for *copy* input parameter), *arr_t* is a new array of the same shape as the input array, with dtype, order given by *dtype*, *order*.

Raises

ComplexWarning
When casting from complex to float or int. To avoid this, one should use `a.real.astype(t)`.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 2.5])
>>> x
array([1. ,  2. ,  2.5])
```

```
>>> x.astype(int)
array([1, 2, 2])
```

method

`recarray.`**`byteswap`**(*inplace=False*)

Swap the bytes of the array elements

Toggle between low-endian and big-endian data representation by returning a byteswapped array, optionally swapped in-place. Arrays of byte-strings are not swapped. The real and imaginary parts of a complex number are swapped individually.

Parameters

inplace
[bool, optional] If `True`, swap bytes in-place, default is `False`.

Returns

out
[ndarray] The byteswapped array. If *inplace* is `True`, this is a view to self.

Examples

```
>>> import numpy as np
>>> A = np.array([1, 256, 8755], dtype=np.int16)
>>> list(map(hex, A))
['0x1', '0x100', '0x2233']
>>> A.byteswap(inplace=True)
array([  256,     1, 13090], dtype=int16)
>>> list(map(hex, A))
['0x100', '0x1', '0x3322']
```

Arrays of byte-strings are not swapped

```
>>> A = np.array([b'ceg', b'fac'])
>>> A.byteswap()
array([b'ceg', b'fac'], dtype='|S3')
```

`A.view(A.dtype.newbyteorder()).byteswap()` produces an array with the same values but different representation in memory

```
>>> A = np.array([1, 2, 3],dtype=np.int64)
>>> A.view(np.uint8)
array([1, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0,
       0, 0], dtype=uint8)
>>> A.view(A.dtype.newbyteorder()).byteswap(inplace=True)
array([1, 2, 3], dtype='>i8')
>>> A.view(np.uint8)
array([0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0,
       0, 3], dtype=uint8)
```

method

`recarray.`**`choose`**(*choices*, *out=None*, *mode='raise'*)

Use an index array to construct a new array from a set of choices.

Refer to *`numpy.choose`* for full documentation.

See also:

`numpy.choose`
equivalent function

method

`recarray.`**`clip`**(*min=None*, *max=None*, *out=None*, ***kwargs*)

Return an array whose values are limited to `[min, max]`. One of max or min must be given.

Refer to *`numpy.clip`* for full documentation.

See also:

`numpy.clip`
equivalent function

method

`recarray.`**`compress`**(*condition*, *axis=None*, *out=None*)

Return selected slices of this array along given axis.

Refer to *`numpy.compress`* for full documentation.

See also:

`numpy.compress`
equivalent function

method

recarray.**conj**()

Complex-conjugate all elements.

Refer to *numpy.conjugate* for full documentation.

See also:

numpy.conjugate
equivalent function

method

recarray.**conjugate**()

Return the complex conjugate, element-wise.

Refer to *numpy.conjugate* for full documentation.

See also:

numpy.conjugate
equivalent function

method

recarray.**copy**(*order='C'*)

Return a copy of the array.

Parameters

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout of the copy. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible. (Note that this function and *numpy.copy* are very similar but have different default values for their order= arguments, and this function always passes sub-classes through.)

See also:

numpy.copy
Similar function with different default behavior

numpy.copyto

Notes

This function is the preferred method for creating an array copy. The function *numpy.copy* is similar, but it defaults to using order 'K', and will not pass sub-classes through by default.

Examples

```
>>> import numpy as np
>>> x = np.array([[1,2,3],[4,5,6]], order='F')
```

```
>>> y = x.copy()
```

```
>>> x.fill(0)
```

```
>>> x
array([[0, 0, 0],
       [0, 0, 0]])
```

```
>>> y
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> y.flags['C_CONTIGUOUS']
True
```

For arrays containing Python objects (e.g. dtype=object), the copy is a shallow one. The new array will contain the same object which may lead to surprises if that object can be modified (is mutable):

```
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> b = a.copy()
>>> b[2][0] = 10
>>> a
array([1, 'm', list([10, 3, 4])], dtype=object)
```

To ensure all elements within an `object` array are copied, use `copy.deepcopy`:

```
>>> import copy
>>> a = np.array([1, 'm', [2, 3, 4]], dtype=object)
>>> c = copy.deepcopy(a)
>>> c[2][0] = 10
>>> c
array([1, 'm', list([10, 3, 4])], dtype=object)
>>> a
array([1, 'm', list([2, 3, 4])], dtype=object)
```

method

`recarray.`**`cumprod`**(*axis=None*, *dtype=None*, *out=None*)

Return the cumulative product of the elements along the given axis.

Refer to *`numpy.cumprod`* for full documentation.

See also:

`numpy.cumprod`
equivalent function

method

recarray.**cumsum**(*axis=None*, *dtype=None*, *out=None*)

Return the cumulative sum of the elements along the given axis.

Refer to *numpy.cumsum* for full documentation.

See also:

numpy.cumsum
equivalent function

method

recarray.**diagonal**(*offset=0*, *axis1=0*, *axis2=1*)

Return specified diagonals. In NumPy 1.9 the returned array is a read-only view instead of a copy as in previous NumPy versions. In a future version the read-only restriction will be removed.

Refer to *numpy.diagonal* for full documentation.

See also:

numpy.diagonal
equivalent function

method

recarray.**dump**(*file*)

Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

Parameters

file
[str or Path] A string naming the dump file.

method

recarray.**dumps**()

Returns the pickle of the array as a string. pickle.loads will convert the string back to an array.

Parameters

None

method

recarray.**fill**(*value*)

Fill the array with a scalar value.

Parameters

value
[scalar] All elements of *a* will be assigned this value.

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2])
>>> a.fill(0)
>>> a
array([0, 0])
>>> a = np.empty(2)
>>> a.fill(1)
>>> a
array([1.,  1.])
```

Fill expects a scalar value and always behaves the same as assigning to a single array element. The following is a rare example where this distinction is important:

```
>>> a = np.array([None, None], dtype=object)
>>> a[0] = np.array(3)
>>> a
array([array(3), None], dtype=object)
>>> a.fill(np.array(3))
>>> a
array([array(3), array(3)], dtype=object)
```

Where other forms of assignments will unpack the array being assigned:

```
>>> a[...] = np.array(3)
>>> a
array([3, 3], dtype=object)
```

method

recarray.**flatten**(*order='C'*)

Return a copy of the array collapsed into one dimension.

Parameters

order
[{'C', 'F', 'A', 'K'}, optional] 'C' means to flatten in row-major (C-style) order. 'F' means to flatten in column-major (Fortran- style) order. 'A' means to flatten in column-major order if *a* is Fortran *contiguous* in memory, row-major order otherwise. 'K' means to flatten *a* in the order the elements occur in memory. The default is 'C'.

Returns

y
[ndarray] A copy of the input array, flattened to one dimension.

See also:

ravel
Return a flattened array.

flat
A 1-D flat iterator over the array.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,2], [3,4]])
>>> a.flatten()
array([1, 2, 3, 4])
>>> a.flatten('F')
array([1, 3, 2, 4])
```

method

recarray.**getfield**(*dtype*, *offset=0*)

Returns a field of the given array as a certain type.

A field is a view of the array data with a given data-type. The values in the view are determined by the given type and the offset into the current array in bytes. The offset needs to be such that the view dtype fits in the array dtype; for example an array of dtype complex128 has 16-byte elements. If taking a view with a 32-bit integer (4 bytes), the offset needs to be between 0 and 12 bytes.

Parameters

dtype
[str or dtype] The data type of the view. The dtype size of the view can not be larger than that of the array itself.

offset
[int] Number of bytes to skip before beginning the element view.

Examples

```
>>> import numpy as np
>>> x = np.diag([1.+1.j]*2)
>>> x[1, 1] = 2 + 4.j
>>> x
array([[1.+1.j,  0.+0.j],
       [0.+0.j,  2.+4.j]])
>>> x.getfield(np.float64)
array([[1.,  0.],
       [0.,  2.]])
```

By choosing an offset of 8 bytes we can select the complex part of the array for our view:

```
>>> x.getfield(np.float64, offset=8)
array([[1.,  0.],
       [0.,  4.]])
```

method

recarray.**item**(**args*)

Copy an element of an array to a standard Python scalar and return it.

Parameters

***args**
[Arguments (variable number and type)]

- none: in this case, the method only works for arrays with one element (*a.size == 1*), which element is copied into a standard Python scalar object and returned.

- int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.
- tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.

Returns

z
[Standard Python scalar object] A copy of the specified element of the array as a suitable Python scalar

Notes

When the data type of *a* is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

item is very similar to a[args], except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python's optimized math.

Examples

```
>>> import numpy as np
>>> np.random.seed(123)
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[2, 2, 6],
       [1, 3, 6],
       [1, 0, 1]])
>>> x.item(3)
1
>>> x.item(7)
0
>>> x.item((0, 1))
2
>>> x.item((2, 2))
1
```

For an array with object dtype, elements are returned as-is.

```
>>> a = np.array([np.int64(1)], dtype=object)
>>> a.item() #return np.int64
np.int64(1)
```

method

recarray.**max**(*axis=None*, *out=None*, *keepdims=False*, *initial=<no value>*, *where=True*)

Return the maximum along a given axis.

Refer to *numpy.amax* for full documentation.

See also:

numpy.amax
equivalent function

method

recarray.**mean**(*axis=None*, *dtype=None*, *out=None*, *keepdims=False*, *, *where=True*)

Returns the average of the array elements along given axis.

Refer to *numpy.mean* for full documentation.

See also:

numpy.mean
equivalent function

method

recarray.**min**(*axis=None*, *out=None*, *keepdims=False*, *initial=<no value>*, *where=True*)

Return the minimum along a given axis.

Refer to *numpy.amin* for full documentation.

See also:

numpy.amin
equivalent function

method

recarray.**nonzero**()

Return the indices of the elements that are non-zero.

Refer to *numpy.nonzero* for full documentation.

See also:

numpy.nonzero
equivalent function

method

recarray.**partition**(*kth*, *axis=-1*, *kind='introselect'*, *order=None*)

Partially sorts the elements in the array in such a way that the value of the element in k-th position is in the position it would be in a sorted array. In the output array, all elements smaller than the k-th element are located to the left of this element and all equal or greater are located to its right. The ordering of the elements in the two partitions on the either side of the k-th element in the output array is undefined.

Parameters

kth
[int or sequence of ints] Element index to partition by. The kth element value will be in its final sorted position and all smaller elements will be moved before it and all equal or greater elements behind it. The order of all elements in the partitions is undefined. If provided with a sequence of kth it will partition all elements indexed by kth of them into their sorted position at once.

Deprecated since version 1.22.0: Passing booleans as index is deprecated.

axis
[int, optional] Axis along which to sort. Default is -1, which means sort along the last axis.

kind
[{'introselect'}, optional] Selection algorithm. Default is 'introselect'.

order
[str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need to be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

See also:

numpy.partition
Return a partitioned copy of an array.

argpartition
Indirect partition.

sort
Full sort.

Notes

See `np.partition` for notes on the different algorithms.

Examples

```
>>> import numpy as np
>>> a = np.array([3, 4, 2, 1])
>>> a.partition(3)
>>> a
array([2, 1, 3, 4]) # may vary
```

```
>>> a.partition((1, 3))
>>> a
array([1, 2, 3, 4])
```

method

`recarray.`**`prod`**(*axis=None*, *dtype=None*, *out=None*, *keepdims=False*, *initial=1*, *where=True*)

Return the product of the array elements over the given axis

Refer to *numpy.prod* for full documentation.

See also:

numpy.prod
equivalent function

method

`recarray.`**`put`**(*indices*, *values*, *mode='raise'*)

Set `a.flat[n] = values[n]` for all *n* in indices.

Refer to *numpy.put* for full documentation.

See also:

numpy.put
equivalent function

method

recarray.**ravel**([*order*])

Return a flattened array.

Refer to *numpy.ravel* for full documentation.

See also:

numpy.ravel
equivalent function

ndarray.flat
a flat iterator on the array.

method

recarray.**repeat**(*repeats*, *axis=None*)

Repeat elements of an array.

Refer to *numpy.repeat* for full documentation.

See also:

numpy.repeat
equivalent function

method

recarray.**reshape**(*shape*, */*, ***, *order='C'*, *copy=None*)

Returns an array containing the same data with a new shape.

Refer to *numpy.reshape* for full documentation.

See also:

numpy.reshape
equivalent function

Notes

Unlike the free function *numpy.reshape*, this method on *ndarray* allows the elements of the shape parameter to be passed in as separate arguments. For example, `a.reshape(10, 11)` is equivalent to `a.reshape((10, 11))`.

method

recarray.**resize**(*new_shape*, *refcheck=True*)

Change shape and size of array in-place.

Parameters

new_shape
[tuple of ints, or *n* ints] Shape of resized array.

refcheck
[bool, optional] If False, reference count will not be checked. Default is True.

Returns

None

Raises

ValueError
If *a* does not own its own data or references or views to it exist, and the data memory must be changed. PyPy only: will always raise if the data memory must be changed, since there is no reliable way to determine if references or views to it exist.

SystemError
If the *order* keyword argument is specified. This behaviour is a bug in NumPy.

See also:

resize
Return a new array with the specified shape.

Notes

This reallocates space for the data area if necessary.

Only contiguous arrays (data elements consecutive in memory) can be resized.

The purpose of the reference count check is to make sure you do not use this array as a buffer for another Python object and then reallocate the memory. However, reference counts can increase in other ways so if you are sure that you have not shared the memory for this array with another Python object, then you may safely set *refcheck* to False.

Examples

Shrinking an array: array is flattened (in the order that the data are stored in memory), resized, and reshaped:

```
>>> import numpy as np
```

```
>>> a = np.array([[0, 1], [2, 3]], order='C')
>>> a.resize((2, 1))
>>> a
array([[0],
       [1]])
```

```
>>> a = np.array([[0, 1], [2, 3]], order='F')
>>> a.resize((2, 1))
>>> a
array([[0],
       [2]])
```

Enlarging an array: as above, but missing entries are filled with zeros:

```
>>> b = np.array([[0, 1], [2, 3]])
>>> b.resize(2, 3) # new_shape parameter doesn't have to be a tuple
>>> b
array([[0, 1, 2],
       [3, 0, 0]])
```

Referencing an array prevents resizing…

```
>>> c = a
>>> a.resize((1, 1))
Traceback (most recent call last):
...
ValueError: cannot resize an array that references or is referenced ...
```

Unless *refcheck* is False:

```
>>> a.resize((1, 1), refcheck=False)
>>> a
array([[0]])
>>> c
array([[0]])
```

method

recarray.**round**(*decimals=0*, *out=None*)

Return *a* with each element rounded to the given number of decimals.

Refer to *numpy.around* for full documentation.

See also:

numpy.around
equivalent function

method

recarray.**searchsorted**(*v*, *side='left'*, *sorter=None*)

Find indices where elements of v should be inserted in a to maintain order.

For full documentation, see *numpy.searchsorted*

See also:

numpy.searchsorted
equivalent function

method

recarray.**setfield**(*val*, *dtype*, *offset=0*)

Put a value into a specified place in a field defined by a data-type.

Place *val* into *a*'s field defined by *dtype* and beginning *offset* bytes into the field.

Parameters

val
[object] Value to be placed in field.

dtype
[dtype object] Data-type of the field in which to place *val*.

offset
[int, optional] The number of bytes into the field at which to place *val*.

Returns

None

See also:

getfield

Examples

```
>>> import numpy as np
>>> x = np.eye(3)
>>> x.getfield(np.float64)
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
>>> x.setfield(3, np.int32)
>>> x.getfield(np.int32)
array([[3, 3, 3],
       [3, 3, 3],
       [3, 3, 3]], dtype=int32)
>>> x
array([[1.0e+000, 1.5e-323, 1.5e-323],
       [1.5e-323, 1.0e+000, 1.5e-323],
       [1.5e-323, 1.5e-323, 1.0e+000]])
>>> x.setfield(np.eye(3), np.int32)
>>> x
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
```

method

`recarray.`**`setflags`**(*write=None*, *align=None*, *uic=None*)

Set array flags WRITEABLE, ALIGNED, WRITEBACKIFCOPY, respectively.

These Boolean-valued flags affect how numpy interprets the memory area used by *a* (see Notes below). The ALIGNED flag can only be set to True if the data is actually aligned according to the type. The WRITEBACKIFCOPY flag can never be set to True. The flag WRITEABLE can only be set to True if the array owns its own memory, or the ultimate owner of the memory exposes a writeable buffer interface, or is a string. (The exception for string is made so that unpickling can be done without copying memory.)

Parameters

write
[bool, optional] Describes whether or not *a* can be written to.

align
[bool, optional] Describes whether or not *a* is aligned properly for its type.

uic
[bool, optional] Describes whether or not *a* is a copy of another “base” array.

Notes

Array flags provide information about how the memory area used for the array is to be interpreted. There are 7 Boolean flags in use, only three of which can be changed by the user: WRITEBACKIFCOPY, WRITEABLE, and ALIGNED.

WRITEABLE (W) the data area can be written to;

ALIGNED (A) the data and strides are aligned appropriately for the hardware (as determined by the compiler);

WRITEBACKIFCOPY (X) this array is a copy of some other array (referenced by .base). When the C-API function PyArray_ResolveWritebackIfCopy is called, the base array will be updated with the contents of this array.

All flags can be accessed using the single (upper case) letter as well as the full name.

Examples

```
>>> import numpy as np
>>> y = np.array([[3, 1, 7],
...               [2, 0, 0],
...               [8, 5, 9]])
>>> y
array([[3, 1, 7],
       [2, 0, 0],
       [8, 5, 9]])
>>> y.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
  OWNDATA : True
  WRITEABLE : True
  ALIGNED : True
  WRITEBACKIFCOPY : False
>>> y.setflags(write=0, align=0)
>>> y.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
  OWNDATA : True
  WRITEABLE : False
  ALIGNED : False
  WRITEBACKIFCOPY : False
>>> y.setflags(uic=1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: cannot set WRITEBACKIFCOPY flag to True
```

method

`recarray.`**`sort`**(*axis=-1*, *kind=None*, *order=None*)

Sort an array in-place. Refer to *`numpy.sort`* for full documentation.

Parameters

axis
[int, optional] Axis along which to sort. Default is -1, which means sort along the last axis.

kind
[{'quicksort', 'mergesort', 'heapsort', 'stable'}, optional] Sorting algorithm. The default is

'quicksort'. Note that both 'stable' and 'mergesort' use timsort under the covers and, in general, the actual implementation will vary with datatype. The 'mergesort' option is retained for backwards compatibility.

order
[str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

See also:

numpy.sort
Return a sorted copy of an array.

numpy.argsort
Indirect sort.

numpy.lexsort
Indirect stable sort on multiple keys.

numpy.searchsorted
Find elements in sorted array.

numpy.partition
Partial sort.

Notes

See *numpy.sort* for notes on the different sorting algorithms.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,4], [3,1]])
>>> a.sort(axis=1)
>>> a
array([[1, 4],
       [1, 3]])
>>> a.sort(axis=0)
>>> a
array([[1, 3],
       [1, 4]])
```

Use the *order* keyword to specify a field to use when sorting a structured array:

```
>>> a = np.array([('a', 2), ('c', 1)], dtype=[('x', 'S1'), ('y', int)])
>>> a.sort(order='y')
>>> a
array([(b'c', 1), (b'a', 2)],
      dtype=[('x', 'S1'), ('y', '<i8')])
```

method

recarray.**squeeze**(*axis=None*)

Remove axes of length one from *a*.

Refer to *numpy.squeeze* for full documentation.

See also:

numpy.squeeze
equivalent function

method

recarray.**std**(*axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=False*, ***, *where=True*)

Returns the standard deviation of the array elements along given axis.

Refer to *numpy.std* for full documentation.

See also:

numpy.std
equivalent function

method

recarray.**sum**(*axis=None*, *dtype=None*, *out=None*, *keepdims=False*, *initial=0*, *where=True*)

Return the sum of the array elements over the given axis.

Refer to *numpy.sum* for full documentation.

See also:

numpy.sum
equivalent function

method

recarray.**swapaxes**(*axis1*, *axis2*)

Return a view of the array with *axis1* and *axis2* interchanged.

Refer to *numpy.swapaxes* for full documentation.

See also:

numpy.swapaxes
equivalent function

method

recarray.**take**(*indices*, *axis=None*, *out=None*, *mode='raise'*)

Return an array formed from the elements of *a* at the given indices.

Refer to *numpy.take* for full documentation.

See also:

numpy.take
equivalent function

method

recarray.**tobytes**(*order='C'*)

Construct Python bytes containing the raw data bytes in the array.

Constructs Python bytes showing a copy of the raw contents of data memory. The bytes object is produced in C-order by default. This behavior is controlled by the `order` parameter.

Parameters

order
[{'C', 'F', 'A'}, optional] Controls the memory layout of the bytes object. 'C' means C-order, 'F' means F-order, 'A' (short for *Any*) means 'F' if *a* is Fortran contiguous, 'C' otherwise. Default is 'C'.

Returns

s
[bytes] Python bytes exhibiting a copy of *a*'s raw data.

See also:

frombuffer
Inverse of this operation, construct a 1-dimensional array from Python bytes.

Examples

```
>>> import numpy as np
>>> x = np.array([[0, 1], [2, 3]], dtype='<u2')
>>> x.tobytes()
b'\x00\x00\x01\x00\x02\x00\x03\x00'
>>> x.tobytes('C') == x.tobytes()
True
>>> x.tobytes('F')
b'\x00\x00\x02\x00\x01\x00\x03\x00'
```

method

recarray.**tofile**(*fid*, *sep=''*, *format='%s'*)

Write array to a file as text or binary (default).

Data is always written in 'C' order, independent of the order of *a*. The data produced by this method can be recovered using the function fromfile().

Parameters

fid
[file or str or Path] An open file object, or a string containing a filename.

sep
[str] Separator between array items for text output. If "" (empty), a binary file is written, equivalent to `file.write(a.tobytes())`.

format
[str] Format string for text file output. Each entry in the array is formatted to text by first converting it to the closest Python type, and then using "format" % item.

Notes

This is a convenience function for quick storage of array data. Information on endianness and precision is lost, so this method is not a good choice for files intended to archive data or transport data between machines with different endianness. Some of these problems can be overcome by outputting the data as text files, at the expense of speed and file size.

When fid is a file object, array contents are directly written to the file, bypassing the file object's `write` method. As a result, tofile cannot be used with files objects supporting compression (e.g., GzipFile) or file-like objects that do not support `fileno()` (e.g., BytesIO).

method

`recarray.`**`tolist`**`()`

Return the array as an `a.ndim`-levels deep nested list of Python scalars.

Return a copy of the array data as a (nested) Python list. Data items are converted to the nearest compatible builtin Python type, via the *`item`* function.

If `a.ndim` is 0, then since the depth of the nested list is 0, it will not be a list at all, but a simple Python scalar.

Parameters

none

Returns

y
[object, or list of object, or list of list of object, or …] The possibly nested list of array elements.

Notes

The array may be recreated via `a = np.array(a.tolist())`, although this may sometimes lose precision.

Examples

For a 1D array, `a.tolist()` is almost the same as `list(a)`, except that `tolist` changes numpy scalars to Python scalars:

```
>>> import numpy as np
>>> a = np.uint32([1, 2])
>>> a_list = list(a)
>>> a_list
[np.uint32(1), np.uint32(2)]
>>> type(a_list[0])
<class 'numpy.uint32'>
>>> a_tolist = a.tolist()
>>> a_tolist
[1, 2]
>>> type(a_tolist[0])
<class 'int'>
```

Additionally, for a 2D array, `tolist` applies recursively:

```
>>> a = np.array([[1, 2], [3, 4]])
>>> list(a)
[array([1, 2]), array([3, 4])]
>>> a.tolist()
[[1, 2], [3, 4]]
```

The base case for this recursion is a 0D array:

```
>>> a = np.array(1)
>>> list(a)
Traceback (most recent call last):
  ...
TypeError: iteration over a 0-d array
>>> a.tolist()
1
```

method

recarray.**tostring**(*order='C'*)

A compatibility alias for *tobytes*, with exactly the same behavior.

Despite its name, it returns bytes not strs.

Deprecated since version 1.19.0.

method

recarray.**trace**(*offset=0*, *axis1=0*, *axis2=1*, *dtype=None*, *out=None*)

Return the sum along diagonals of the array.

Refer to *numpy.trace* for full documentation.

See also:

numpy.trace
equivalent function

method

recarray.**transpose**(**axes*)

Returns a view of the array with axes transposed.

Refer to *numpy.transpose* for full documentation.

Parameters

axes
[None, tuple of ints, or *n* ints]

- None or no argument: reverses the order of the axes.
- tuple of ints: *i* in the *j*-th place in the tuple means that the array's *i*-th axis becomes the transposed array's *j*-th axis.
- *n* ints: same as an n-tuple of the same ints (this form is intended simply as a "convenience" alternative to the tuple form).

Returns

p
[ndarray] View of the array with its axes suitably permuted.

See also:

transpose
Equivalent function.

ndarray.T
Array property returning the array transposed.

ndarray.reshape
Give a new shape to an array without changing its data.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.transpose()
array([[1, 3],
       [2, 4]])
>>> a.transpose((1, 0))
array([[1, 3],
       [2, 4]])
>>> a.transpose(1, 0)
array([[1, 3],
       [2, 4]])
```

```
>>> a = np.array([1, 2, 3, 4])
>>> a
array([1, 2, 3, 4])
>>> a.transpose()
array([1, 2, 3, 4])
```

method

recarray.**var**(*axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=False*, ***, *where=True*)

Returns the variance of the array elements, along given axis.

Refer to *numpy.var* for full documentation.

See also:

numpy.var
equivalent function

method

recarray.**view**(*[dtype][, type]*)

New view of array with the same data.

Note: Passing None for `dtype` is different from omitting the parameter, since the former invokes `dtype(None)` which is an alias for `dtype('float64')`.

Parameters

dtype
: [data-type or ndarray sub-class, optional] Data-type descriptor of the returned view, e.g., float32 or int16. Omitting it results in the view having the same data-type as *a*. This argument can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the `type` parameter).

type
: [Python type, optional] Type of the returned view, e.g., ndarray or matrix. Again, omission of the parameter results in type preservation.

Notes

`a.view()` is used two different ways:

`a.view(some_dtype)` or `a.view(dtype=some_dtype)` constructs a view of the array's memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

`a.view(ndarray_subclass)` or `a.view(type=ndarray_subclass)` just returns an instance of *ndarray_subclass* that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

For `a.view(some_dtype)`, if `some_dtype` has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the last axis of `a` must be contiguous. This axis will be resized in the result.

Changed in version 1.23.0: Only the last axis needs to be contiguous. Previously, the entire array had to be C-contiguous.

Examples

```
>>> import numpy as np
>>> x = np.array([(-1, 2)], dtype=[('a', np.int8), ('b', np.int8)])
```

Viewing array data using a different type and dtype:

```
>>> nonneg = np.dtype([("a", np.uint8), ("b", np.uint8)])
>>> y = x.view(dtype=nonneg, type=np.recarray)
>>> x["a"]
array([-1], dtype=int8)
>>> y.a
array([255], dtype=uint8)
```

Creating a view on a structured array so it can be used in calculations

```
>>> x = np.array([(1, 2),(3,4)], dtype=[('a', np.int8), ('b', np.int8)])
>>> xv = x.view(dtype=np.int8).reshape(-1,2)
>>> xv
array([[1, 2],
       [3, 4]], dtype=int8)
>>> xv.mean(0)
array([2.,  3.])
```

Making changes to the view changes the underlying array

```
>>> xv[0,1] = 20
>>> x
array([(1, 20), (3,  4)], dtype=[('a', 'i1'), ('b', 'i1')])
```

Using a view to convert an array to a recarray:

```
>>> z = x.view(np.recarray)
>>> z.a
array([1, 3], dtype=int8)
```

Views share data:

```
>>> x[0] = (9, 10)
>>> z[0]
np.record((9, 10), dtype=[('a', 'i1'), ('b', 'i1')])
```

Views that change the dtype size (bytes per entry) should normally be avoided on arrays defined by slices, transposes, fortran-ordering, etc.:

```
>>> x = np.array([[1, 2, 3], [4, 5, 6]], dtype=np.int16)
>>> y = x[:, ::2]
>>> y
array([[1, 3],
       [4, 6]], dtype=int16)
>>> y.view(dtype=[('width', np.int16), ('length', np.int16)])
Traceback (most recent call last):
    ...
ValueError: To change to a dtype of a different size, the last axis must be␣
↪contiguous
>>> z = y.copy()
>>> z.view(dtype=[('width', np.int16), ('length', np.int16)])
array([[(1, 3)],
       [(4, 6)]], dtype=[('width', '<i2'), ('length', '<i2')])
```

However, views that change dtype are totally fine for arrays with a contiguous last axis, even if the rest of the axes are not C-contiguous:

```
>>> x = np.arange(2 * 3 * 4, dtype=np.int8).reshape(2, 3, 4)
>>> x.transpose(1, 0, 2).view(np.int16)
array([[[ 256,  770],
        [3340, 3854]],

       [[1284, 1798],
        [4368, 4882]],

       [[2312, 2826],
        [5396, 5910]]], dtype=int16)
```

dot
field
to_device

class numpy.**record**

A data-type scalar that allows field access as attribute lookup.

Attributes

T
Scalar attribute identical to the corresponding array attribute.

base
base object

data
Pointer to start of data.

device
dtype
dtype object

flags
integer value of flags

flat
A 1-D view of the scalar.

imag
The imaginary part of the scalar.

itemset
itemsize
The length of one element in bytes.

nbytes
ndim
The number of array dimensions.

newbyteorder
ptp
real
The real part of the scalar.

shape
Tuple of array dimensions.

size
The number of elements in the gentype.

strides
Tuple of bytes steps in each dimension.

Methods

all	Scalar method identical to the corresponding array attribute.
any	Scalar method identical to the corresponding array attribute.
argmax	Scalar method identical to the corresponding array attribute.
argmin	Scalar method identical to the corresponding array attribute.
argsort	Scalar method identical to the corresponding array attribute.

continues on next page

Table 9 – continued from previous page

astype	Scalar method identical to the corresponding array attribute.
byteswap	Scalar method identical to the corresponding array attribute.
choose	Scalar method identical to the corresponding array attribute.
clip	Scalar method identical to the corresponding array attribute.
compress	Scalar method identical to the corresponding array attribute.
conjugate	Scalar method identical to the corresponding array attribute.
copy	Scalar method identical to the corresponding array attribute.
cumprod	Scalar method identical to the corresponding array attribute.
cumsum	Scalar method identical to the corresponding array attribute.
diagonal	Scalar method identical to the corresponding array attribute.
dump	Scalar method identical to the corresponding array attribute.
dumps	Scalar method identical to the corresponding array attribute.
fill	Scalar method identical to the corresponding array attribute.
flatten	Scalar method identical to the corresponding array attribute.
getfield	Scalar method identical to the corresponding array attribute.
item	Scalar method identical to the corresponding array attribute.
max	Scalar method identical to the corresponding array attribute.
mean	Scalar method identical to the corresponding array attribute.
min	Scalar method identical to the corresponding array attribute.
nonzero	Scalar method identical to the corresponding array attribute.
pprint()	Pretty-print all fields.
prod	Scalar method identical to the corresponding array attribute.
put	Scalar method identical to the corresponding array attribute.
ravel	Scalar method identical to the corresponding array attribute.
repeat	Scalar method identical to the corresponding array attribute.
reshape	Scalar method identical to the corresponding array attribute.

continues on next page

Table 9 – continued from previous page

resize	Scalar method identical to the corresponding array attribute.
round	Scalar method identical to the corresponding array attribute.
searchsorted	Scalar method identical to the corresponding array attribute.
setfield	Scalar method identical to the corresponding array attribute.
setflags	Scalar method identical to the corresponding array attribute.
sort	Scalar method identical to the corresponding array attribute.
squeeze	Scalar method identical to the corresponding array attribute.
std	Scalar method identical to the corresponding array attribute.
sum	Scalar method identical to the corresponding array attribute.
swapaxes	Scalar method identical to the corresponding array attribute.
take	Scalar method identical to the corresponding array attribute.
tofile	Scalar method identical to the corresponding array attribute.
tolist	Scalar method identical to the corresponding array attribute.
tostring	Scalar method identical to the corresponding array attribute.
trace	Scalar method identical to the corresponding array attribute.
transpose	Scalar method identical to the corresponding array attribute.
var	Scalar method identical to the corresponding array attribute.
view	Scalar method identical to the corresponding array attribute.

method

record.**all**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.all*.

method

record.**any**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.any*.

method

record.**argmax**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.argmax*.

method

record.**argmin**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.argmin*.

method

record.**argsort**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.argsort*.

method

record.**astype**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.astype*.

method

record.**byteswap**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.byteswap*.

method

record.**choose**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.choose*.

method

record.**clip**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.clip*.

method

record.**compress**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.compress*.

method

record.**conjugate**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.conjugate*.

method

record.**copy**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.copy*.

method

record.**cumprod**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.cumprod*.

method

record.**cumsum**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.cumsum*.

method

record.**diagonal**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.diagonal*.

method

record.**dump**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.dump*.

method

record.**dumps**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.dumps*.

method

record.**fill**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.fill*.

method

record.**flatten**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.flatten*.

method

record.**getfield**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.getfield*.

method

record.**item**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.item*.

method

record.**max**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.max*.

method

record.**mean**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.mean*.

method

record.**min**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.min*.

method

record.**nonzero**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.nonzero*.

method

record.**pprint**()

Pretty-print all fields.

method

record.**prod**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.prod*.

method

record.**put**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.put*.

method

record.**ravel**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.ravel*.

method

record.**repeat**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.repeat*.

method

record.**reshape**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.reshape*.

method

record.**resize**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.resize*.

method

record.**round**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.round*.

method

record.**searchsorted**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.searchsorted*.

method

record.**setfield**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.setfield*.

method

record.**setflags**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.setflags*.

method

record.**sort**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.sort*.

method

record.**squeeze**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.squeeze*.

method

record.**std**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.std*.

method

record.**sum**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.sum*.

method

record.**swapaxes**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.swapaxes*.

method

record.**take**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.take*.

method

record.**tofile**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.tofile*.

method

record.**tolist**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.tolist*.

method

record.**tostring**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.tostring*.

method

record.**trace**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.trace*.

method

record.**transpose**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.transpose*.

method

record.**var**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.var*.

method

record.**view**()

Scalar method identical to the corresponding array attribute.

Please see *ndarray.view*.

conj
to_device
tobytes

Note: The pandas DataFrame is more powerful than record array. If possible, please use pandas DataFrame instead.

Masked arrays (`numpy.ma`)

See also:

Masked arrays

Standard container class

For backward compatibility and as a standard "container "class, the UserArray from Numeric has been brought over to NumPy and named *numpy.lib.user_array.container* The container class is a Python class whose self.array attribute is an ndarray. Multiple inheritance is probably easier with numpy.lib.user_array.container than with the ndarray itself and so it is included by default. It is not documented here beyond mentioning its existence because you are encouraged to use the ndarray class directly if you can.

numpy.lib.user_array.container(data[, ...])	Standard container-class for easy multiple-inheritance.

class numpy.lib.user_array.**container**(*data*, *dtype=None*, *copy=True*)

Standard container-class for easy multiple-inheritance.

Methods

copy
tostring
byteswap
astype

Array iterators

Iterators are a powerful concept for array processing. Essentially, iterators implement a generalized for-loop. If *myiter* is an iterator object, then the Python code:

```
for val in myiter:
    ...
    some code involving val
    ...
```

calls `val = next(myiter)` repeatedly until `StopIteration` is raised by the iterator. There are several ways to iterate over an array that may be useful: default iteration, flat iteration, and N-dimensional enumeration.

Default iteration

The default iterator of an ndarray object is the default Python iterator of a sequence type. Thus, when the array object itself is used as an iterator. The default behavior is equivalent to:

```
for i in range(arr.shape[0]):
    val = arr[i]
```

This default iterator selects a sub-array of dimension $N-1$ from the array. This can be a useful construct for defining recursive algorithms. To loop over the entire array requires N for-loops.

```
>>> import numpy as np
>>> a = np.arange(24).reshape(3,2,4) + 10
>>> for val in a:
...     print('item:', val)
item: [[10 11 12 13]
[14 15 16 17]]
item: [[18 19 20 21]
[22 23 24 25]]
item: [[26 27 28 29]
[30 31 32 33]]
```

Flat iteration

ndarray.flat	A 1-D iterator over the array.

As mentioned previously, the flat attribute of ndarray objects returns an iterator that will cycle over the entire array in C-style contiguous order.

```
>>> import numpy as np
>>> a = np.arange(24).reshape(3,2,4) + 10
>>> for i, val in enumerate(a.flat):
...     if i%5 == 0: print(i, val)
0 10
5 15
10 20
15 25
20 30
```

Here, I've used the built-in enumerate iterator to return the iterator index as well as the value.

N-dimensional enumeration

ndenumerate(arr)	Multidimensional index iterator.

class numpy.**ndenumerate**(*arr*)

Multidimensional index iterator.

Return an iterator yielding pairs of array coordinates and values.

Parameters

arr
[ndarray] Input array.

See also:

ndindex, *flatiter*

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> for index, x in np.ndenumerate(a):
...     print(index, x)
(0, 0) 1
(0, 1) 2
(1, 0) 3
(1, 1) 4
```

Sometimes it may be useful to get the N-dimensional index while iterating. The ndenumerate iterator can achieve this.

```
>>> import numpy as np
>>> for i, val in np.ndenumerate(a):
...     if sum(i)%5 == 0: print(i, val)
(0, 0, 0) 10
(1, 1, 3) 25
(2, 0, 3) 29
(2, 1, 2) 32
```

Iterator for broadcasting

broadcast	Produce an object that mimics broadcasting.

class numpy.**broadcast**

Produce an object that mimics broadcasting.

Parameters

in1, in2, …
[array_like] Input parameters.

Returns

b
[broadcast object] Broadcast the input parameters against one another, and return an object that encapsulates the result. Amongst others, it has `shape` and `nd` properties, and may be used as an iterator.

See also:

broadcast_arrays
broadcast_to
broadcast_shapes

Examples

Manually adding two vectors, using broadcasting:

```
>>> import numpy as np
>>> x = np.array([[1], [2], [3]])
>>> y = np.array([4, 5, 6])
>>> b = np.broadcast(x, y)
```

```
>>> out = np.empty(b.shape)
>>> out.flat = [u+v for (u,v) in b]
>>> out
array([[5.,  6.,  7.],
       [6.,  7.,  8.],
       [7.,  8.,  9.]])
```

Compare against built-in broadcasting:

```
>>> x + y
array([[5, 6, 7],
       [6, 7, 8],
       [7, 8, 9]])
```

Attributes

index
current index in broadcasted result

iters
tuple of iterators along `self`'s "components."

nd
Number of dimensions of broadcasted result.

ndim
Number of dimensions of broadcasted result.

numiter
Number of iterators possessed by the broadcasted result.

shape
Shape of broadcasted result.

size
Total size of broadcasted result.

Methods

reset()	Reset the broadcasted result's iterator(s).

method

broadcast.**reset**()
Reset the broadcasted result's iterator(s).

Parameters

None

Returns

None

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 3])
>>> y = np.array([[4], [5], [6]])
>>> b = np.broadcast(x, y)
>>> b.index
0
>>> next(b), next(b), next(b)
((1, 4), (2, 4), (3, 4))
>>> b.index
3
>>> b.reset()
>>> b.index
0
```

The general concept of broadcasting is also available from Python using the *broadcast* iterator. This object takes N objects as inputs and returns an iterator that returns tuples providing each of the input sequence elements in the broadcasted result.

```
>>> import numpy as np
>>> for val in np.broadcast([[1, 0], [2, 3]], [0, 1]):
...     print(val)
(np.int64(1), np.int64(0))
(np.int64(0), np.int64(1))
(np.int64(2), np.int64(0))
(np.int64(3), np.int64(1))
```

1.2.7 Masked arrays

Masked arrays are arrays that may have missing or invalid entries. The *numpy.ma* module provides a nearly work-alike replacement for numpy that supports data arrays with masks.

The `numpy.ma` module

Rationale

Masked arrays are arrays that may have missing or invalid entries. The *numpy.ma* module provides a nearly work-alike replacement for numpy that supports data arrays with masks.

What is a masked array?

In many circumstances, datasets can be incomplete or tainted by the presence of invalid data. For example, a sensor may have failed to record a data, or recorded an invalid value. The *numpy.ma* module provides a convenient way to address this issue, by introducing masked arrays.

A masked array is the combination of a standard *numpy.ndarray* and a mask. A mask is either *nomask*, indicating that no value of the associated array is invalid, or an array of booleans that determines for each element of the associated array whether the value is valid or not. When an element of the mask is `False`, the corresponding element of the associated array is valid and is said to be unmasked. When an element of the mask is `True`, the corresponding element of the associated array is said to be masked (invalid).

The package ensures that masked entries are not used in computations.

As an illustration, let's consider the following dataset:

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> x = np.array([1, 2, 3, -1, 5])
```

We wish to mark the fourth entry as invalid. The easiest is to create a masked array:

```
>>> mx = ma.masked_array(x, mask=[0, 0, 0, 1, 0])
```

We can now compute the mean of the dataset, without taking the invalid data into account:

```
>>> mx.mean()
2.75
```

The `numpy.ma` module

The main feature of the *numpy.ma* module is the *MaskedArray* class, which is a subclass of *numpy.ndarray*. The class, its attributes and methods are described in more details in the *MaskedArray class* section.

The *numpy.ma* module can be used as an addition to *numpy*:

```
>>> import numpy as np
>>> import numpy.ma as ma
```

To create an array with the second element invalid, we would do:

```
>>> y = ma.array([1, 2, 3], mask = [0, 1, 0])
```

To create a masked array where all values close to 1.e20 are invalid, we would do:

```
>>> z = ma.masked_values([1.0, 1.e20, 3.0, 4.0], 1.e20)
```

For a complete discussion of creation methods for masked arrays please see section *Constructing masked arrays*.

Using numpy.ma

Constructing masked arrays

There are several ways to construct a masked array.

- A first possibility is to directly invoke the *MaskedArray* class.
- A second possibility is to use the two masked array constructors, *array* and *masked_array*.

array(data[, dtype, copy, order, mask, ...])	An array class with possibly masked values.
masked_array	alias of *MaskedArray*

- A third option is to take the view of an existing array. In that case, the mask of the view is set to *nomask* if the array has no named fields, or an array of boolean with the same structure as the array otherwise.

```
>>> import numpy as np
>>> x = np.array([1, 2, 3])
>>> x.view(ma.MaskedArray)
masked_array(data=[1, 2, 3],
             mask=False,
       fill_value=999999)
>>> x = np.array([(1, 1.), (2, 2.)], dtype=[('a',int), ('b', float)])
>>> x.view(ma.MaskedArray)
masked_array(data=[(1, 1.0), (2, 2.0)],
             mask=[(False, False), (False, False)],
       fill_value=(999999, 1e+20),
             dtype=[('a', '<i8'), ('b', '<f8')])
```

- Yet another possibility is to use any of the following functions:

asarray(a[, dtype, order])	Convert the input to a masked array of the given data-type.
asanyarray(a[, dtype])	Convert the input to a masked array, conserving sub-classes.
fix_invalid(a[, mask, copy, fill_value])	Return input with invalid data masked and replaced by a fill value.
masked_equal(x, value[, copy])	Mask an array where equal to a given value.
masked_greater(x, value[, copy])	Mask an array where greater than a given value.
masked_greater_equal(x, value[, copy])	Mask an array where greater than or equal to a given value.
masked_inside(x, v1, v2[, copy])	Mask an array inside a given interval.
masked_invalid(a[, copy])	Mask an array where invalid values occur (NaNs or infs).
masked_less(x, value[, copy])	Mask an array where less than a given value.
masked_less_equal(x, value[, copy])	Mask an array where less than or equal to a given value.
masked_not_equal(x, value[, copy])	Mask an array where *not* equal to a given value.
masked_object(x, value[, copy, shrink])	Mask the array *x* where the data are exactly equal to value.
masked_outside(x, v1, v2[, copy])	Mask an array outside a given interval.
masked_values(x, value[, rtol, atol, copy, ...])	Mask using floating point equality.
masked_where(condition, a[, copy])	Mask an array where a condition is met.

Accessing the data

The underlying data of a masked array can be accessed in several ways:

- through the *data* attribute. The output is a view of the array as a *numpy.ndarray* or one of its subclasses, depending on the type of the underlying data at the masked array creation.
- through the *__array__* method. The output is then a *numpy.ndarray*.
- by directly taking a view of the masked array as a *numpy.ndarray* or one of its subclass (which is actually what using the *data* attribute does).
- by using the *getdata* function.

None of these methods is completely satisfactory if some entries have been marked as invalid. As a general rule, where a representation of the array is required without any masked entries, it is recommended to fill the array with the *filled* method.

Accessing the mask

The mask of a masked array is accessible through its *mask* attribute. We must keep in mind that a `True` entry in the mask indicates an *invalid* data.

Another possibility is to use the *getmask* and *getmaskarray* functions. `getmask(x)` outputs the mask of `x` if `x` is a masked array, and the special value *nomask* otherwise. `getmaskarray(x)` outputs the mask of `x` if `x` is a masked array. If `x` has no invalid entry or is not a masked array, the function outputs a boolean array of `False` with as many elements as `x`.

Accessing only the valid entries

To retrieve only the valid entries, we can use the inverse of the mask as an index. The inverse of the mask can be calculated with the *numpy.logical_not* function or simply with the ~ operator:

```
>>> import numpy as np
>>> x = ma.array([[1, 2], [3, 4]], mask=[[0, 1], [1, 0]])
>>> x[~x.mask]
masked_array(data=[1, 4],
             mask=[False, False],
       fill_value=999999)
```

Another way to retrieve the valid data is to use the *compressed* method, which returns a one-dimensional *ndarray* (or one of its subclasses, depending on the value of the *baseclass* attribute):

```
>>> x.compressed()
array([1, 4])
```

Note that the output of *compressed* is always 1D.

Modifying the mask

Masking an entry

The recommended way to mark one or several specific entries of a masked array as invalid is to assign the special value *masked* to them:

```
>>> x = ma.array([1, 2, 3])
>>> x[0] = ma.masked
>>> x
masked_array(data=[--, 2, 3],
             mask=[ True, False, False],
```

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```
       fill_value=999999)
>>> y = ma.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
>>> y[(0, 1, 2), (1, 2, 0)] = ma.masked
>>> y
masked_array(
  data=[[1, --, 3],
        [4, 5, --],
        [--, 8, 9]],
  mask=[[False,  True, False],
        [False, False,  True],
        [ True, False, False]],
  fill_value=999999)
>>> z = ma.array([1, 2, 3, 4])
>>> z[:-2] = ma.masked
>>> z
masked_array(data=[--, --, 3, 4],
             mask=[ True,  True, False, False],
       fill_value=999999)
```

A second possibility is to modify the *mask* directly, but this usage is discouraged.

Note: When creating a new masked array with a simple, non-structured datatype, the mask is initially set to the special value *nomask*, that corresponds roughly to the boolean `False`. Trying to set an element of *nomask* will fail with a `TypeError` exception, as a boolean does not support item assignment.

All the entries of an array can be masked at once by assigning `True` to the mask:

```
>>> import numpy.ma as ma
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1])
>>> x.mask = True
>>> x
masked_array(data=[--, --, --],
             mask=[ True,  True,  True],
       fill_value=999999,
            dtype=int64)
```

Finally, specific entries can be masked and/or unmasked by assigning to the mask a sequence of booleans:

```
>>> x = ma.array([1, 2, 3])
>>> x.mask = [0, 1, 0]
>>> x
masked_array(data=[1, --, 3],
             mask=[False,  True, False],
       fill_value=999999)
```

Unmasking an entry

To unmask one or several specific entries, we can just assign one or several new valid values to them:

```
>>> import numpy.ma as ma
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1])
>>> x
masked_array(data=[1, 2, --],
             mask=[False, False,  True],
       fill_value=999999)
>>> x[-1] = 5
>>> x
masked_array(data=[1, 2, 5],
             mask=[False, False, False],
       fill_value=999999)
```

Note: Unmasking an entry by direct assignment will silently fail if the masked array has a *hard* mask, as shown by the *hardmask* attribute. This feature was introduced to prevent overwriting the mask. To force the unmasking of an entry where the array has a hard mask, the mask must first to be softened using the *soften_mask* method before the allocation. It can be re-hardened with *harden_mask* as follows:

```
>>> import numpy.ma as ma
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1], hard_mask=True)
>>> x
masked_array(data=[1, 2, --],
             mask=[False, False,  True],
       fill_value=999999)
>>> x[-1] = 5
>>> x
masked_array(data=[1, 2, --],
             mask=[False, False,  True],
       fill_value=999999)
>>> x.soften_mask()
masked_array(data=[1, 2, --],
             mask=[False, False,  True],
       fill_value=999999)
>>> x[-1] = 5
>>> x
masked_array(data=[1, 2, 5],
             mask=[False, False, False],
       fill_value=999999)
>>> x.harden_mask()
masked_array(data=[1, 2, 5],
             mask=[False, False, False],
       fill_value=999999)
```

To unmask all masked entries of a masked array (provided the mask isn't a hard mask), the simplest solution is to assign the constant *nomask* to the mask:

```
>>> import numpy.ma as ma
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1])
>>> x
masked_array(data=[1, 2, --],
             mask=[False, False,  True],
       fill_value=999999)
```

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```
>>> x.mask = ma.nomask
>>> x
masked_array(data=[1, 2, 3],
             mask=[False, False, False],
       fill_value=999999)
```

Indexing and slicing

As a *MaskedArray* is a subclass of *numpy.ndarray*, it inherits its mechanisms for indexing and slicing.

When accessing a single entry of a masked array with no named fields, the output is either a scalar (if the corresponding entry of the mask is `False`) or the special value *masked* (if the corresponding entry of the mask is `True`):

```
>>> import numpy.ma as ma
>>> x = ma.array([1, 2, 3], mask=[0, 0, 1])
>>> x[0]
1
>>> x[-1]
masked
>>> x[-1] is ma.masked
True
```

If the masked array has named fields, accessing a single entry returns a *numpy.void* object if none of the fields are masked, or a 0d masked array with the same dtype as the initial array if at least one of the fields is masked.

```
>>> import numpy.ma as ma
>>> y = ma.masked_array([(1,2), (3, 4)],
...                     mask=[(0, 0), (0, 1)],
...                    dtype=[('a', int), ('b', int)])
>>> y[0]
(1, 2)
>>> y[-1]
(3, --)
```

When accessing a slice, the output is a masked array whose *data* attribute is a view of the original data, and whose mask is either *nomask* (if there was no invalid entries in the original array) or a view of the corresponding slice of the original mask. The view is required to ensure propagation of any modification of the mask to the original.

```
>>> import numpy.ma as ma
>>> x = ma.array([1, 2, 3, 4, 5], mask=[0, 1, 0, 0, 1])
>>> mx = x[:3]
>>> mx
masked_array(data=[1, --, 3],
             mask=[False,  True, False],
       fill_value=999999)
>>> mx[1] = -1
>>> mx
masked_array(data=[1, -1, 3],
             mask=[False, False, False],
       fill_value=999999)
>>> x.mask
array([False, False, False, False,  True])
>>> x.data
array([ 1, -1,  3,  4,  5])
```

Accessing a field of a masked array with structured datatype returns a *MaskedArray*.

Operations on masked arrays

Arithmetic and comparison operations are supported by masked arrays. As much as possible, invalid entries of a masked array are not processed, meaning that the corresponding `data` entries *should* be the same before and after the operation.

Warning: We need to stress that this behavior may not be systematic, that masked data may be affected by the operation in some cases and therefore users should not rely on this data remaining unchanged.

The `numpy.ma` module comes with a specific implementation of most ufuncs. Unary and binary functions that have a validity domain (such as `log` or `divide`) return the `masked` constant whenever the input is masked or falls outside the validity domain:

```
>>> import numpy.ma as ma
>>> ma.log([-1, 0, 1, 2])
masked_array(data=[--, --, 0.0, 0.6931471805599453],
             mask=[ True,  True, False, False],
       fill_value=1e+20)
```

Masked arrays also support standard numpy ufuncs. The output is then a masked array. The result of a unary ufunc is masked wherever the input is masked. The result of a binary ufunc is masked wherever any of the input is masked. If the ufunc also returns the optional context output (a 3-element tuple containing the name of the ufunc, its arguments and its domain), the context is processed and entries of the output masked array are masked wherever the corresponding input fall outside the validity domain:

```
>>> import numpy.ma as ma
>>> x = ma.array([-1, 1, 0, 2, 3], mask=[0, 0, 0, 0, 1])
>>> np.log(x)
masked_array(data=[--, 0.0, --, 0.6931471805599453, --],
             mask=[ True, False,  True, False,  True],
       fill_value=1e+20)
```

Examples

Data with a given value representing missing data

Let's consider a list of elements, `x`, where values of -9999. represent missing data. We wish to compute the average value of the data and the vector of anomalies (deviations from the average):

```
>>> import numpy.ma as ma
>>> x = [0.,1.,-9999.,3.,4.]
>>> mx = ma.masked_values (x, -9999.)
>>> print(mx.mean())
2.0
>>> print(mx - mx.mean())
[-2.0 -1.0 -- 1.0 2.0]
>>> print(mx.anom())
[-2.0 -1.0 -- 1.0 2.0]
```

Filling in the missing data

Suppose now that we wish to print that same data, but with the missing values replaced by the average value.

```
>>> import numpy.ma as ma
>>> mx = ma.masked_values (x, -9999.)
>>> print(mx.filled(mx.mean()))
[0.  1.  2.  3.  4.]
```

Numerical operations

Numerical operations can be easily performed without worrying about missing values, dividing by zero, square roots of negative numbers, etc.:

```
>>> import numpy.ma as ma
>>> x = ma.array([1., -1., 3., 4., 5., 6.], mask=[0,0,0,0,1,0])
>>> y = ma.array([1., 2., 0., 4., 5., 6.], mask=[0,0,0,0,0,1])
>>> print(ma.sqrt(x/y))
[1.0 -- -- 1.0 -- --]
```

Four values of the output are invalid: the first one comes from taking the square root of a negative number, the second from the division by zero, and the last two where the inputs were masked.

Ignoring extreme values

Let's consider an array `d` of floats between 0 and 1. We wish to compute the average of the values of `d` while ignoring any data outside the range `[0.2, 0.9]`:

```
>>> import numpy as np
>>> import numpy.ma as ma
>>> d = np.linspace(0, 1, 20)
>>> print(d.mean() - ma.masked_outside(d, 0.2, 0.9).mean())
-0.05263157894736836
```

Constants of the `numpy.ma` module

In addition to the *`MaskedArray`* class, the *`numpy.ma`* module defines several constants.

`numpy.ma.`**`masked`**

The *`masked`* constant is a special case of *`MaskedArray`*, with a float datatype and a null shape. It is used to test whether a specific entry of a masked array is masked, or to mask one or several entries of a masked array:

```
>>> import numpy as np

>>> x = ma.array([1, 2, 3], mask=[0, 1, 0])
>>> x[1] is ma.masked
True
>>> x[-1] = ma.masked
>>> x
masked_array(data=[1, --, --],
             mask=[False,  True,  True],
       fill_value=999999)
```

`numpy.ma.`**`nomask`**

Value indicating that a masked array has no invalid entry. *`nomask`* is used internally to speed up computations when the mask is not needed. It is represented internally as `np.False_`.

numpy.ma.**masked_print_option**

String used in lieu of missing data when a masked array is printed. By default, this string is `'--'`.

Use `set_display()` to change the default string. Example usage: `numpy.ma.masked_print_option.set_display('X')` replaces missing data with `'X'`.

The `MaskedArray` class

class numpy.ma.**MaskedArray**

A subclass of *ndarray* designed to manipulate numerical arrays with missing data.

An instance of *MaskedArray* can be thought as the combination of several elements:

- The *data*, as a regular *numpy.ndarray* of any shape or datatype (the data).
- A boolean *mask* with the same shape as the data, where a `True` value indicates that the corresponding element of the data is invalid. The special value *nomask* is also acceptable for arrays without named fields, and indicates that no data is invalid.
- A *fill_value*, a value that may be used to replace the invalid entries in order to return a standard *numpy.ndarray*.

Attributes and properties of masked arrays

See also:

Array Attributes

ma.MaskedArray.**data**

Returns the underlying data, as a view of the masked array.

If the underlying data is a subclass of *numpy.ndarray*, it is returned as such.

```
>>> x = np.ma.array(np.matrix([[1, 2], [3, 4]]), mask=[[0, 1], [1, 0]])
>>> x.data
matrix([[1, 2],
        [3, 4]])
```

The type of the data can be accessed through the *baseclass* attribute.

ma.MaskedArray.**mask**

Current mask.

ma.MaskedArray.**recordmask**

Get or set the mask of the array if it has no named fields. For structured arrays, returns a ndarray of booleans where entries are `True` if **all** the fields are masked, `False` otherwise:

```
>>> x = np.ma.array([(1, 1), (2, 2), (3, 3), (4, 4), (5, 5)],
...         mask=[(0, 0), (1, 0), (1, 1), (0, 1), (0, 0)],
...        dtype=[('a', int), ('b', int)])
>>> x.recordmask
array([False, False,  True, False, False])
```

ma.MaskedArray.**fill_value**

The filling value of the masked array is a scalar. When setting, None will set to a default based on the data type.

Examples

```
>>> import numpy as np
>>> for dt in [np.int32, np.int64, np.float64, np.complex128]:
...     np.ma.array([0, 1], dtype=dt).get_fill_value()
...
np.int64(999999)
np.int64(999999)
np.float64(1e+20)
np.complex128(1e+20+0j)
```

```
>>> x = np.ma.array([0, 1.], fill_value=-np.inf)
>>> x.fill_value
np.float64(-inf)
>>> x.fill_value = np.pi
>>> x.fill_value
np.float64(3.1415926535897931)
```

Reset to default:

```
>>> x.fill_value = None
>>> x.fill_value
np.float64(1e+20)
```

ma.MaskedArray.**baseclass**

Class of the underlying data (read-only).

ma.MaskedArray.**sharedmask**

Share status of the mask (read-only).

ma.MaskedArray.**hardmask**

Specifies whether values can be unmasked through assignments.

By default, assigning definite values to masked array entries will unmask them. When *hardmask* is `True`, the mask will not change through assignments.

See also:

ma.MaskedArray.harden_mask
ma.MaskedArray.soften_mask

Examples

```
>>> import numpy as np
>>> x = np.arange(10)
>>> m = np.ma.masked_array(x, x>5)
>>> assert not m.hardmask
```

Since *m* has a soft mask, assigning an element value unmasks that element:

```
>>> m[8] = 42
>>> m
masked_array(data=[0, 1, 2, 3, 4, 5, --, --, 42, --],
             mask=[False, False, False, False, False, False,
                   True, True, False, True],
       fill_value=999999)
```

After hardening, the mask is not affected by assignments:

```
>>> hardened = np.ma.harden_mask(m)
>>> assert m.hardmask and hardened is m
>>> m[:] = 23
>>> m
masked_array(data=[23, 23, 23, 23, 23, 23, --, --, 23, --],
             mask=[False, False, False, False, False, False,
                   True, True, False, True],
       fill_value=999999)
```

As *MaskedArray* is a subclass of *ndarray*, a masked array also inherits all the attributes and properties of a *ndarray* instance.

MaskedArray.base	Base object if memory is from some other object.
MaskedArray.ctypes	An object to simplify the interaction of the array with the ctypes module.
MaskedArray.dtype	Data-type of the array's elements.
MaskedArray.flags	Information about the memory layout of the array.
MaskedArray.itemsize	Length of one array element in bytes.
MaskedArray.nbytes	Total bytes consumed by the elements of the array.
MaskedArray.ndim	Number of array dimensions.
MaskedArray.shape	Tuple of array dimensions.
MaskedArray.size	Number of elements in the array.
MaskedArray.strides	Tuple of bytes to step in each dimension when traversing an array.
MaskedArray.imag	The imaginary part of the masked array.
MaskedArray.real	The real part of the masked array.
MaskedArray.flat	Return a flat iterator, or set a flattened version of self to value.
MaskedArray.__array_priority__	

attribute

ma.MaskedArray.**base**

Base object if memory is from some other object.

Examples

The base of an array that owns its memory is None:

```
>>> import numpy as np
>>> x = np.array([1,2,3,4])
>>> x.base is None
True
```

Slicing creates a view, whose memory is shared with x:

```
>>> y = x[2:]
>>> y.base is x
True
```

attribute

ma.MaskedArray.**ctypes**

An object to simplify the interaction of the array with the ctypes module.

This attribute creates an object that makes it easier to use arrays when calling shared libraries with the ctypes module. The returned object has, among others, data, shape, and strides attributes (see Notes below) which themselves return ctypes objects that can be used as arguments to a shared library.

Parameters

None

Returns

c

[Python object] Possessing attributes data, shape, strides, etc.

See also:

numpy.ctypeslib

Notes

Below are the public attributes of this object which were documented in "Guide to NumPy" (we have omitted undocumented public attributes, as well as documented private attributes):

_ctypes.**data**

A pointer to the memory area of the array as a Python integer. This memory area may contain data that is not aligned, or not in correct byte-order. The memory area may not even be writeable. The array flags and data-type of this array should be respected when passing this attribute to arbitrary C-code to avoid trouble that can include Python crashing. User Beware! The value of this attribute is exactly the same as: `self._array_interface_['data'][0]`.

Note that unlike `data_as`, a reference won't be kept to the array: code like `ctypes.c_void_p((a + b).ctypes.data)` will result in a pointer to a deallocated array, and should be spelt `(a + b).ctypes.data_as(ctypes.c_void_p)`

_ctypes.**shape**

(c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the C-integer corresponding to `dtype('p')` on this platform (see *c_intp*). This base-type could be `ctypes.c_int`, `ctypes.c_long`, or `ctypes.c_longlong` depending on the platform. The ctypes array contains the shape of the underlying array.

_ctypes.**strides**

(c_intp*self.ndim): A ctypes array of length self.ndim where the basetype is the same as for the shape attribute. This ctypes array contains the strides information from the underlying array. This strides information is important for showing how many bytes must be jumped to get to the next element in the array.

_ctypes.**data_as**(*obj*)

Return the data pointer cast to a particular c-types object. For example, calling `self._as_parameter_` is equivalent to `self.data_as(ctypes.c_void_p)`. Perhaps you want to use the data as a pointer to a ctypes array of floating-point data: `self.data_as(ctypes.POINTER(ctypes.c_double))`.

The returned pointer will keep a reference to the array.

_ctypes.**shape_as**(*obj*)

Return the shape tuple as an array of some other c-types type. For example: `self.shape_as(ctypes.c_short)`.

_ctypes.**strides_as**(*obj*)

Return the strides tuple as an array of some other c-types type. For example: `self.strides_as(ctypes.c_longlong)`.

If the ctypes module is not available, then the ctypes attribute of array objects still returns something useful, but ctypes objects are not returned and errors may be raised instead. In particular, the object will still have the `as_parameter` attribute which will return an integer equal to the data attribute.

Examples

```
>>> import numpy as np
>>> import ctypes
>>> x = np.array([[0, 1], [2, 3]], dtype=np.int32)
>>> x
array([[0, 1],
       [2, 3]], dtype=int32)
>>> x.ctypes.data
31962608 # may vary
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_uint32))
<__main__.LP_c_uint object at 0x7ff2fc1fc200> # may vary
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_uint32)).contents
c_uint(0)
>>> x.ctypes.data_as(ctypes.POINTER(ctypes.c_uint64)).contents
c_ulong(4294967296)
>>> x.ctypes.shape
<numpy._core._internal.c_long_Array_2 object at 0x7ff2fc1fce60> # may vary
>>> x.ctypes.strides
<numpy._core._internal.c_long_Array_2 object at 0x7ff2fc1ff320> # may vary
```

property

property ma.MaskedArray.**dtype**

Data-type of the array's elements.

Warning: Setting `arr.dtype` is discouraged and may be deprecated in the future. Setting will replace the `dtype` without modifying the memory (see also *ndarray.view* and *ndarray.astype*).

Parameters

None

Returns

d

[numpy dtype object]

See also:

ndarray.astype

Cast the values contained in the array to a new data-type.

ndarray.view

Create a view of the same data but a different data-type.

numpy.dtype

Examples

```
>>> x
array([[0, 1],
       [2, 3]])
>>> x.dtype
dtype('int32')
>>> type(x.dtype)
<type 'numpy.dtype'>
```

attribute

ma.MaskedArray.**flags**

Information about the memory layout of the array.

Notes

The *flags* object can be accessed dictionary-like (as in `a.flags['WRITEABLE']`), or by using lowercased attribute names (as in `a.flags.writeable`). Short flag names are only supported in dictionary access.

Only the WRITEBACKIFCOPY, WRITEABLE, and ALIGNED flags can be changed by the user, via direct assignment to the attribute or dictionary entry, or by calling *ndarray.setflags*.

The array flags cannot be set arbitrarily:

- WRITEBACKIFCOPY can only be set `False`.
- ALIGNED can only be set `True` if the data is truly aligned.
- WRITEABLE can only be set `True` if the array owns its own memory or the ultimate owner of the memory exposes a writeable buffer interface or is a string.

Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension `arr.strides[dim]` may be *arbitrary* if `arr.shape[dim] == 1` or the array has no elements. It does *not* generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true.

Attributes

C_CONTIGUOUS (C)
The data is in a single, C-style contiguous segment.

F_CONTIGUOUS (F)
The data is in a single, Fortran-style contiguous segment.

OWNDATA (O)
The array owns the memory it uses or borrows it from another object.

WRITEABLE (W)
The data area can be written to. Setting this to False locks the data, making it read-only. A view (slice, etc.) inherits WRITEABLE from its base array at creation time, but a view of a writeable array may be subsequently locked while the base array remains writeable. (The opposite is not true, in that a view of a locked array may not be made writeable. However, currently, locking a base object does not lock any views that already reference it, so under that circumstance it is possible to alter the contents of a locked array via a previously created writeable view onto it.) Attempting to change a non-writeable array raises a RuntimeError exception.

ALIGNED (A)
The data and all elements are aligned appropriately for the hardware.

WRITEBACKIFCOPY (X)
This array is a copy of some other array. The C-API function PyArray_ResolveWritebackIfCopy must be called before deallocating to the base array will be updated with the contents of this array.

FNC
F_CONTIGUOUS and not C_CONTIGUOUS.

FORC
F_CONTIGUOUS or C_CONTIGUOUS (one-segment test).

BEHAVED (B)
ALIGNED and WRITEABLE.

CARRAY (CA)
BEHAVED and C_CONTIGUOUS.

FARRAY (FA)
BEHAVED and F_CONTIGUOUS and not C_CONTIGUOUS.

attribute

ma.MaskedArray.**itemsize**

Length of one array element in bytes.

Examples

```
>>> import numpy as np
>>> x = np.array([1,2,3], dtype=np.float64)
>>> x.itemsize
8
>>> x = np.array([1,2,3], dtype=np.complex128)
>>> x.itemsize
16
```

attribute

ma.MaskedArray.**nbytes**

Total bytes consumed by the elements of the array.

See also:

sys.getsizeof
Memory consumed by the object itself without parents in case view. This does include memory consumed by non-element attributes.

Notes

Does not include memory consumed by non-element attributes of the array object.

Examples

```
>>> import numpy as np
>>> x = np.zeros((3,5,2), dtype=np.complex128)
>>> x.nbytes
480
>>> np.prod(x.shape) * x.itemsize
480
```

attribute

ma.MaskedArray.**ndim**

Number of array dimensions.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 3])
>>> x.ndim
1
>>> y = np.zeros((2, 3, 4))
>>> y.ndim
3
```

property

property ma.MaskedArray.**shape**

Tuple of array dimensions.

The shape property is usually used to get the current shape of an array, but may also be used to reshape the array in-place by assigning a tuple of array dimensions to it. As with *numpy.reshape*, one of the new shape dimensions can be -1, in which case its value is inferred from the size of the array and the remaining dimensions. Reshaping an array in-place will fail if a copy is required.

Warning: Setting `arr.shape` is discouraged and may be deprecated in the future. Using *ndarray.reshape* is the preferred approach.

See also:

numpy.shape
Equivalent getter function.

numpy.reshape
Function similar to setting `shape`.

ndarray.reshape
Method similar to setting `shape`.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 3, 4])
>>> x.shape
(4,)
>>> y = np.zeros((2, 3, 4))
>>> y.shape
(2, 3, 4)
>>> y.shape = (3, 8)
>>> y
array([[ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.]])
>>> y.shape = (3, 6)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: total size of new array must be unchanged
>>> np.zeros((4,2))[::2].shape = (-1,)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: Incompatible shape for in-place modification. Use
`.reshape()` to make a copy with the desired shape.
```

attribute

ma.MaskedArray.**size**

Number of elements in the array.

Equal to `np.prod(a.shape)`, i.e., the product of the array's dimensions.

Notes

a.size returns a standard arbitrary precision Python integer. This may not be the case with other methods of obtaining the same value (like the suggested `np.prod(a.shape)`, which returns an instance of `np.int_`), and may be relevant if the value is used further in calculations that may overflow a fixed size integer type.

Examples

```
>>> import numpy as np
>>> x = np.zeros((3, 5, 2), dtype=np.complex128)
>>> x.size
30
>>> np.prod(x.shape)
30
```

attribute

ma.MaskedArray.**strides**

Tuple of bytes to step in each dimension when traversing an array.

The byte offset of element `(i[0], i[1], ..., i[n])` in an array *a* is:

```
offset = sum(np.array(i) * a.strides)
```

A more detailed explanation of strides can be found in *The N-dimensional array (ndarray)*.

Warning: Setting `arr.strides` is discouraged and may be deprecated in the future. *`numpy.lib.stride_tricks.as_strided`* should be preferred to create a new view of the same data in a safer way.

See also:

`numpy.lib.stride_tricks.as_strided`

Notes

Imagine an array of 32-bit integers (each 4 bytes):

```
x = np.array([[0, 1, 2, 3, 4],
              [5, 6, 7, 8, 9]], dtype=np.int32)
```

This array is stored in memory as 40 bytes, one after the other (known as a contiguous block of memory). The strides of an array tell us how many bytes we have to skip in memory to move to the next position along a certain axis. For example, we have to skip 4 bytes (1 value) to move to the next column, but 20 bytes (5 values) to get to the same position in the next row. As such, the strides for the array *x* will be `(20, 4)`.

Examples

```
>>> import numpy as np
>>> y = np.reshape(np.arange(2*3*4), (2,3,4))
>>> y
array([[[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]],
       [[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]]])
>>> y.strides
(48, 16, 4)
>>> y[1,1,1]
17
>>> offset=sum(y.strides * np.array((1,1,1)))
>>> offset/y.itemsize
17
```

```
>>> x = np.reshape(np.arange(5*6*7*8), (5,6,7,8)).transpose(2,3,1,0)
>>> x.strides
(32, 4, 224, 1344)
>>> i = np.array([3,5,2,2])
>>> offset = sum(i * x.strides)
>>> x[3,5,2,2]
813
>>> offset / x.itemsize
813
```

property

property ma.MaskedArray.**imag**

The imaginary part of the masked array.

This property is a view on the imaginary part of this *MaskedArray*.

See also:

real

Examples

```
>>> import numpy as np
>>> x = np.ma.array([1+1.j, -2j, 3.45+1.6j], mask=[False, True, False])
>>> x.imag
masked_array(data=[1.0, --, 1.6],
             mask=[False,  True, False],
       fill_value=1e+20)
```

property

property ma.MaskedArray.**real**

The real part of the masked array.

This property is a view on the real part of this *MaskedArray*.

See also:

imag

Examples

```
>>> import numpy as np
>>> x = np.ma.array([1+1.j, -2j, 3.45+1.6j], mask=[False, True, False])
>>> x.real
masked_array(data=[1.0, --, 3.45],
             mask=[False,  True, False],
       fill_value=1e+20)
```

property

property ma.MaskedArray.**flat**

Return a flat iterator, or set a flattened version of self to value.

attribute

ma.MaskedArray.**__array_priority__ = 15**

`MaskedArray` methods

See also:

Array methods

Conversion

MaskedArray.__float__()	Convert to float.
MaskedArray.__int__()	Convert to int.
MaskedArray.view([dtype, type, fill_value])	Return a view of the MaskedArray data.
MaskedArray.astype(dtype[, order, casting, ...])	Copy of the array, cast to a specified type.
MaskedArray.byteswap([inplace])	Swap the bytes of the array elements
MaskedArray.compressed()	Return all the non-masked data as a 1-D array.
MaskedArray.filled([fill_value])	Return a copy of self, with masked values filled with a given value.
MaskedArray.tofile(fid[, sep, format])	Save a masked array to a file in binary format.
MaskedArray.toflex()	Transforms a masked array into a flexible-type array.
MaskedArray.tolist([fill_value])	Return the data portion of the masked array as a hierarchical Python list.
MaskedArray.torecords()	Transforms a masked array into a flexible-type array.
MaskedArray.tostring([fill_value, order])	A compatibility alias for *tobytes*, with exactly the same behavior.
MaskedArray.tobytes([fill_value, order])	Return the array data as a string containing the raw bytes in the array.

method

ma.MaskedArray.**__float__**()

Convert to float.

method

ma.MaskedArray.**__int__**()

Convert to int.

method

ma.MaskedArray.**view**(*dtype=None*, *type=None*, *fill_value=None*)

Return a view of the MaskedArray data.

Parameters

dtype

[data-type or ndarray sub-class, optional] Data-type descriptor of the returned view, e.g., float32 or int16. The default, None, results in the view having the same data-type as *a*. As with `ndarray.view`, dtype can also be specified as an ndarray sub-class, which then specifies the type of the returned object (this is equivalent to setting the `type` parameter).

type

[Python type, optional] Type of the returned view, either ndarray or a subclass. The default None results in type preservation.

fill_value

[scalar, optional] The value to use for invalid entries (None by default). If None, then this argument is inferred from the passed *dtype*, or in its absence the original array, as discussed in the notes below.

See also:

numpy.ndarray.view
Equivalent method on ndarray object.

Notes

`a.view()` is used two different ways:

`a.view(some_dtype)` or `a.view(dtype=some_dtype)` constructs a view of the array's memory with a different data-type. This can cause a reinterpretation of the bytes of memory.

`a.view(ndarray_subclass)` or `a.view(type=ndarray_subclass)` just returns an instance of *ndarray_subclass* that looks at the same array (same shape, dtype, etc.) This does not cause a reinterpretation of the memory.

If *fill_value* is not specified, but *dtype* is specified (and is not an ndarray sub-class), the *fill_value* of the MaskedArray will be reset. If neither *fill_value* nor *dtype* are specified (or if *dtype* is an ndarray sub-class), then the fill value is preserved. Finally, if *fill_value* is specified, but *dtype* is not, the fill value is set to the specified value.

For `a.view(some_dtype)`, if `some_dtype` has a different number of bytes per entry than the previous dtype (for example, converting a regular array to a structured array), then the behavior of the view cannot be predicted just from the superficial appearance of `a` (shown by `print(a)`). It also depends on exactly how `a` is stored in memory. Therefore if `a` is C-ordered versus fortran-ordered, versus defined as a slice or transpose, etc., the view may give different results.

method

`ma.MaskedArray.`**`astype`**(*dtype*, *order='K'*, *casting='unsafe'*, *subok=True*, *copy=True*)

Copy of the array, cast to a specified type.

Parameters

dtype
[str or dtype] Typecode or data-type to which the array is cast.

order
[{'C', 'F', 'A', 'K'}, optional] Controls the memory layout order of the result. 'C' means C order, 'F' means Fortran order, 'A' means 'F' order if all the arrays are Fortran contiguous, 'C' order otherwise, and 'K' means as close to the order the array elements appear in memory as possible. Default is 'K'.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'unsafe' for backwards compatibility.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.
- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

subok
[bool, optional] If True, then sub-classes will be passed-through (default), otherwise the returned array will be forced to be a base-class array.

copy
: [bool, optional] By default, astype always returns a newly allocated array. If this is set to false, and the `dtype`, *order*, and *subok* requirements are satisfied, the input array is returned instead of a copy.

Returns

arr_t
: [ndarray] Unless `copy` is False and the other conditions for returning the input array are satisfied (see description for `copy` input parameter), *arr_t* is a new array of the same shape as the input array, with dtype, order given by `dtype`, *order*.

Raises

ComplexWarning
: When casting from complex to float or int. To avoid this, one should use `a.real.astype(t)`.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 2.5])
>>> x
array([1. ,  2. ,  2.5])
```

```
>>> x.astype(int)
array([1, 2, 2])
```

method

`ma.MaskedArray.`**`byteswap`**(*inplace=False*)

Swap the bytes of the array elements

Toggle between low-endian and big-endian data representation by returning a byteswapped array, optionally swapped in-place. Arrays of byte-strings are not swapped. The real and imaginary parts of a complex number are swapped individually.

Parameters

inplace
: [bool, optional] If `True`, swap bytes in-place, default is `False`.

Returns

out
: [ndarray] The byteswapped array. If *inplace* is `True`, this is a view to self.

Examples

```
>>> import numpy as np
>>> A = np.array([1, 256, 8755], dtype=np.int16)
>>> list(map(hex, A))
['0x1', '0x100', '0x2233']
>>> A.byteswap(inplace=True)
array([  256,     1, 13090], dtype=int16)
>>> list(map(hex, A))
['0x100', '0x1', '0x3322']
```

Arrays of byte-strings are not swapped

```
>>> A = np.array([b'ceg', b'fac'])
>>> A.byteswap()
array([b'ceg', b'fac'], dtype='|S3')
```

`A.view(A.dtype.newbyteorder()).byteswap()` produces an array with the same values but different representation in memory

```
>>> A = np.array([1, 2, 3],dtype=np.int64)
>>> A.view(np.uint8)
array([1, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0, 0, 3, 0, 0, 0, 0, 0,
       0, 0], dtype=uint8)
>>> A.view(A.dtype.newbyteorder()).byteswap(inplace=True)
array([1, 2, 3], dtype='>i8')
>>> A.view(np.uint8)
array([0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 2, 0, 0, 0, 0, 0, 0,
       0, 3], dtype=uint8)
```

method

`ma.MaskedArray.`**`toflex`**`()`

Transforms a masked array into a flexible-type array.

The flexible type array that is returned will have two fields:

- the `_data` field stores the `_data` part of the array.
- the `_mask` field stores the `_mask` part of the array.

Parameters

None

Returns

record

[ndarray] A new flexible-type *ndarray* with two fields: the first element containing a value, the second element containing the corresponding mask boolean. The returned record shape matches self.shape.

Notes

A side-effect of transforming a masked array into a flexible *ndarray* is that meta information (`fill_value`, …) will be lost.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> x
masked_array(
  data=[[1, --, 3],
        [--, 5, --],
        [7, --, 9]],
  mask=[[False,  True, False],
        [ True, False,  True],
```

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```
       [False,  True, False]],
  fill_value=999999)
>>> x.toflex()
array([[(1, False), (2,  True), (3, False)],
       [(4,  True), (5, False), (6,  True)],
       [(7, False), (8,  True), (9, False)]],
      dtype=[('_data', '<i8'), ('_mask', '?')])
```

method

ma.MaskedArray.**tostring**(*fill_value=None*, *order='C'*)

A compatibility alias for *tobytes*, with exactly the same behavior.

Despite its name, it returns *bytes* not *str*s.

Deprecated since version 1.19.0.

Shape manipulation

For reshape, resize, and transpose, the single tuple argument may be replaced with `n` integers which will be interpreted as an n-tuple.

MaskedArray.flatten([order])	Return a copy of the array collapsed into one dimension.
MaskedArray.ravel([order])	Returns a 1D version of self, as a view.
MaskedArray.reshape(*s, **kwargs)	Give a new shape to the array without changing its data.
MaskedArray.resize(newshape[, refcheck, order])	
MaskedArray.squeeze([axis])	Remove axes of length one from *a*.
MaskedArray.swapaxes(axis1, axis2)	Return a view of the array with *axis1* and *axis2* interchanged.
MaskedArray.transpose(*axes)	Returns a view of the array with axes transposed.
MaskedArray.T	View of the transposed array.

property

property ma.MaskedArray.**T**

View of the transposed array.

Same as `self.transpose()`.

See also:

transpose

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> a.T
array([[1, 3],
       [2, 4]])
```

```
>>> a = np.array([1, 2, 3, 4])
>>> a
array([1, 2, 3, 4])
>>> a.T
array([1, 2, 3, 4])
```

Item selection and manipulation

For array methods that take an `axis` keyword, it defaults to None. If axis is None, then the array is treated as a 1-D array. Any other value for `axis` represents the dimension along which the operation should proceed.

MaskedArray.argmax([axis, fill_value, out, ...])	Returns array of indices of the maximum values along the given axis.
MaskedArray.argmin([axis, fill_value, out, ...])	Return array of indices to the minimum values along the given axis.
MaskedArray.argsort([axis, kind, order, ...])	Return an ndarray of indices that sort the array along the specified axis.
MaskedArray.choose(choices[, out, mode])	Use an index array to construct a new array from a set of choices.
MaskedArray.compress(condition[, axis, out])	Return *a* where condition is `True`.
MaskedArray.diagonal([offset, axis1, axis2])	Return specified diagonals.
MaskedArray.fill(value)	Fill the array with a scalar value.
MaskedArray.item(*args)	Copy an element of an array to a standard Python scalar and return it.
MaskedArray.nonzero()	Return the indices of unmasked elements that are not zero.
MaskedArray.put(indices, values[, mode])	Set storage-indexed locations to corresponding values.
MaskedArray.repeat(repeats[, axis])	Repeat elements of an array.
MaskedArray.searchsorted(v[, side, sorter])	Find indices where elements of v should be inserted in a to maintain order.
MaskedArray.sort([axis, kind, order, ...])	Sort the array, in-place
MaskedArray.take(indices[, axis, out, mode])	Take elements from a masked array along an axis.

method

`ma.MaskedArray.`**`choose`**(*choices*, *out=None*, *mode='raise'*)

Use an index array to construct a new array from a set of choices.

Refer to *numpy.choose* for full documentation.

See also:

numpy.choose
equivalent function

method

`ma.MaskedArray.`**`compress`**(*condition*, *axis=None*, *out=None*)

Return *a* where condition is `True`.

If condition is a *MaskedArray*, missing values are considered as `False`.

Parameters

condition
[var] Boolean 1-d array selecting which entries to return. If len(condition) is less than the size of a along the axis, then output is truncated to length of condition array.

axis
[{None, int}, optional] Axis along which the operation must be performed.

out
[{None, ndarray}, optional] Alternative output array in which to place the result. It must have the same shape as the expected output but the type will be cast if necessary.

Returns

result
[MaskedArray] A *MaskedArray* object.

Notes

Please note the difference with *compressed* ! The output of *compress* has a mask, the output of *compressed* does not.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> x
masked_array(
  data=[[1, --, 3],
        [--, 5, --],
        [7, --, 9]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
>>> x.compress([1, 0, 1])
masked_array(data=[1, 3],
             mask=[False, False],
       fill_value=999999)
```

```
>>> x.compress([1, 0, 1], axis=1)
masked_array(
  data=[[1, 3],
        [--, --],
        [7, 9]],
  mask=[[False, False],
        [ True,  True],
        [False, False]],
  fill_value=999999)
```

method

ma.MaskedArray.**diagonal**(*offset=0*, *axis1=0*, *axis2=1*)

Return specified diagonals. In NumPy 1.9 the returned array is a read-only view instead of a copy as in previous NumPy versions. In a future version the read-only restriction will be removed.

Refer to *numpy.diagonal* for full documentation.

See also:

numpy.diagonal
equivalent function

method

ma.MaskedArray.**fill**(*value*)

Fill the array with a scalar value.

Parameters

value
[scalar] All elements of *a* will be assigned this value.

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2])
>>> a.fill(0)
>>> a
array([0, 0])
>>> a = np.empty(2)
>>> a.fill(1)
>>> a
array([1.,  1.])
```

Fill expects a scalar value and always behaves the same as assigning to a single array element. The following is a rare example where this distinction is important:

```
>>> a = np.array([None, None], dtype=object)
>>> a[0] = np.array(3)
>>> a
array([array(3), None], dtype=object)
>>> a.fill(np.array(3))
>>> a
array([array(3), array(3)], dtype=object)
```

Where other forms of assignments will unpack the array being assigned:

```
>>> a[...] = np.array(3)
>>> a
array([3, 3], dtype=object)
```

method

ma.MaskedArray.**item**(**args*)

Copy an element of an array to a standard Python scalar and return it.

Parameters

***args**
[Arguments (variable number and type)]

- none: in this case, the method only works for arrays with one element (*a.size == 1*), which element is copied into a standard Python scalar object and returned.
- int_type: this argument is interpreted as a flat index into the array, specifying which element to copy and return.

- tuple of int_types: functions as does a single int_type argument, except that the argument is interpreted as an nd-index into the array.

Returns

z

[Standard Python scalar object] A copy of the specified element of the array as a suitable Python scalar

Notes

When the data type of *a* is longdouble or clongdouble, item() returns a scalar array object because there is no available Python scalar that would not lose information. Void arrays return a buffer object for item(), unless fields are defined, in which case a tuple is returned.

item is very similar to a[args], except, instead of an array scalar, a standard Python scalar is returned. This can be useful for speeding up access to elements of the array and doing arithmetic on elements of the array using Python's optimized math.

Examples

```
>>> import numpy as np
>>> np.random.seed(123)
>>> x = np.random.randint(9, size=(3, 3))
>>> x
array([[2, 2, 6],
       [1, 3, 6],
       [1, 0, 1]])
>>> x.item(3)
1
>>> x.item(7)
0
>>> x.item((0, 1))
2
>>> x.item((2, 2))
1
```

For an array with object dtype, elements are returned as-is.

```
>>> a = np.array([np.int64(1)], dtype=object)
>>> a.item() #return np.int64
np.int64(1)
```

method

ma.MaskedArray.**put**(*indices*, *values*, *mode='raise'*)

Set storage-indexed locations to corresponding values.

Sets self._data.flat[n] = values[n] for each n in indices. If *values* is shorter than *indices* then it will repeat. If *values* has some masked values, the initial mask is updated in consequence, else the corresponding values are unmasked.

Parameters

indices

[1-D array_like] Target indices, interpreted as integers.

values
[array_like] Values to place in self._data copy at target indices.

mode
[{'raise', 'wrap', 'clip'}, optional] Specifies how out-of-bounds indices will behave. 'raise' : raise an error. 'wrap' : wrap around. 'clip' : clip to the range.

Notes

values can be a scalar or length 1 array.

Examples

```
>>> import numpy as np
>>> x = np.ma.array([[1,2,3],[4,5,6],[7,8,9]], mask=[0] + [1,0]*4)
>>> x
masked_array(
  data=[[1, --, 3],
        [--, 5, --],
        [7, --, 9]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
>>> x.put([0,4,8],[10,20,30])
>>> x
masked_array(
  data=[[10, --, 3],
        [--, 20, --],
        [7, --, 30]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
```

```
>>> x.put(4,999)
>>> x
masked_array(
  data=[[10, --, 3],
        [--, 999, --],
        [7, --, 30]],
  mask=[[False,  True, False],
        [ True, False,  True],
        [False,  True, False]],
  fill_value=999999)
```

method

ma.MaskedArray.**repeat**(*repeats*, *axis=None*)

Repeat elements of an array.

Refer to *numpy.repeat* for full documentation.

See also:

numpy.repeat
equivalent function

method

ma.MaskedArray.**searchsorted**(*v*, *side='left'*, *sorter=None*)

Find indices where elements of v should be inserted in a to maintain order.

For full documentation, see *numpy.searchsorted*

See also:

numpy.searchsorted
equivalent function

method

ma.MaskedArray.**take**(*indices*, *axis=None*, *out=None*, *mode='raise'*)

Take elements from a masked array along an axis.

This function does the same thing as "fancy" indexing (indexing arrays using arrays) for masked arrays. It can be easier to use if you need elements along a given axis.

Parameters

a
[masked_array] The source masked array.

indices
[array_like] The indices of the values to extract. Also allow scalars for indices.

axis
[int, optional] The axis over which to select values. By default, the flattened input array is used.

out
[MaskedArray, optional] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype. Note that *out* is always buffered if *mode='raise'*; use other modes for better performance.

mode
[{'raise', 'wrap', 'clip'}, optional] Specifies how out-of-bounds indices will behave.

- 'raise' – raise an error (default)
- 'wrap' – wrap around
- 'clip' – clip to the range

'clip' mode means that all indices that are too large are replaced by the index that addresses the last element along that axis. Note that this disables indexing with negative numbers.

Returns

out
[MaskedArray] The returned array has the same type as *a*.

See also:

numpy.take
Equivalent function for ndarrays.

compress
Take elements using a boolean mask.

take_along_axis
Take elements by matching the array and the index arrays.

Notes

This function behaves similarly to *numpy.take*, but it handles masked values. The mask is retained in the output array, and masked values in the input array remain masked in the output.

Examples

```
>>> import numpy as np
>>> a = np.ma.array([4, 3, 5, 7, 6, 8], mask=[0, 0, 1, 0, 1, 0])
>>> indices = [0, 1, 4]
>>> np.ma.take(a, indices)
masked_array(data=[4, 3, --],
             mask=[False, False,  True],
    fill_value=999999)
```

When *indices* is not one-dimensional, the output also has these dimensions:

```
>>> np.ma.take(a, [[0, 1], [2, 3]])
masked_array(data=[[4, 3],
                  [--, 7]],
             mask=[[False, False],
                   [ True, False]],
    fill_value=999999)
```

Pickling and copy

MaskedArray.copy([order])	Return a copy of the array.
MaskedArray.dump(file)	Dump a pickle of the array to the specified file.
MaskedArray.dumps()	Returns the pickle of the array as a string.

method

ma.MaskedArray.**dump**(*file*)

Dump a pickle of the array to the specified file. The array can be read back with pickle.load or numpy.load.

Parameters

file
[str or Path] A string naming the dump file.

method

ma.MaskedArray.**dumps**()

Returns the pickle of the array as a string. pickle.loads will convert the string back to an array.

Parameters

None

Calculations

MaskedArray.all([axis, out, keepdims])	Returns True if all elements evaluate to True.
MaskedArray.anom([axis, dtype])	Compute the anomalies (deviations from the arithmetic mean) along the given axis.
MaskedArray.any([axis, out, keepdims])	Returns True if any of the elements of *a* evaluate to True.
MaskedArray.clip([min, max, out])	Return an array whose values are limited to `[min, max]`.
MaskedArray.conj()	Complex-conjugate all elements.
MaskedArray.conjugate()	Return the complex conjugate, element-wise.
MaskedArray.cumprod([axis, dtype, out])	Return the cumulative product of the array elements over the given axis.
MaskedArray.cumsum([axis, dtype, out])	Return the cumulative sum of the array elements over the given axis.
MaskedArray.max([axis, out, fill_value, ...])	Return the maximum along a given axis.
MaskedArray.mean([axis, dtype, out, keepdims])	Returns the average of the array elements along given axis.
MaskedArray.min([axis, out, fill_value, ...])	Return the minimum along a given axis.
MaskedArray.prod([axis, dtype, out, keepdims])	Return the product of the array elements over the given axis.
MaskedArray.product([axis, dtype, out, keepdims])	Return the product of the array elements over the given axis.
MaskedArray.ptp([axis, out, fill_value, ...])	Return (maximum - minimum) along the given dimension (i.e. peak-to-peak value).
MaskedArray.round([decimals, out])	Return each element rounded to the given number of decimals.
MaskedArray.std([axis, dtype, out, ddof, ...])	Returns the standard deviation of the array elements along given axis.
MaskedArray.sum([axis, dtype, out, keepdims])	Return the sum of the array elements over the given axis.
MaskedArray.trace([offset, axis1, axis2, ...])	Return the sum along diagonals of the array.
MaskedArray.var([axis, dtype, out, ddof, ...])	Compute the variance along the specified axis.

method

ma.MaskedArray.**conj**()

Complex-conjugate all elements.

Refer to *numpy.conjugate* for full documentation.

See also:

numpy.conjugate
equivalent function

method

ma.MaskedArray.**conjugate**()

Return the complex conjugate, element-wise.

Refer to *numpy.conjugate* for full documentation.

See also:

numpy.conjugate
equivalent function

method

ma.MaskedArray.**product**(*axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*)

Return the product of the array elements over the given axis.

Masked elements are set to 1 internally for computation.

Refer to *numpy.prod* for full documentation.

See also:

numpy.ndarray.prod
corresponding function for ndarrays

numpy.prod
equivalent function

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

Arithmetic and comparison operations

Comparison operators:

MaskedArray.__lt__(other)	Return self<value.
MaskedArray.__le__(other)	Return self<=value.
MaskedArray.__gt__(other)	Return self>value.
MaskedArray.__ge__(other)	Return self>=value.
MaskedArray.__eq__(other)	Check whether other equals self elementwise.
MaskedArray.__ne__(other)	Check whether other does not equal self elementwise.

method

ma.MaskedArray.**__lt__**(*other*)

Return self<value.

method

ma.MaskedArray.**__le__**(*other*)

Return self<=value.

method

ma.MaskedArray.**__gt__**(*other*)

Return self>value.

method

ma.MaskedArray.**__ge__**(*other*)

Return self>=value.

method

ma.MaskedArray.**__eq__**(*other*)

Check whether other equals self elementwise.

When either of the elements is masked, the result is masked as well, but the underlying boolean data are still set, with self and other considered equal if both are masked, and unequal otherwise.

For structured arrays, all fields are combined, with masked values ignored. The result is masked if all fields were masked, with self and other considered equal only if both were fully masked.

method

ma.MaskedArray.**__ne__**(*other*)

Check whether other does not equal self elementwise.

When either of the elements is masked, the result is masked as well, but the underlying boolean data are still set, with self and other considered equal if both are masked, and unequal otherwise.

For structured arrays, all fields are combined, with masked values ignored. The result is masked if all fields were masked, with self and other considered equal only if both were fully masked.

Truth value of an array (`bool()`):

MaskedArray.__bool__(/)	True if self else False

method

ma.MaskedArray.**__bool__**(/)

True if self else False

Arithmetic:

MaskedArray.__abs__(self)	
MaskedArray.__add__(other)	Add self to other, and return a new masked array.
MaskedArray.__radd__(other)	Add other to self, and return a new masked array.
MaskedArray.__sub__(other)	Subtract other from self, and return a new masked array.
MaskedArray.__rsub__(other)	Subtract self from other, and return a new masked array.
MaskedArray.__mul__(other)	Multiply self by other, and return a new masked array.
MaskedArray.__rmul__(other)	Multiply other by self, and return a new masked array.
MaskedArray.__div__(other)	Divide other into self, and return a new masked array.
MaskedArray.__truediv__(other)	Divide other into self, and return a new masked array.
MaskedArray.__rtruediv__(other)	Divide self into other, and return a new masked array.
MaskedArray.__floordiv__(other)	Divide other into self, and return a new masked array.
MaskedArray.__rfloordiv__(other)	Divide self into other, and return a new masked array.
MaskedArray.__mod__(value, /)	Return self%value.
MaskedArray.__rmod__(value, /)	Return value%self.
MaskedArray.__divmod__(value, /)	Return divmod(self, value).
MaskedArray.__rdivmod__(value, /)	Return divmod(value, self).
MaskedArray.__pow__(other)	Raise self to the power other, masking the potential NaNs/Infs
MaskedArray.__rpow__(other)	Raise other to the power self, masking the potential NaNs/Infs
MaskedArray.__lshift__(value, /)	Return self<<value.
MaskedArray.__rlshift__(value, /)	Return value<<self.
MaskedArray.__rshift__(value, /)	Return self>>value.
MaskedArray.__rrshift__(value, /)	Return value>>self.
MaskedArray.__and__(value, /)	Return self&value.
MaskedArray.__rand__(value, /)	Return value&self.
MaskedArray.__or__(value, /)	Return self|value.
MaskedArray.__ror__(value, /)	Return value|self.
MaskedArray.__xor__(value, /)	Return self^value.
MaskedArray.__rxor__(value, /)	Return value^self.

method

ma.MaskedArray.**__abs__**(*self*)

method

ma.MaskedArray.**__add__**(*other*)

Add self to other, and return a new masked array.

method

ma.MaskedArray.**__radd__**(*other*)

Add other to self, and return a new masked array.

method

ma.MaskedArray.**__sub__**(*other*)

Subtract other from self, and return a new masked array.

method

ma.MaskedArray.**__rsub__**(*other*)

Subtract self from other, and return a new masked array.

method

ma.MaskedArray.**__mul__**(*other*)

Multiply self by other, and return a new masked array.

method

ma.MaskedArray.**__rmul__**(*other*)

Multiply other by self, and return a new masked array.

method

ma.MaskedArray.**__div__**(*other*)

Divide other into self, and return a new masked array.

method

ma.MaskedArray.**__truediv__**(*other*)

Divide other into self, and return a new masked array.

method

ma.MaskedArray.**__rtruediv__**(*other*)

Divide self into other, and return a new masked array.

method

ma.MaskedArray.**__floordiv__**(*other*)

Divide other into self, and return a new masked array.

method

ma.MaskedArray.**__rfloordiv__**(*other*)

Divide self into other, and return a new masked array.

method

ma.MaskedArray.**__mod__**(*value*, */*)

Return self%value.

method

ma.MaskedArray.**__rmod__**(*value*, */*)

Return value%self.

method

ma.MaskedArray.**__divmod__**(*value*, */*)

Return divmod(self, value).

method

ma.MaskedArray.**__rdivmod__**(*value*, */*)

Return divmod(value, self).

method

ma.MaskedArray.**__pow__**(*other*)

Raise self to the power other, masking the potential NaNs/Infs

method

ma.MaskedArray.**__rpow__**(*other*)

Raise other to the power self, masking the potential NaNs/Infs

method

ma.MaskedArray.**__lshift__**(*value*, /)

Return self<<value.

method

ma.MaskedArray.**__rlshift__**(*value*, /)

Return value<<self.

method

ma.MaskedArray.**__rshift__**(*value*, /)

Return self>>value.

method

ma.MaskedArray.**__rrshift__**(*value*, /)

Return value>>self.

method

ma.MaskedArray.**__and__**(*value*, /)

Return self&value.

method

ma.MaskedArray.**__rand__**(*value*, /)

Return value&self.

method

ma.MaskedArray.**__or__**(*value*, /)

Return self|value.

method

ma.MaskedArray.**__ror__**(*value*, /)

Return value|self.

method

ma.MaskedArray.**__xor__**(*value*, /)

Return self^value.

method

ma.MaskedArray.**__rxor__**(*value*, /)

Return value^self.

Arithmetic, in-place:

MaskedArray.__iadd__(other)	Add other to self in-place.
MaskedArray.__isub__(other)	Subtract other from self in-place.
MaskedArray.__imul__(other)	Multiply self by other in-place.
MaskedArray.__idiv__(other)	Divide self by other in-place.
MaskedArray.__itruediv__(other)	True divide self by other in-place.
MaskedArray.__ifloordiv__(other)	Floor divide self by other in-place.
MaskedArray.__imod__(value, /)	Return self%=value.
MaskedArray.__ipow__(other)	Raise self to the power other, in place.
MaskedArray.__ilshift__(value, /)	Return self<<=value.
MaskedArray.__irshift__(value, /)	Return self>>=value.
MaskedArray.__iand__(value, /)	Return self&=value.
MaskedArray.__ior__(value, /)	Return self|=value.
MaskedArray.__ixor__(value, /)	Return self^=value.

method

ma.MaskedArray.**__iadd__**(*other*)

Add other to self in-place.

method

ma.MaskedArray.**__isub__**(*other*)

Subtract other from self in-place.

method

ma.MaskedArray.**__imul__**(*other*)

Multiply self by other in-place.

method

ma.MaskedArray.**__idiv__**(*other*)

Divide self by other in-place.

method

ma.MaskedArray.**__itruediv__**(*other*)

True divide self by other in-place.

method

ma.MaskedArray.**__ifloordiv__**(*other*)

Floor divide self by other in-place.

method

ma.MaskedArray.**__imod__**(*value*, */*)

Return self%=value.

method

ma.MaskedArray.**__ipow__**(*other*)

Raise self to the power other, in place.

method

ma.MaskedArray.**__ilshift__**(*value*, */*)

Return self<<=value.

method

ma.MaskedArray.**__irshift__**(*value*, */*)

Return self>>=value.

method

ma.MaskedArray.**__iand__**(*value*, */*)

Return self&=value.

method

ma.MaskedArray.**__ior__**(*value*, */*)

Return self|=value.

method

ma.MaskedArray.**__ixor__**(*value*, */*)

Return self^=value.

Representation

MaskedArray.__repr__()	Literal string representation.
MaskedArray.__str__()	Return str(self).
MaskedArray.ids()	Return the addresses of the data and mask areas.
MaskedArray.iscontiguous()	Return a boolean indicating whether the data is contiguous.

method

ma.MaskedArray.**__repr__**()

Literal string representation.

method

ma.MaskedArray.**__str__**()

Return str(self).

method

ma.MaskedArray.**ids**()

Return the addresses of the data and mask areas.

Parameters

None

Examples

```
>>> import numpy as np
>>> x = np.ma.array([1, 2, 3], mask=[0, 1, 1])
>>> x.ids()
(166670640, 166659832) # may vary
```

If the array has no mask, the address of *nomask* is returned. This address is typically not close to the data in memory:

```
>>> x = np.ma.array([1, 2, 3])
>>> x.ids()
(166691080, 3083169284) # may vary
```

method

ma.MaskedArray.**iscontiguous**()

Return a boolean indicating whether the data is contiguous.

Parameters

None

Examples

```
>>> import numpy as np
>>> x = np.ma.array([1, 2, 3])
>>> x.iscontiguous()
True
```

iscontiguous returns one of the flags of the masked array:

```
>>> x.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : True
  OWNDATA : False
  WRITEABLE : True
  ALIGNED : True
  WRITEBACKIFCOPY : False
```

Special methods

For standard library functions:

MaskedArray.__copy__()	Used if copy.copy is called on an array.
MaskedArray.__deepcopy__(memo, /)	Used if copy.deepcopy is called on an array.
MaskedArray.__getstate__()	Return the internal state of the masked array, for pickling purposes.
MaskedArray.__reduce__()	Return a 3-tuple for pickling a MaskedArray.
MaskedArray.__setstate__(state)	Restore the internal state of the masked array, for pickling purposes.

method

ma.MaskedArray.**__copy__**()

Used if copy.copy is called on an array. Returns a copy of the array.

Equivalent to a.copy(order='K').

method

ma.MaskedArray.**__deepcopy__**(*memo*, /)

Used if copy.deepcopy is called on an array.

method

ma.MaskedArray.**__getstate__**()

Return the internal state of the masked array, for pickling purposes.

method

ma.MaskedArray.**__reduce__**()

Return a 3-tuple for pickling a MaskedArray.

method

ma.MaskedArray.**__setstate__**(*state*)

Restore the internal state of the masked array, for pickling purposes. state is typically the output of the __getstate__ output, and is a 5-tuple:

- class name
- a tuple giving the shape of the data
- a typecode for the data
- a binary string for the data
- a binary string for the mask.

Basic customization:

MaskedArray.__new__(cls[, data, mask, ...])	Create a new masked array from scratch.
MaskedArray.__array__([dtype], *[, copy])	For dtype parameter it returns a new reference to self if dtype is not given or it matches array's data type.
MaskedArray.__array_wrap__(obj[, context, ...])	Special hook for ufuncs.

method

static ma.MaskedArray.**__new__**(*cls*, *data=None*, *mask=np.False_*, *dtype=None*, *copy=False*, *subok=True*, *ndmin=0*, *fill_value=None*, *keep_mask=True*, *hard_mask=None*, *shrink=True*, *order=None*)

Create a new masked array from scratch.

Notes

A masked array can also be created by taking a .view(MaskedArray).

method

ma.MaskedArray.**__array__**([*dtype*,]*, *copy=None*)

For `dtype` parameter it returns a new reference to self if `dtype` is not given or it matches array's data type. A new array of provided data type is returned if `dtype` is different from the current data type of the array. For `copy` parameter it returns a new reference to self if `copy=False` or `copy=None` and copying isn't enforced by `dtype` parameter. The method returns a new array for `copy=True`, regardless of `dtype` parameter.

A more detailed explanation of the `__array__` interface can be found in dunder_array.interface.

method

ma.MaskedArray.**__array_wrap__**(*obj*, *context=None*, *return_scalar=False*)

Special hook for ufuncs.

Wraps the numpy array and sets the mask according to context.

Container customization: (see *Indexing*)

MaskedArray.__len__(/)	Return len(self).
MaskedArray.__getitem__(indx)	x.__getitem__(y) <==> x[y]
MaskedArray.__setitem__(indx, value)	x.__setitem__(i, y) <==> x[i]=y
MaskedArray.__delitem__(key, /)	Delete self[key].
MaskedArray.__contains__(key, /)	Return key in self.

method

ma.MaskedArray.**__len__**(/)

Return len(self).

method

ma.MaskedArray.**__getitem__**(*indx*)

x.__getitem__(y) <==> x[y]

Return the item described by i, as a masked array.

method

ma.MaskedArray.**__setitem__**(*indx*, *value*)

x.__setitem__(i, y) <==> x[i]=y

Set item described by index. If value is masked, masks those locations.

method

ma.MaskedArray.**__delitem__**(*key*, /)

Delete self[key].

method

ma.MaskedArray.**__contains__**(*key*, /)

Return key in self.

Specific methods

Handling the mask

The following methods can be used to access information about the mask or to manipulate the mask.

MaskedArray.__setmask__(mask[, copy])	Set the mask.
MaskedArray.harden_mask()	Force the mask to hard, preventing unmasking by assignment.
MaskedArray.soften_mask()	Force the mask to soft (default), allowing unmasking by assignment.
MaskedArray.unshare_mask()	Copy the mask and set the *sharedmask* flag to `False`.
MaskedArray.shrink_mask()	Reduce a mask to nomask when possible.

method

`ma.MaskedArray.__setmask__`(*mask*, *copy=False*)

Set the mask.

Handling the *fill_value*

MaskedArray.get_fill_value()	The filling value of the masked array is a scalar.
MaskedArray.set_fill_value([value])	

Counting the missing elements

MaskedArray.count([axis, keepdims])	Count the non-masked elements of the array along the given axis.

1.2.8 The array interface protocol

Note: This page describes the NumPy-specific API for accessing the contents of a NumPy array from other C extensions. **PEP 3118** – `The Revised Buffer Protocol` introduces similar, standardized API to Python 2.6 and 3.0 for any extension module to use. Cython's buffer array support uses the **PEP 3118** API; see the Cython NumPy tutorial. Cython provides a way to write code that supports the buffer protocol with Python versions older than 2.6 because it has a backward-compatible implementation utilizing the array interface described here.

version
3

The array interface (sometimes called array protocol) was created in 2005 as a means for array-like Python objects to reuse each other's data buffers intelligently whenever possible. The homogeneous N-dimensional array interface is a default mechanism for objects to share N-dimensional array memory and information. The interface consists of a Python-side and a C-side using two attributes. Objects wishing to be considered an N-dimensional array in application code should

support at least one of these attributes. Objects wishing to support an N-dimensional array in application code should look for at least one of these attributes and use the information provided appropriately.

This interface describes homogeneous arrays in the sense that each item of the array has the same "type". This type can be very simple or it can be a quite arbitrary and complicated C-like structure.

There are two ways to use the interface: A Python side and a C-side. Both are separate attributes.

Python side

This approach to the interface consists of the object having an *__array_interface__* attribute.

`object.`**`__array_interface__`**

A dictionary of items (3 required and 5 optional). The optional keys in the dictionary have implied defaults if they are not provided.

The keys are:

shape (required)

Tuple whose elements are the array size in each dimension. Each entry is an integer (a Python `int`). Note that these integers could be larger than the platform `int` or `long` could hold (a Python `int` is a C `long`). It is up to the code using this attribute to handle this appropriately; either by raising an error when overflow is possible, or by using `long long` as the C type for the shapes.

typestr (required)

A string providing the basic type of the homogeneous array The basic string format consists of 3 parts: a character describing the byteorder of the data (<: little-endian, >: big-endian, `|`: not-relevant), a character code giving the basic type of the array, and an integer providing the number of bytes the type uses.

The basic type character codes are:

`t`	Bit field (following integer gives the number of bits in the bit field).
`b`	Boolean (integer type where all values are only `True` or `False`)
`i`	Integer
`u`	Unsigned integer
`f`	Floating point
`c`	Complex floating point
`m`	Timedelta
`M`	Datetime
`O`	Object (i.e. the memory contains a pointer to `PyObject`)
`S`	String (fixed-length sequence of char)
`U`	Unicode (fixed-length sequence of `Py_UCS4`)
`V`	Other (void * – each item is a fixed-size chunk of memory)

descr (optional)

A list of tuples providing a more detailed description of the memory layout for each item in the homogeneous array. Each tuple in the list has two or three elements. Normally, this attribute would be used when *typestr* is `V[0-9]+`, but this is not a requirement. The only requirement is that the number of bytes represented in the *typestr* key is the same as the total number of bytes represented here. The idea is to support descriptions of C-like structs that make up array elements. The elements of each tuple in the list are

1. A string providing a name associated with this portion of the datatype. This could also be a tuple of `('full name', 'basic_name')` where basic name would be a valid Python variable name representing the full name of the field.

2. Either a basic-type description string as in *typestr* or another list (for nested structured types)

3. An optional shape tuple providing how many times this part of the structure should be repeated. No repeats are assumed if this is not given. Very complicated structures can be described using this generic interface. Notice, however, that each element of the array is still of the same data-type. Some examples of using this interface are given below.

Default: `[('', typestr)]`

data (optional)
A 2-tuple whose first argument is a Python integer that points to the data-area storing the array contents.

Note: When converting from C/C++ via `PyLong_From*` or high-level bindings such as Cython or pybind11, make sure to use an integer of sufficiently large bitness.

This pointer must point to the first element of data (in other words any offset is always ignored in this case). The second entry in the tuple is a read-only flag (true means the data area is read-only).

This attribute can also be an object exposing the buffer interface which will be used to share the data. If this key is not present (or returns None), then memory sharing will be done through the buffer interface of the object itself. In this case, the offset key can be used to indicate the start of the buffer. A reference to the object exposing the array interface must be stored by the new object if the memory area is to be secured.

Default: `None`

strides (optional)
Either `None` to indicate a C-style contiguous array or a tuple of strides which provides the number of bytes needed to jump to the next array element in the corresponding dimension. Each entry must be an integer (a Python `int`). As with shape, the values may be larger than can be represented by a C `int` or `long`; the calling code should handle this appropriately, either by raising an error, or by using `long long` in C. The default is `None` which implies a C-style contiguous memory buffer. In this model, the last dimension of the array varies the fastest. For example, the default strides tuple for an object whose array entries are 8 bytes long and whose shape is `(10, 20, 30)` would be `(4800, 240, 8)`.

Default: `None` (C-style contiguous)

mask (optional)
`None` or an object exposing the array interface. All elements of the mask array should be interpreted only as true or not true indicating which elements of this array are valid. The shape of this object should be *"broadcastable"* to the shape of the original array.

Default: `None` (All array values are valid)

offset (optional)
An integer offset into the array data region. This can only be used when data is `None` or returns a `memoryview` object.

Default: `0`.

version (required)
An integer showing the version of the interface (i.e. 3 for this version). Be careful not to use this to invalidate objects exposing future versions of the interface.

C-struct access

This approach to the array interface allows for faster access to an array using only one attribute lookup and a well-defined C-structure.

`object.__array_struct__`

A `PyCapsule` whose `pointer` member contains a pointer to a filled *`PyArrayInterface`* structure. Memory for the structure is dynamically created and the `PyCapsule` is also created with an appropriate destructor so the retriever of this attribute simply has to apply `Py_DECREF` to the object returned by this attribute when it is finished. Also, either the data needs to be copied out, or a reference to the object exposing this attribute must be held to ensure the data is not freed. Objects exposing the *`__array_struct__`* interface must also not reallocate their memory if other objects are referencing them.

The *`PyArrayInterface`* structure is defined in `numpy/ndarrayobject.h` as:

```
typedef struct {
  int two;              /* contains the integer 2 -- simple sanity check */
  int nd;               /* number of dimensions */
  char typekind;        /* kind in array --- character code of typestr */
  int itemsize;         /* size of each element */
  int flags;            /* flags indicating how the data should be interpreted */
                        /*   must set ARR_HAS_DESCR bit to validate descr */
  Py_ssize_t *shape;    /* A length-nd array of shape information */
  Py_ssize_t *strides;  /* A length-nd array of stride information */
  void *data;           /* A pointer to the first element of the array */
  PyObject *descr;      /* NULL or data-description (same as descr key
                           of __array_interface__) -- must set ARR_HAS_DESCR
                           flag or this will be ignored. */
} PyArrayInterface;
```

The flags member may consist of 5 bits showing how the data should be interpreted and one bit showing how the Interface should be interpreted. The data-bits are *`NPY_ARRAY_C_CONTIGUOUS`* (0x1), *`NPY_ARRAY_F_CONTIGUOUS`* (0x2), *`NPY_ARRAY_ALIGNED`* (0x100), *`NPY_ARRAY_NOTSWAPPED`* (0x200), and *`NPY_ARRAY_WRITEABLE`* (0x400). A final flag *`NPY_ARR_HAS_DESCR`* (0x800) indicates whether or not this structure has the arrdescr field. The field should not be accessed unless this flag is present.

`NPY_ARR_HAS_DESCR`

New since June 16, 2006:

In the past most implementations used the `desc` member of the `PyCObject` (now `PyCapsule`) itself (do not confuse this with the "descr" member of the *`PyArrayInterface`* structure above — they are two separate things) to hold the pointer to the object exposing the interface. This is now an explicit part of the interface. Be sure to take a reference to the object and call `PyCapsule_SetContext` before returning the `PyCapsule`, and configure a destructor to decref this reference.

Note: *`__array_struct__`* is considered legacy and should not be used for new code. Use the buffer protocol or the DLPack protocol *`numpy.from_dlpack`* instead.

Type description examples

For clarity it is useful to provide some examples of the type description and corresponding *__array_interface__* 'descr' entries. Thanks to Scott Gilbert for these examples:

In every case, the 'descr' key is optional, but of course provides more information which may be important for various applications:

```
* Float data
    typestr == '>f4'
    descr == [('','>f4')]

* Complex double
    typestr == '>c8'
    descr == [('real','>f4'), ('imag','>f4')]

* RGB Pixel data
    typestr == '|V3'
    descr == [('r','|u1'), ('g','|u1'), ('b','|u1')]

* Mixed endian (weird but could happen).
    typestr == '|V8' (or '>u8')
    descr == [('big','>i4'), ('little','<i4')]

* Nested structure
    struct {
        int ival;
        struct {
            unsigned short sval;
            unsigned char bval;
            unsigned char cval;
        } sub;
    }
    typestr == '|V8' (or '<u8' if you want)
    descr == [('ival','<i4'), ('sub', [('sval','<u2'), ('bval','|u1'), ('cval','|u1')␣
↪]) ]

* Nested array
    struct {
        int ival;
        double data[16*4];
    }
    typestr == '|V516'
    descr == [('ival','>i4'), ('data','>f8',(16,4))]

* Padded structure
    struct {
        int ival;
        double dval;
    }
    typestr == '|V16'
    descr == [('ival','>i4'),('','|V4'),('dval','>f8')]
```

It should be clear that any structured type could be described using this interface.

Differences with array interface (version 2)

The version 2 interface was very similar. The differences were largely aesthetic. In particular:

1. The PyArrayInterface structure had no descr member at the end (and therefore no flag ARR_HAS_DESCR)
2. The `context` member of the `PyCapsule` (formally the `desc` member of the `PyCObject`) returned from `__array_struct__` was not specified. Usually, it was the object exposing the array (so that a reference to it could be kept and destroyed when the C-object was destroyed). It is now an explicit requirement that this field be used in some way to hold a reference to the owning object.

   Note: Until August 2020, this said:

   > Now it must be a tuple whose first element is a string with "PyArrayInterface Version #" and whose second element is the object exposing the array.

   This design was retracted almost immediately after it was proposed, in <https://mail.python.org/pipermail/numpy-discussion/2006-June/020995.html>. Despite 14 years of documentation to the contrary, at no point was it valid to assume that `__array_interface__` capsules held this tuple content.

   ---

3. The tuple returned from `__array_interface__['data']` used to be a hex-string (now it is an integer or a long integer).
4. There was no `__array_interface__` attribute instead all of the keys (except for version) in the `__array_interface__` dictionary were their own attribute: Thus to obtain the Python-side information you had to access separately the attributes:

   - `__array_data__`
   - `__array_shape__`
   - `__array_strides__`
   - `__array_typestr__`
   - `__array_descr__`
   - `__array_offset__`
   - `__array_mask__`

1.2.9 Datetimes and timedeltas

Starting in NumPy 1.7, there are core array data types which natively support datetime functionality. The data type is called *`datetime64`*, so named because `datetime` is already taken by the Python standard library.

Datetime64 conventions and assumptions

Similar to the Python `date` class, dates are expressed in the current Gregorian Calendar, indefinitely extended both in the future and in the past.[1] Contrary to Python `date`, which supports only years in the 1 AD — 9999 AD range, *`datetime64`* allows also for dates BC; years BC follow the Astronomical year numbering convention, i.e. year 2 BC is numbered −1, year 1 BC is numbered 0, year 1 AD is numbered 1.

Time instants, say 16:23:32.234, are represented counting hours, minutes, seconds and fractions from midnight: i.e. 00:00:00.000 is midnight, 12:00:00.000 is noon, etc. Each calendar day has exactly 86400 seconds. This is a "naive" time, with no explicit notion of timezones or specific time scales (UT1, UTC, TAI, etc.).[2]

[1] The calendar obtained by extending the Gregorian calendar before its official adoption on Oct. 15, 1582 is called Proleptic Gregorian Calendar

[2] The assumption of 86400 seconds per calendar day is not valid for UTC, the present day civil time scale. In fact due to the presence of leap

Basic datetimes

The most basic way to create datetimes is from strings in ISO 8601 date or datetime format. It is also possible to create datetimes from an integer by offset relative to the Unix epoch (00:00:00 UTC on 1 January 1970). The unit for internal storage is automatically selected from the form of the string, and can be either a *date unit* or a *time unit*. The date units are years ('Y'), months ('M'), weeks ('W'), and days ('D'), while the time units are hours ('h'), minutes ('m'), seconds ('s'), milliseconds ('ms'), and some additional SI-prefix seconds-based units. The `datetime64` data type also accepts the string "NAT", in any combination of lowercase/uppercase letters, for a "Not A Time" value.

Example

A simple ISO date:

```
>>> import numpy as np
```

```
>>> np.datetime64('2005-02-25')
np.datetime64('2005-02-25')
```

From an integer and a date unit, 1 year since the UNIX epoch:

```
>>> np.datetime64(1, 'Y')
np.datetime64('1971')
```

Using months for the unit:

```
>>> np.datetime64('2005-02')
np.datetime64('2005-02')
```

Specifying just the month, but forcing a 'days' unit:

```
>>> np.datetime64('2005-02', 'D')
np.datetime64('2005-02-01')
```

From a date and time:

```
>>> np.datetime64('2005-02-25T03:30')
np.datetime64('2005-02-25T03:30')
```

NAT (not a time):

```
>>> np.datetime64('nat')
np.datetime64('NaT')
```

When creating an array of datetimes from a string, it is still possible to automatically select the unit from the inputs, by using the datetime type with generic units.

Example

```
>>> import numpy as np
```

```
>>> np.array(['2007-07-13', '2006-01-13', '2010-08-13'], dtype='datetime64')
array(['2007-07-13', '2006-01-13', '2010-08-13'], dtype='datetime64[D]')
```

seconds on rare occasions a day may be 86401 or 86399 seconds long. On the contrary the 86400s day assumption holds for the TAI timescale. An explicit support for TAI and TAI to UTC conversion, accounting for leap seconds, is proposed but not yet implemented. See also the *shortcomings* section below.

```
>>> np.array(['2001-01-01T12:00', '2002-02-03T13:56:03.172'], dtype='datetime64')
array(['2001-01-01T12:00:00.000', '2002-02-03T13:56:03.172'],
      dtype='datetime64[ms]')
```

An array of datetimes can be constructed from integers representing POSIX timestamps with the given unit.

Example

```
>>> import numpy as np
```

```
>>> np.array([0, 1577836800], dtype='datetime64[s]')
array(['1970-01-01T00:00:00', '2020-01-01T00:00:00'],
      dtype='datetime64[s]')
```

```
>>> np.array([0, 1577836800000]).astype('datetime64[ms]')
array(['1970-01-01T00:00:00.000', '2020-01-01T00:00:00.000'],
      dtype='datetime64[ms]')
```

The datetime type works with many common NumPy functions, for example *arange* can be used to generate ranges of dates.

Example

All the dates for one month:

```
>>> import numpy as np
```

```
>>> np.arange('2005-02', '2005-03', dtype='datetime64[D]')
array(['2005-02-01', '2005-02-02', '2005-02-03', '2005-02-04',
       '2005-02-05', '2005-02-06', '2005-02-07', '2005-02-08',
       '2005-02-09', '2005-02-10', '2005-02-11', '2005-02-12',
       '2005-02-13', '2005-02-14', '2005-02-15', '2005-02-16',
       '2005-02-17', '2005-02-18', '2005-02-19', '2005-02-20',
       '2005-02-21', '2005-02-22', '2005-02-23', '2005-02-24',
       '2005-02-25', '2005-02-26', '2005-02-27', '2005-02-28'],
      dtype='datetime64[D]')
```

The datetime object represents a single moment in time. If two datetimes have different units, they may still be representing the same moment of time, and converting from a bigger unit like months to a smaller unit like days is considered a 'safe' cast because the moment of time is still being represented exactly.

Example

```
>>> import numpy as np
```

```
>>> np.datetime64('2005') == np.datetime64('2005-01-01')
True
```

```
>>> np.datetime64('2010-03-14T15') == np.datetime64('2010-03-14T15:00:00.00')
True
```

Deprecated since version 1.11.0: NumPy does not store timezone information. For backwards compatibility, datetime64 still parses timezone offsets, which it handles by converting to UTC±00:00 (Zulu time). This behaviour is deprecated and will raise an error in the future.

Datetime and timedelta arithmetic

NumPy allows the subtraction of two datetime values, an operation which produces a number with a time unit. Because NumPy doesn't have a physical quantities system in its core, the *timedelta64* data type was created to complement *datetime64*. The arguments for *timedelta64* are a number, to represent the number of units, and a date/time unit, such as (D)ay, (M)onth, (Y)ear, (h)ours, (m)inutes, or (s)econds. The *timedelta64* data type also accepts the string "NAT" in place of the number for a "Not A Time" value.

Example

```
>>> import numpy as np
```

```
>>> np.timedelta64(1, 'D')
np.timedelta64(1,'D')
```

```
>>> np.timedelta64(4, 'h')
np.timedelta64(4,'h')
```

```
>>> np.timedelta64('nAt')
np.timedelta64('NaT')
```

Datetimes and Timedeltas work together to provide ways for simple datetime calculations.

Example

```
>>> import numpy as np
```

```
>>> np.datetime64('2009-01-01') - np.datetime64('2008-01-01')
np.timedelta64(366,'D')
```

```
>>> np.datetime64('2009') + np.timedelta64(20, 'D')
np.datetime64('2009-01-21')
```

```
>>> np.datetime64('2011-06-15T00:00') + np.timedelta64(12, 'h')
np.datetime64('2011-06-15T12:00')
```

```
>>> np.timedelta64(1,'W') / np.timedelta64(1,'D')
7.0
```

```
>>> np.timedelta64(1,'W') % np.timedelta64(10,'D')
np.timedelta64(7,'D')
```

```
>>> np.datetime64('nat') - np.datetime64('2009-01-01')
np.timedelta64('NaT','D')
```

```
>>> np.datetime64('2009-01-01') + np.timedelta64('nat')
np.datetime64('NaT')
```

There are two Timedelta units ('Y', years and 'M', months) which are treated specially, because how much time they represent changes depending on when they are used. While a timedelta day unit is equivalent to 24 hours, month and year units cannot be converted directly into days without using 'unsafe' casting.

The *numpy.ndarray.astype* method can be used for unsafe conversion of months/years to days. The conversion follows calculating the averaged values from the 400 year leap-year cycle.

Example

```
>>> import numpy as np
```

```
>>> a = np.timedelta64(1, 'Y')
```

```
>>> np.timedelta64(a, 'M')
numpy.timedelta64(12,'M')
```

```
>>> np.timedelta64(a, 'D')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Cannot cast NumPy timedelta64 scalar from metadata [Y] to [D] according to␣
↪the rule 'same_kind'
```

Datetime units

The Datetime and Timedelta data types support a large number of time units, as well as generic units which can be coerced into any of the other units based on input data.

Datetimes are always stored with an epoch of 1970-01-01T00:00. This means the supported dates are always a symmetric interval around the epoch, called "time span" in the table below.

The length of the span is the range of a 64-bit integer times the length of the date or unit. For example, the time span for 'W' (week) is exactly 7 times longer than the time span for 'D' (day), and the time span for 'D' (day) is exactly 24 times longer than the time span for 'h' (hour).

Here are the date units:

Code	Meaning	Time span (relative)	Time span (absolute)
Y	year	+/- 9.2e18 years	[9.2e18 BC, 9.2e18 AD]
M	month	+/- 7.6e17 years	[7.6e17 BC, 7.6e17 AD]
W	week	+/- 1.7e17 years	[1.7e17 BC, 1.7e17 AD]
D	day	+/- 2.5e16 years	[2.5e16 BC, 2.5e16 AD]

And here are the time units:

Code	Meaning	Time span (relative)	Time span (absolute)
h	hour	+/- 1.0e15 years	[1.0e15 BC, 1.0e15 AD]
m	minute	+/- 1.7e13 years	[1.7e13 BC, 1.7e13 AD]
s	second	+/- 2.9e11 years	[2.9e11 BC, 2.9e11 AD]
ms	millisecond	+/- 2.9e8 years	[2.9e8 BC, 2.9e8 AD]
us / μs	microsecond	+/- 2.9e5 years	[290301 BC, 294241 AD]
ns	nanosecond	+/- 292 years	[1678 AD, 2262 AD]
ps	picosecond	+/- 106 days	[1969 AD, 1970 AD]
fs	femtosecond	+/- 2.6 hours	[1969 AD, 1970 AD]
as	attosecond	+/- 9.2 seconds	[1969 AD, 1970 AD]

Business day functionality

To allow the datetime to be used in contexts where only certain days of the week are valid, NumPy includes a set of "busday" (business day) functions.

The default for busday functions is that the only valid days are Monday through Friday (the usual business days). The implementation is based on a "weekmask" containing 7 Boolean flags to indicate valid days; custom weekmasks are possible that specify other sets of valid days.

The "busday" functions can additionally check a list of "holiday" dates, specific dates that are not valid days.

The function *busday_offset* allows you to apply offsets specified in business days to datetimes with a unit of 'D' (day).

Example

```
>>> import numpy as np
```

```
>>> np.busday_offset('2011-06-23', 1)
np.datetime64('2011-06-24')
```

```
>>> np.busday_offset('2011-06-23', 2)
np.datetime64('2011-06-27')
```

When an input date falls on the weekend or a holiday, *busday_offset* first applies a rule to roll the date to a valid business day, then applies the offset. The default rule is 'raise', which simply raises an exception. The rules most typically used are 'forward' and 'backward'.

Example

```
>>> import numpy as np
```

```
>>> np.busday_offset('2011-06-25', 2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: Non-business day date in busday_offset
```

```
>>> np.busday_offset('2011-06-25', 0, roll='forward')
np.datetime64('2011-06-27')
```

```
>>> np.busday_offset('2011-06-25', 2, roll='forward')
np.datetime64('2011-06-29')
```

```
>>> np.busday_offset('2011-06-25', 0, roll='backward')
np.datetime64('2011-06-24')
```

```
>>> np.busday_offset('2011-06-25', 2, roll='backward')
np.datetime64('2011-06-28')
```

In some cases, an appropriate use of the roll and the offset is necessary to get a desired answer.

Example

The first business day on or after a date:

```
>>> import numpy as np
```

```
>>> np.busday_offset('2011-03-20', 0, roll='forward')
np.datetime64('2011-03-21')
>>> np.busday_offset('2011-03-22', 0, roll='forward')
np.datetime64('2011-03-22')
```

The first business day strictly after a date:

```
>>> np.busday_offset('2011-03-20', 1, roll='backward')
np.datetime64('2011-03-21')
>>> np.busday_offset('2011-03-22', 1, roll='backward')
np.datetime64('2011-03-23')
```

The function is also useful for computing some kinds of days like holidays. In Canada and the U.S., Mother's day is on the second Sunday in May, which can be computed with a custom weekmask.

Example

```
>>> import numpy as np
```

```
>>> np.busday_offset('2012-05', 1, roll='forward', weekmask='Sun')
np.datetime64('2012-05-13')
```

When performance is important for manipulating many business dates with one particular choice of weekmask and holidays, there is an object *busdaycalendar* which stores the data necessary in an optimized form.

np.is_busday():

To test a *datetime64* value to see if it is a valid day, use *is_busday*.

Example

```
>>> import numpy as np
```

```
>>> np.is_busday(np.datetime64('2011-07-15'))  # a Friday
True
>>> np.is_busday(np.datetime64('2011-07-16')) # a Saturday
False
>>> np.is_busday(np.datetime64('2011-07-16'), weekmask="Sat Sun")
True
>>> a = np.arange(np.datetime64('2011-07-11'), np.datetime64('2011-07-18'))
>>> np.is_busday(a)
array([ True,  True,  True,  True,  True, False, False])
```

np.busday_count():

To find how many valid days there are in a specified range of datetime64 dates, use *busday_count*:

Example

```
>>> import numpy as np
```

```
>>> np.busday_count(np.datetime64('2011-07-11'), np.datetime64('2011-07-18'))
5
>>> np.busday_count(np.datetime64('2011-07-18'), np.datetime64('2011-07-11'))
-5
```

If you have an array of datetime64 day values, and you want a count of how many of them are valid dates, you can do this:

Example

```
>>> import numpy as np
```

```
>>> a = np.arange(np.datetime64('2011-07-11'), np.datetime64('2011-07-18'))
>>> np.count_nonzero(np.is_busday(a))
5
```

Custom weekmasks

Here are several examples of custom weekmask values. These examples specify the "busday" default of Monday through Friday being valid days.

Some examples:

```
# Positional sequences; positions are Monday through Sunday.
# Length of the sequence must be exactly 7.
weekmask = [1, 1, 1, 1, 1, 0, 0]
# list or other sequence; 0 == invalid day, 1 == valid day
weekmask = "1111100"
# string '0' == invalid day, '1' == valid day

# string abbreviations from this list: Mon Tue Wed Thu Fri Sat Sun
weekmask = "Mon Tue Wed Thu Fri"
# any amount of whitespace is allowed; abbreviations are case-sensitive.
weekmask = "MonTue Wed  Thu\tFri"
```

Datetime64 shortcomings

The assumption that all days are exactly 86400 seconds long makes *datetime64* largely compatible with Python datetime and "POSIX time" semantics; therefore they all share the same well known shortcomings with respect to the UTC timescale and historical time determination. A brief non exhaustive summary is given below.

- It is impossible to parse valid UTC timestamps occurring during a positive leap second.

Example

"2016-12-31 23:59:60 UTC" was a leap second, therefore "2016-12-31 23:59:60.450 UTC" is a valid timestamp which is not parseable by *datetime64*:

```
>>> import numpy as np
```

```
>>> np.datetime64("2016-12-31 23:59:60.450")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: Seconds out of range in datetime string "2016-12-31 23:59:60.450"
```

- Timedelta64 computations between two UTC dates can be wrong by an integer number of SI seconds.

Example

Compute the number of SI seconds between "2021-01-01 12:56:23.423 UTC" and "2001-01-01 00:00:00.000 UTC":

```
>>> import numpy as np
```

```
>>> (
...   np.datetime64("2021-01-01 12:56:23.423")
...   - np.datetime64("2001-01-01")
... ) / np.timedelta64(1, "s")
631198583.423
```

However, the correct answer is *631198588.423* SI seconds, because there were 5 leap seconds between 2001 and 2021.

- Timedelta64 computations for dates in the past do not return SI seconds, as one would expect.

Example

Compute the number of seconds between "000-01-01 UT" and "1600-01-01 UT", where UT is universal time:

```
>>> import numpy as np
```

```
>>> a = np.datetime64("0000-01-01", "us")
>>> b = np.datetime64("1600-01-01", "us")
>>> b - a
numpy.timedelta64(50491123200000000,'us')
```

The computed results, *50491123200* seconds, are obtained as the elapsed number of days (*584388*) times *86400* seconds; this is the number of seconds of a clock in sync with the Earth's rotation. The exact value in SI seconds can only be estimated, e.g., using data published in Measurement of the Earth's rotation: 720 BC to AD 2015, 2016, Royal Society's Proceedings A 472, by Stephenson et.al.. A sensible estimate is *50491112870* ± *90* seconds, with a difference of 10330 seconds.

1.3 Universal functions (`ufunc`)

See also:

ufuncs-basics

A universal function (or ufunc for short) is a function that operates on *ndarrays* in an element-by-element fashion, supporting array broadcasting, type casting, and several other standard features. That is, a ufunc is a "vectorized" wrapper for a function that takes a fixed number of specific inputs and produces a fixed number of specific outputs. For detailed information on universal functions, see ufuncs-basics.

1.3.1 `ufunc`

numpy.ufunc()	Functions that operate element by element on whole arrays.

class numpy.**ufunc**

Functions that operate element by element on whole arrays.

To see the documentation for a specific ufunc, use *info*. For example, `np.info(np.sin)`. Because ufuncs are written in C (for speed) and linked into Python with NumPy's ufunc facility, Python's help() function finds this page whenever help() is called on a ufunc.

A detailed explanation of ufuncs can be found in the docs for *Universal functions (ufunc)*.

Calling ufuncs: `op(*x[, out], where=True, **kwargs)`

Apply *op* to the arguments **x* elementwise, broadcasting the arguments.

The broadcasting rules are:

- Dimensions of length 1 may be prepended to either array.
- Arrays may be repeated along dimensions of length 1.

Parameters

***x**
[array_like] Input arrays.

out
[ndarray, None, or tuple of ndarray and None, optional] Alternate array object(s) in which to put the result; if provided, it must have a shape that the inputs broadcast to. A tuple of arrays (possible only as a keyword argument) must have length equal to the number of outputs; use None for uninitialized outputs to be allocated by the ufunc.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

r
[ndarray or tuple of ndarray] *r* will have the shape that the arrays in *x* broadcast to; if *out* is provided, it will be returned. If not, *r* will be allocated and may contain uninitialized values. If the function has more than one output, then the result will be a tuple of arrays.

Attributes

identity
The identity value.

nargs
The number of arguments.

nin
The number of inputs.

nout
The number of outputs.

ntypes
The number of types.

signature
Definition of the core elements a generalized ufunc operates on.

types
Returns a list with types grouped input->output.

Methods

__call__(*args, **kwargs)	Call self as a function.
accumulate(array[, axis, dtype, out])	Accumulate the result of applying the operator to all elements.
at(a, indices[, b])	Performs unbuffered in place operation on operand 'a' for elements specified by 'indices'.
outer(A, B, /, **kwargs)	Apply the ufunc *op* to all pairs (a, b) with a in *A* and b in *B*.
reduce(array[, axis, dtype, out, keepdims, ...])	Reduces *array*'s dimension by one, by applying ufunc along one axis.
reduceat(array, indices[, axis, dtype, out])	Performs a (local) reduce with specified slices over a single axis.
resolve_dtypes(dtypes, *[, signature, ...])	Find the dtypes NumPy will use for the operation.

method

ufunc.**__call__**(**args*, ***kwargs*)

Call self as a function.

method

ufunc.**accumulate**(*array*, *axis=0*, *dtype=None*, *out=None*)

Accumulate the result of applying the operator to all elements.

For a one-dimensional array, accumulate produces results equivalent to:

```
r = np.empty(len(A))
t = op.identity        # op = the ufunc being applied to A's  elements
for i in range(len(A)):
    t = op(t, A[i])
    r[i] = t
return r
```

For example, add.accumulate() is equivalent to np.cumsum().

For a multi-dimensional array, accumulate is applied along only one axis (axis zero by default; see Examples below) so repeated use is necessary if one wants to accumulate over multiple axes.

Parameters

array
[array_like] The array to act on.

axis
[int, optional] The axis along which to apply the accumulation; default is zero.

dtype
[data-type code, optional] The data-type used to represent the intermediate results. Defaults to the data-type of the output array if such is provided, or the data-type of the input array if no output array is provided.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If not provided or None, a freshly-allocated array is returned. For consistency with ufunc.__call__, if given as a keyword, this may be wrapped in a 1-element tuple.

Returns

r
[ndarray] The accumulated values. If *out* was supplied, *r* is a reference to *out*.

Examples

1-D array examples:

```
>>> import numpy as np
>>> np.add.accumulate([2, 3, 5])
array([ 2,  5, 10])
>>> np.multiply.accumulate([2, 3, 5])
array([ 2,  6, 30])
```

2-D array examples:

```
>>> I = np.eye(2)
>>> I
array([[1.,  0.],
       [0.,  1.]])
```

Accumulate along axis 0 (rows), down columns:

```
>>> np.add.accumulate(I, 0)
array([[1.,  0.],
       [1.,  1.]])
>>> np.add.accumulate(I) # no axis specified = axis zero
array([[1.,  0.],
       [1.,  1.]])
```

Accumulate along axis 1 (columns), through rows:

```
>>> np.add.accumulate(I, 1)
array([[1.,  1.],
       [0.,  1.]])
```

method

`ufunc.at`(*a*, *indices*, *b=None*, */*)

Performs unbuffered in place operation on operand 'a' for elements specified by 'indices'. For addition ufunc, this method is equivalent to `a[indices] += b`, except that results are accumulated for elements that are indexed more than once. For example, `a[[0,0]] += 1` will only increment the first element once because of buffering, whereas `add.at(a, [0,0], 1)` will increment the first element twice.

Parameters

a
[array_like] The array to perform in place operation on.

indices
[array_like or tuple] Array like index object or slice object for indexing into first operand. If first operand has multiple dimensions, indices can be a tuple of array like index objects or slice objects.

b
[array_like] Second operand for ufuncs requiring two operands. Operand must be broadcastable over first operand after indexing or slicing.

Examples

Set items 0 and 1 to their negative values:

```
>>> import numpy as np
>>> a = np.array([1, 2, 3, 4])
>>> np.negative.at(a, [0, 1])
>>> a
array([-1, -2,  3,  4])
```

Increment items 0 and 1, and increment item 2 twice:

```
>>> a = np.array([1, 2, 3, 4])
>>> np.add.at(a, [0, 1, 2, 2], 1)
>>> a
array([2, 3, 5, 4])
```

Add items 0 and 1 in first array to second array, and store results in first array:

```
>>> a = np.array([1, 2, 3, 4])
>>> b = np.array([1, 2])
>>> np.add.at(a, [0, 1], b)
>>> a
array([2, 4, 3, 4])
```

method

`ufunc.outer`(*A*, *B*, */*, ***kwargs*)

Apply the ufunc *op* to all pairs (a, b) with a in *A* and b in *B*.

Let `M = A.ndim`, `N = B.ndim`. Then the result, *C*, of `op.outer(A, B)` is an array of dimension M + N such that:

$$C[i_0, ..., i_{M-1}, j_0, ..., j_{N-1}] = op(A[i_0, ..., i_{M-1}], B[j_0, ..., j_{N-1}])$$

For *A* and *B* one-dimensional, this is equivalent to:

```
r = empty(len(A),len(B))
for i in range(len(A)):
    for j in range(len(B)):
        r[i,j] = op(A[i], B[j])  # op = ufunc in question
```

Parameters

A
[array_like] First array

B
[array_like] Second array

kwargs
[any] Arguments to pass on to the ufunc. Typically *dtype* or *out*. See *ufunc* for a comprehensive overview of all available arguments.

Returns

r
[ndarray] Output array

See also:

numpy.outer
A less powerful version of `np.multiply.outer` that *ravel*s all inputs to 1D. This exists primarily for compatibility with old code.

tensordot
`np.tensordot(a, b, axes=((), ()))` and `np.multiply.outer(a, b)` behave same for all dimensions of a and b.

Examples

```
>>> np.multiply.outer([1, 2, 3], [4, 5, 6])
array([[ 4,  5,  6],
       [ 8, 10, 12],
       [12, 15, 18]])
```

A multi-dimensional example:

```
>>> A = np.array([[1, 2, 3], [4, 5, 6]])
>>> A.shape
(2, 3)
>>> B = np.array([[1, 2, 3, 4]])
>>> B.shape
(1, 4)
>>> C = np.multiply.outer(A, B)
>>> C.shape; C
(2, 3, 1, 4)
array([[[[ 1,  2,  3,  4]],
        [[ 2,  4,  6,  8]],
        [[ 3,  6,  9, 12]]],
       [[[ 4,  8, 12, 16]],
        [[ 5, 10, 15, 20]],
        [[ 6, 12, 18, 24]]]])
```

method

`ufunc.`**`reduce`**(*array*, *axis=0*, *dtype=None*, *out=None*, *keepdims=False*, *initial=<no value>*, *where=True*)

Reduces *array*'s dimension by one, by applying ufunc along one axis.

Let $array.shape = (N_0, ..., N_i, ..., N_{M-1})$. Then $ufunc.reduce(array, axis = i)[k_0, .., k_{i-1}, k_{i+1}, .., k_{M-1}]$ = the result of iterating j over $range(N_i)$, cumulatively applying ufunc to each $array[k_0, .., k_{i-1}, j, k_{i+1}, .., k_{M-1}]$. For a one-dimensional array, reduce produces results equivalent to:

```
r = op.identity # op = ufunc
for i in range(len(A)):
  r = op(r, A[i])
return r
```

For example, add.reduce() is equivalent to sum().

Parameters

array
[array_like] The array to act on.

axis
[None or int or tuple of ints, optional] Axis or axes along which a reduction is performed. The default (*axis* = 0) is perform a reduction over the first dimension of the input array. *axis* may be negative, in which case it counts from the last to the first axis.

If this is None, a reduction is performed over all the axes. If this is a tuple of ints, a reduction is performed on multiple axes, instead of a single axis or all the axes as before.

For operations which are either not commutative or not associative, doing a reduction over multiple axes is not well-defined. The ufuncs do not currently raise an exception in this case, but will likely do so in the future.

dtype
[data-type code, optional] The data type used to perform the operation. Defaults to that of `out` if given, and the data type of `array` otherwise (though upcast to conserve precision for some cases, such as `numpy.add.reduce` for integer or boolean input).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If not provided or None, a freshly-allocated array is returned. For consistency with `ufunc.__call__`, if given as a keyword, this may be wrapped in a 1-element tuple.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *array*.

initial
[scalar, optional] The value with which to start the reduction. If the ufunc has no identity or the dtype is object, this defaults to None - otherwise it defaults to ufunc.identity. If `None` is given, the first element of the reduction is used, and an error is thrown if the reduction is empty.

where
[array_like of bool, optional] A boolean array which is broadcasted to match the dimensions of *array*, and selects elements to include in the reduction. Note that for ufuncs like `minimum` that do not have an identity defined, one has to pass in also `initial`.

Returns

r
[ndarray] The reduced array. If *out* was supplied, *r* is a reference to it.

Examples

```
>>> import numpy as np
>>> np.multiply.reduce([2,3,5])
30
```

A multi-dimensional array example:

```
>>> X = np.arange(8).reshape((2,2,2))
>>> X
array([[[0, 1],
        [2, 3]],
       [[4, 5],
        [6, 7]]])
>>> np.add.reduce(X, 0)
```

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```
array([[ 4,  6],
       [ 8, 10]])
>>> np.add.reduce(X) # confirm: default axis value is 0
array([[ 4,  6],
       [ 8, 10]])
>>> np.add.reduce(X, 1)
array([[ 2,  4],
       [10, 12]])
>>> np.add.reduce(X, 2)
array([[ 1,  5],
       [ 9, 13]])
```

You can use the `initial` keyword argument to initialize the reduction with a different value, and `where` to select specific elements to include:

```
>>> np.add.reduce([10], initial=5)
15
>>> np.add.reduce(np.ones((2, 2, 2)), axis=(0, 2), initial=10)
array([14., 14.])
>>> a = np.array([10., np.nan, 10])
>>> np.add.reduce(a, where=~np.isnan(a))
20.0
```

Allows reductions of empty arrays where they would normally fail, i.e. for ufuncs without an identity.

```
>>> np.minimum.reduce([], initial=np.inf)
inf
>>> np.minimum.reduce([[1., 2.], [3., 4.]], initial=10., where=[True, False])
array([ 1., 10.])
>>> np.minimum.reduce([])
Traceback (most recent call last):
    ...
ValueError: zero-size array to reduction operation minimum which has no␣
↪identity
```

method

`ufunc.`**`reduceat`**(*array*, *indices*, *axis=0*, *dtype=None*, *out=None*)

Performs a (local) reduce with specified slices over a single axis.

For i in `range(len(indices))`, *`reduceat`* computes `ufunc.reduce(array[indices[i]:indices[i+1]])`, which becomes the i-th generalized "row" parallel to *axis* in the final result (i.e., in a 2-D array, for example, if *axis = 0*, it becomes the i-th row, but if *axis = 1*, it becomes the i-th column). There are three exceptions to this:

- when `i = len(indices) - 1` (so for the last index), `indices[i+1] = array.shape[axis]`.
- if `indices[i] >= indices[i + 1]`, the i-th generalized "row" is simply `array[indices[i]]`.
- if `indices[i] >= len(array)` or `indices[i] < 0`, an error is raised.

The shape of the output depends on the size of *`indices`*, and may be larger than *`array`* (this happens if `len(indices) > array.shape[axis]`).

Parameters

array
[array_like] The array to act on.

indices
[array_like] Paired indices, comma separated (not colon), specifying slices to reduce.

axis
[int, optional] The axis along which to apply the reduceat.

dtype
[data-type code, optional] The data type used to perform the operation. Defaults to that of `out` if given, and the data type of `array` otherwise (though upcast to conserve precision for some cases, such as `numpy.add.reduce` for integer or boolean input).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If not provided or None, a freshly-allocated array is returned. For consistency with `ufunc.__call__`, if given as a keyword, this may be wrapped in a 1-element tuple.

Returns

r
[ndarray] The reduced values. If *out* was supplied, *r* is a reference to *out*.

Notes

A descriptive example:

If *`array`* is 1-D, the function *ufunc.accumulate(array)* is the same as `ufunc.reduceat(array, indices)[::2]` where *`indices`* is `range(len(array) - 1)` with a zero placed in every other element: `indices = zeros(2 * len(array) - 1), indices[1::2] = range(1, len(array))`.

Don't be fooled by this attribute's name: *reduceat(array)* is not necessarily smaller than *`array`*.

Examples

To take the running sum of four successive values:

```
>>> import numpy as np
>>> np.add.reduceat(np.arange(8),[0,4, 1,5, 2,6, 3,7])[::2]
array([ 6, 10, 14, 18])
```

A 2-D example:

```
>>> x = np.linspace(0, 15, 16).reshape(4,4)
>>> x
array([[ 0.,   1.,   2.,   3.],
       [ 4.,   5.,   6.,   7.],
       [ 8.,   9.,  10.,  11.],
       [12.,  13.,  14.,  15.]])
```

```
# reduce such that the result has the following five rows:
# [row1 + row2 + row3]
# [row4]
# [row2]
```

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```
# [row3]
# [row1 + row2 + row3 + row4]
```

```
>>> np.add.reduceat(x, [0, 3, 1, 2, 0])
array([[12.,  15.,  18.,  21.],
       [12.,  13.,  14.,  15.],
       [ 4.,   5.,   6.,   7.],
       [ 8.,   9.,  10.,  11.],
       [24.,  28.,  32.,  36.]])
```

```
# reduce such that result has the following two columns:
# [col1 * col2 * col3, col4]
```

```
>>> np.multiply.reduceat(x, [0, 3], 1)
array([[   0.,     3.],
       [ 120.,     7.],
       [ 720.,    11.],
       [2184.,    15.]])
```

method

`ufunc.`**`resolve_dtypes`**(*dtypes*, ***, *signature=None*, *casting=None*, *reduction=False*)

Find the dtypes NumPy will use for the operation. Both input and output dtypes are returned and may differ from those provided.

Note: This function always applies NEP 50 rules since it is not provided any actual values. The Python types `int`, `float`, and `complex` thus behave weak and should be passed for "untyped" Python input.

Parameters

dtypes
[tuple of dtypes, None, or literal int, float, complex] The input dtypes for each operand. Output operands can be None, indicating that the dtype must be found.

signature
[tuple of DTypes or None, optional] If given, enforces exact DType (classes) of the specific operand. The ufunc `dtype` argument is equivalent to passing a tuple with only output dtypes set.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] The casting mode when casting is necessary. This is identical to the ufunc call casting modes.

reduction
[boolean] If given, the resolution assumes a reduce operation is happening which slightly changes the promotion and type resolution rules. *dtypes* is usually something like `(None, np.dtype("i2"), None)` for reductions (first input is also the output).

Note: The default casting mode is "same_kind", however, as of NumPy 1.24, NumPy uses "unsafe" for reductions.

Returns

dtypes
[tuple of dtypes] The dtypes which NumPy would use for the calculation. Note that dtypes may not match the passed in ones (casting is necessary).

Examples

This API requires passing dtypes, define them for convenience:

```
>>> import numpy as np
>>> int32 = np.dtype("int32")
>>> float32 = np.dtype("float32")
```

The typical ufunc call does not pass an output dtype. *numpy.add* has two inputs and one output, so leave the output as `None` (not provided):

```
>>> np.add.resolve_dtypes((int32, float32, None))
(dtype('float64'), dtype('float64'), dtype('float64'))
```

The loop found uses "float64" for all operands (including the output), the first input would be cast.

`resolve_dtypes` supports "weak" handling for Python scalars by passing `int`, `float`, or `complex`:

```
>>> np.add.resolve_dtypes((float32, float, None))
(dtype('float32'), dtype('float32'), dtype('float32'))
```

Where the Python `float` behaves similar to a Python value `0.0` in a ufunc call. (See NEP 50 for details.)

Optional keyword arguments

All ufuncs take optional keyword arguments. Most of these represent advanced usage and will not typically be used.

out

The first output can be provided as either a positional or a keyword parameter. Keyword 'out' arguments are incompatible with positional ones.

The 'out' keyword argument is expected to be a tuple with one entry per output (which can be None for arrays to be allocated by the ufunc). For ufuncs with a single output, passing a single array (instead of a tuple holding a single array) is also valid.

Passing a single array in the 'out' keyword argument to a ufunc with multiple outputs is deprecated, and will raise a warning in numpy 1.10, and an error in a future release.

If 'out' is None (the default), a uninitialized return array is created. The output array is then filled with the results of the ufunc in the places that the broadcast 'where' is True. If 'where' is the scalar True (the default), then this corresponds to the entire output being filled. Note that outputs not explicitly filled are left with their uninitialized values.

Operations where ufunc input and output operands have memory overlap are defined to be the same as for equivalent operations where there is no memory overlap. Operations affected make temporary copies as needed to eliminate data dependency. As detecting these cases is computationally expensive, a heuristic is used, which may in rare cases result in needless temporary copies. For operations where the data dependency is simple enough for the heuristic to analyze, temporary copies will not be made even if the arrays overlap, if it can be deduced copies are not necessary. As an example, `np.add(a, b, out=a)` will not involve copies.

where

Accepts a boolean array which is broadcast together with the operands. Values of True indicate to calculate the ufunc at that position, values of False indicate to leave the value in the output alone. This argument cannot be used for generalized ufuncs as those take non-scalar input.

Note that if an uninitialized return array is created, values of False will leave those values **uninitialized**.

axes

A list of tuples with indices of axes a generalized ufunc should operate on. For instance, for a signature of `(i,j),(j,k)->(i,k)` appropriate for matrix multiplication, the base elements are two-dimensional matrices and these are taken to be stored in the two last axes of each argument. The corresponding axes keyword would be `[(-2, -1), (-2, -1), (-2, -1)]`. For simplicity, for generalized ufuncs that operate on 1-dimensional arrays (vectors), a single integer is accepted instead of a single-element tuple, and for generalized ufuncs for which all outputs are scalars, the output tuples can be omitted.

axis

A single axis over which a generalized ufunc should operate. This is a short-cut for ufuncs that operate over a single, shared core dimension, equivalent to passing in `axes` with entries of `(axis,)` for each single-core-dimension argument and `()` for all others. For instance, for a signature `(i),(i)->()`, it is equivalent to passing in `axes=[(axis,), (axis,), ()]`.

keepdims

If this is set to *True*, axes which are reduced over will be left in the result as a dimension with size one, so that the result will broadcast correctly against the inputs. This option can only be used for generalized ufuncs that operate on inputs that all have the same number of core dimensions and with outputs that have no core dimensions, i.e., with signatures like `(i),(i)->()` or `(m,m)->()`. If used, the location of the dimensions in the output can be controlled with `axes` and `axis`.

casting

May be 'no', 'equiv', 'safe', 'same_kind', or 'unsafe'. See *can_cast* for explanations of the parameter values.

Provides a policy for what kind of casting is permitted. For compatibility with previous versions of NumPy, this defaults to 'unsafe' for numpy < 1.7. In numpy 1.7 a transition to 'same_kind' was begun where ufuncs produce a DeprecationWarning for calls which are allowed under the 'unsafe' rules, but not under the 'same_kind' rules. From numpy 1.10 and onwards, the default is 'same_kind'.

order

Specifies the calculation iteration order/memory layout of the output array. Defaults to 'K'. 'C' means the output should be C-contiguous, 'F' means F-contiguous, 'A' means F-contiguous if the inputs are F-contiguous and not also not C-contiguous, C-contiguous otherwise, and 'K' means to match the element ordering of the inputs as closely as possible.

dtype

Overrides the DType of the output arrays the same way as the *signature*. This should ensure a matching precision of the calculation. The exact calculation DTypes chosen may depend on the ufunc and the inputs may be cast to this DType to perform the calculation.

subok

Defaults to true. If set to false, the output will always be a strict array, not a subtype.

signature

Either a Dtype, a tuple of DTypes, or a special signature string indicating the input and output types of a ufunc.

This argument allows the user to specify exact DTypes to be used for the calculation. Casting will be used as necessary. The actual DType of the input arrays is not considered unless `signature` is `None` for that array.

When all DTypes are fixed, a specific loop is chosen or an error raised if no matching loop exists. If some DTypes are not specified and left `None`, the behaviour may depend on the ufunc. At this time, a list of available signatures is provided by the **types** attribute of the ufunc. (This list may be missing DTypes not defined by NumPy.)

The `signature` only specifies the DType class/type. For example, it can specify that the operation should be `datetime64` or `float64` operation. It does not specify the `datetime64` time-unit or the `float64` byte-order.

For backwards compatibility this argument can also be provided as *sig*, although the long form is preferred. Note that this should not be confused with the generalized ufunc *signature* that is stored in the **signature** attribute of the of the ufunc object.

Attributes

There are some informational attributes that universal functions possess. None of the attributes can be set.

__doc__	A docstring for each ufunc. The first part of the docstring is dynamically generated from the number of outputs, the name, and the number of inputs. The second part of the docstring is provided at creation time and stored with the ufunc.
__name__	The name of the ufunc.

ufunc.nin	The number of inputs.
ufunc.nout	The number of outputs.
ufunc.nargs	The number of arguments.
ufunc.ntypes	The number of types.
ufunc.types	Returns a list with types grouped input->output.
ufunc.identity	The identity value.
ufunc.signature	Definition of the core elements a generalized ufunc operates on.

attribute

`ufunc.`**`nin`**

The number of inputs.

Data attribute containing the number of arguments the ufunc treats as input.

Examples

```
>>> import numpy as np
>>> np.add.nin
2
>>> np.multiply.nin
2
>>> np.power.nin
2
>>> np.exp.nin
1
```

attribute

ufunc.**nout**

The number of outputs.

Data attribute containing the number of arguments the ufunc treats as output.

Notes

Since all ufuncs can take output arguments, this will always be at least 1.

Examples

```
>>> import numpy as np
>>> np.add.nout
1
>>> np.multiply.nout
1
>>> np.power.nout
1
>>> np.exp.nout
1
```

attribute

ufunc.**nargs**

The number of arguments.

Data attribute containing the number of arguments the ufunc takes, including optional ones.

Notes

Typically this value will be one more than what you might expect because all ufuncs take the optional "out" argument.

Examples

```
>>> import numpy as np
>>> np.add.nargs
3
>>> np.multiply.nargs
3
>>> np.power.nargs
3
>>> np.exp.nargs
2
```

attribute

ufunc.**ntypes**

The number of types.

The number of numerical NumPy types - of which there are 18 total - on which the ufunc can operate.

See also:

numpy.ufunc.types

Examples

```
>>> import numpy as np
>>> np.add.ntypes
18
>>> np.multiply.ntypes
18
>>> np.power.ntypes
17
>>> np.exp.ntypes
7
>>> np.remainder.ntypes
14
```

attribute

ufunc.**types**

Returns a list with types grouped input->output.

Data attribute listing the data-type "Domain-Range" groupings the ufunc can deliver. The data-types are given using the character codes.

See also:

numpy.ufunc.ntypes

Examples

```
>>> import numpy as np
>>> np.add.types
['??->?', 'bb->b', 'BB->B', 'hh->h', 'HH->H', 'ii->i', 'II->I', 'll->l',
'LL->L', 'qq->q', 'QQ->Q', 'ff->f', 'dd->d', 'gg->g', 'FF->F', 'DD->D',
'GG->G', 'OO->O']
```

```
>>> np.multiply.types
['??->?', 'bb->b', 'BB->B', 'hh->h', 'HH->H', 'ii->i', 'II->I', 'll->l',
'LL->L', 'qq->q', 'QQ->Q', 'ff->f', 'dd->d', 'gg->g', 'FF->F', 'DD->D',
'GG->G', 'OO->O']
```

```
>>> np.power.types
['bb->b', 'BB->B', 'hh->h', 'HH->H', 'ii->i', 'II->I', 'll->l', 'LL->L',
'qq->q', 'QQ->Q', 'ff->f', 'dd->d', 'gg->g', 'FF->F', 'DD->D', 'GG->G',
'OO->O']
```

```
>>> np.exp.types
['f->f', 'd->d', 'g->g', 'F->F', 'D->D', 'G->G', 'O->O']
```

```
>>> np.remainder.types
['bb->b', 'BB->B', 'hh->h', 'HH->H', 'ii->i', 'II->I', 'll->l', 'LL->L',
'qq->q', 'QQ->Q', 'ff->f', 'dd->d', 'gg->g', 'OO->O']
```

attribute

`ufunc.`**`identity`**

The identity value.

Data attribute containing the identity element for the ufunc, if it has one. If it does not, the attribute value is None.

Examples

```
>>> import numpy as np
>>> np.add.identity
0
>>> np.multiply.identity
1
>>> np.power.identity
1
>>> print(np.exp.identity)
None
```

attribute

`ufunc.`**`signature`**

Definition of the core elements a generalized ufunc operates on.

The signature determines how the dimensions of each input/output array are split into core and loop dimensions:

1. Each dimension in the signature is matched to a dimension of the corresponding passed-in array, starting from the end of the shape tuple.
2. Core dimensions assigned to the same label in the signature must have exactly matching sizes, no broadcasting is performed.

3. The core dimensions are removed from all inputs and the remaining dimensions are broadcast together, defining the loop dimensions.

Notes

Generalized ufuncs are used internally in many linalg functions, and in the testing suite; the examples below are taken from these. For ufuncs that operate on scalars, the signature is None, which is equivalent to '()' for every argument.

Examples

```
>>> import numpy as np
>>> np.linalg._umath_linalg.det.signature
'(m,m)->()'
>>> np.matmul.signature
'(n?,k),(k,m?)->(n?,m?)'
>>> np.add.signature is None
True  # equivalent to '(),()->()'
```

Methods

ufunc.reduce(array[, axis, dtype, out, ...])	Reduces *array*'s dimension by one, by applying ufunc along one axis.
ufunc.accumulate(array[, axis, dtype, out])	Accumulate the result of applying the operator to all elements.
ufunc.reduceat(array, indices[, axis, ...])	Performs a (local) reduce with specified slices over a single axis.
ufunc.outer(A, B, /, **kwargs)	Apply the ufunc *op* to all pairs (a, b) with a in *A* and b in *B*.
ufunc.at(a, indices[, b])	Performs unbuffered in place operation on operand 'a' for elements specified by 'indices'.

Warning: A reduce-like operation on an array with a data-type that has a range "too small" to handle the result will silently wrap. One should use *dtype* to increase the size of the data-type over which reduction takes place.

1.3.2 Available ufuncs

There are currently more than 60 universal functions defined in *numpy* on one or more types, covering a wide variety of operations. Some of these ufuncs are called automatically on arrays when the relevant infix notation is used (*e.g.*, *add(a, b)* is called internally when `a + b` is written and *a* or *b* is an *ndarray*). Nevertheless, you may still want to use the ufunc call in order to use the optional output argument(s) to place the output(s) in an object (or objects) of your choice.

Recall that each ufunc operates element-by-element. Therefore, each scalar ufunc will be described as if acting on a set of scalar inputs to return a set of scalar outputs.

Note: The ufunc still returns its output(s) even if you use the optional output argument(s).

Math operations

add(x1, x2, /[, out, where, casting, order, ...])	Add arguments element-wise.
subtract(x1, x2, /[, out, where, casting, ...])	Subtract arguments, element-wise.
multiply(x1, x2, /[, out, where, casting, ...])	Multiply arguments element-wise.
matmul(x1, x2, /[, out, casting, order, ...])	Matrix product of two arrays.
divide(x1, x2, /[, out, where, casting, ...])	Divide arguments element-wise.
logaddexp(x1, x2, /[, out, where, casting, ...])	Logarithm of the sum of exponentiations of the inputs.
logaddexp2(x1, x2, /[, out, where, casting, ...])	Logarithm of the sum of exponentiations of the inputs in base-2.
true_divide(x1, x2, /[, out, where, ...])	Divide arguments element-wise.
floor_divide(x1, x2, /[, out, where, ...])	Return the largest integer smaller or equal to the division of the inputs.
negative(x, /[, out, where, casting, order, ...])	Numerical negative, element-wise.
positive(x, /[, out, where, casting, order, ...])	Numerical positive, element-wise.
power(x1, x2, /[, out, where, casting, ...])	First array elements raised to powers from second array, element-wise.
float_power(x1, x2, /[, out, where, ...])	First array elements raised to powers from second array, element-wise.
remainder(x1, x2, /[, out, where, casting, ...])	Returns the element-wise remainder of division.
mod(x1, x2, /[, out, where, casting, order, ...])	Returns the element-wise remainder of division.
fmod(x1, x2, /[, out, where, casting, ...])	Returns the element-wise remainder of division.
divmod(x1, x2[, out1, out2], / [[, out, ...])	Return element-wise quotient and remainder simultaneously.
absolute(x, /[, out, where, casting, order, ...])	Calculate the absolute value element-wise.
fabs(x, /[, out, where, casting, order, ...])	Compute the absolute values element-wise.
rint(x, /[, out, where, casting, order, ...])	Round elements of the array to the nearest integer.
sign(x, /[, out, where, casting, order, ...])	Returns an element-wise indication of the sign of a number.
heaviside(x1, x2, /[, out, where, casting, ...])	Compute the Heaviside step function.
conj(x, /[, out, where, casting, order, ...])	Return the complex conjugate, element-wise.
conjugate(x, /[, out, where, casting, ...])	Return the complex conjugate, element-wise.
exp(x, /[, out, where, casting, order, ...])	Calculate the exponential of all elements in the input array.
exp2(x, /[, out, where, casting, order, ...])	Calculate *2**p* for all *p* in the input array.
log(x, /[, out, where, casting, order, ...])	Natural logarithm, element-wise.
log2(x, /[, out, where, casting, order, ...])	Base-2 logarithm of *x*.
log10(x, /[, out, where, casting, order, ...])	Return the base 10 logarithm of the input array, element-wise.
expm1(x, /[, out, where, casting, order, ...])	Calculate `exp(x) - 1` for all elements in the array.
log1p(x, /[, out, where, casting, order, ...])	Return the natural logarithm of one plus the input array, element-wise.
sqrt(x, /[, out, where, casting, order, ...])	Return the non-negative square-root of an array, element-wise.
square(x, /[, out, where, casting, order, ...])	Return the element-wise square of the input.
cbrt(x, /[, out, where, casting, order, ...])	Return the cube-root of an array, element-wise.
reciprocal(x, /[, out, where, casting, ...])	Return the reciprocal of the argument, element-wise.
gcd(x1, x2, /[, out, where, casting, order, ...])	Returns the greatest common divisor of `|x1|` and `|x2|`
lcm(x1, x2, /[, out, where, casting, order, ...])	Returns the lowest common multiple of `|x1|` and `|x2|`

Tip: The optional output arguments can be used to help you save memory for large calculations. If your arrays are large,

complicated expressions can take longer than absolutely necessary due to the creation and (later) destruction of temporary calculation spaces. For example, the expression `G = A * B + C` is equivalent to `T1 = A * B; G = T1 + C; del T1`. It will be more quickly executed as `G = A * B; add(G, C, G)` which is the same as `G = A * B; G += C`.

Trigonometric functions

All trigonometric functions use radians when an angle is called for. The ratio of degrees to radians is $180^\circ/\pi$.

sin(x, /[, out, where, casting, order, ...])	Trigonometric sine, element-wise.
cos(x, /[, out, where, casting, order, ...])	Cosine element-wise.
tan(x, /[, out, where, casting, order, ...])	Compute tangent element-wise.
arcsin(x, /[, out, where, casting, order, ...])	Inverse sine, element-wise.
arccos(x, /[, out, where, casting, order, ...])	Trigonometric inverse cosine, element-wise.
arctan(x, /[, out, where, casting, order, ...])	Trigonometric inverse tangent, element-wise.
arctan2(x1, x2, /[, out, where, casting, ...])	Element-wise arc tangent of `x1/x2` choosing the quadrant correctly.
hypot(x1, x2, /[, out, where, casting, ...])	Given the "legs" of a right triangle, return its hypotenuse.
sinh(x, /[, out, where, casting, order, ...])	Hyperbolic sine, element-wise.
cosh(x, /[, out, where, casting, order, ...])	Hyperbolic cosine, element-wise.
tanh(x, /[, out, where, casting, order, ...])	Compute hyperbolic tangent element-wise.
arcsinh(x, /[, out, where, casting, order, ...])	Inverse hyperbolic sine element-wise.
arccosh(x, /[, out, where, casting, order, ...])	Inverse hyperbolic cosine, element-wise.
arctanh(x, /[, out, where, casting, order, ...])	Inverse hyperbolic tangent element-wise.
degrees(x, /[, out, where, casting, order, ...])	Convert angles from radians to degrees.
radians(x, /[, out, where, casting, order, ...])	Convert angles from degrees to radians.
deg2rad(x, /[, out, where, casting, order, ...])	Convert angles from degrees to radians.
rad2deg(x, /[, out, where, casting, order, ...])	Convert angles from radians to degrees.

Bit-twiddling functions

These function all require integer arguments and they manipulate the bit-pattern of those arguments.

bitwise_and(x1, x2, /[, out, where, ...])	Compute the bit-wise AND of two arrays element-wise.
bitwise_or(x1, x2, /[, out, where, casting, ...])	Compute the bit-wise OR of two arrays element-wise.
bitwise_xor(x1, x2, /[, out, where, ...])	Compute the bit-wise XOR of two arrays element-wise.
invert(x, /[, out, where, casting, order, ...])	Compute bit-wise inversion, or bit-wise NOT, element-wise.
left_shift(x1, x2, /[, out, where, casting, ...])	Shift the bits of an integer to the left.
right_shift(x1, x2, /[, out, where, ...])	Shift the bits of an integer to the right.

Comparison functions

greater(x1, x2, /[, out, where, casting, ...])	Return the truth value of (x1 > x2) element-wise.
greater_equal(x1, x2, /[, out, where, ...])	Return the truth value of (x1 >= x2) element-wise.
less(x1, x2, /[, out, where, casting, ...])	Return the truth value of (x1 < x2) element-wise.
less_equal(x1, x2, /[, out, where, casting, ...])	Return the truth value of (x1 <= x2) element-wise.
not_equal(x1, x2, /[, out, where, casting, ...])	Return (x1 != x2) element-wise.
equal(x1, x2, /[, out, where, casting, ...])	Return (x1 == x2) element-wise.

Warning: Do not use the Python keywords `and` and `or` to combine logical array expressions. These keywords will test the truth value of the entire array (not element-by-element as you might expect). Use the bitwise operators & and | instead.

logical_and(x1, x2, /[, out, where, ...])	Compute the truth value of x1 AND x2 element-wise.
logical_or(x1, x2, /[, out, where, casting, ...])	Compute the truth value of x1 OR x2 element-wise.
logical_xor(x1, x2, /[, out, where, ...])	Compute the truth value of x1 XOR x2, element-wise.
logical_not(x, /[, out, where, casting, ...])	Compute the truth value of NOT x element-wise.

Warning: The bit-wise operators & and | are the proper way to perform element-by-element array comparisons. Be sure you understand the operator precedence: `(a > 2) & (a < 5)` is the proper syntax because `a > 2 & a < 5` will result in an error due to the fact that `2 & a` is evaluated first.

maximum(x1, x2, /[, out, where, casting, ...])	Element-wise maximum of array elements.

Tip: The Python function `max()` will find the maximum over a one-dimensional array, but it will do so using a slower sequence interface. The reduce method of the maximum ufunc is much faster. Also, the `max()` method will not give answers you might expect for arrays with greater than one dimension. The reduce method of minimum also allows you to compute a total minimum over an array.

minimum(x1, x2, /[, out, where, casting, ...])	Element-wise minimum of array elements.

Warning: the behavior of `maximum(a, b)` is different than that of `max(a, b)`. As a ufunc, `maximum(a, b)` performs an element-by-element comparison of *a* and *b* and chooses each element of the result according to which element in the two arrays is larger. In contrast, `max(a, b)` treats the objects *a* and *b* as a whole, looks at the (total) truth value of `a > b` and uses it to return either *a* or *b* (as a whole). A similar difference exists between `minimum(a, b)` and `min(a, b)`.

fmax(x1, x2, /[, out, where, casting, ...])	Element-wise maximum of array elements.
fmin(x1, x2, /[, out, where, casting, ...])	Element-wise minimum of array elements.

Floating functions

Recall that all of these functions work element-by-element over an array, returning an array output. The description details only a single operation.

isfinite(x, /[, out, where, casting, order, ...])	Test element-wise for finiteness (not infinity and not Not a Number).
isinf(x, /[, out, where, casting, order, ...])	Test element-wise for positive or negative infinity.
isnan(x, /[, out, where, casting, order, ...])	Test element-wise for NaN and return result as a boolean array.
isnat(x, /[, out, where, casting, order, ...])	Test element-wise for NaT (not a time) and return result as a boolean array.
fabs(x, /[, out, where, casting, order, ...])	Compute the absolute values element-wise.
signbit(x, /[, out, where, casting, order, ...])	Returns element-wise True where signbit is set (less than zero).
copysign(x1, x2, /[, out, where, casting, ...])	Change the sign of x1 to that of x2, element-wise.
nextafter(x1, x2, /[, out, where, casting, ...])	Return the next floating-point value after x1 towards x2, element-wise.
spacing(x, /[, out, where, casting, order, ...])	Return the distance between x and the nearest adjacent number.
modf(x[, out1, out2], / [[, out, where, ...])	Return the fractional and integral parts of an array, element-wise.
ldexp(x1, x2, /[, out, where, casting, ...])	Returns x1 * 2**x2, element-wise.
frexp(x[, out1, out2], / [[, out, where, ...])	Decompose the elements of x into mantissa and twos exponent.
fmod(x1, x2, /[, out, where, casting, ...])	Returns the element-wise remainder of division.
floor(x, /[, out, where, casting, order, ...])	Return the floor of the input, element-wise.
ceil(x, /[, out, where, casting, order, ...])	Return the ceiling of the input, element-wise.
trunc(x, /[, out, where, casting, order, ...])	Return the truncated value of the input, element-wise.

1.4 Routines and objects by topic

In this chapter routine docstrings are presented, grouped by functionality. Many docstrings contain example code, which demonstrates basic usage of the routine. The examples assume that NumPy is imported with:

```
>>> import numpy as np
```

A convenient way to execute examples is the `%doctest_mode` mode of IPython, which allows for pasting of multi-line examples and preserves indentation.

1.4.1 Constants

NumPy includes several constants:

`numpy.e`

Euler's constant, base of natural logarithms, Napier's constant.

`e = 2.71828182845904523536028747135266249775724709369995...`

See Also

exp : Exponential function log : Natural logarithm

References

https://en.wikipedia.org/wiki/E_%28mathematical_constant%29

numpy.**euler_gamma**

γ = 0.5772156649015328606065120900824024310421...

References

https://en.wikipedia.org/wiki/Euler%27s_constant

numpy.**inf**

IEEE 754 floating point representation of (positive) infinity.

Returns

y
: [float] A floating point representation of positive infinity.

See Also

isinf : Shows which elements are positive or negative infinity

isposinf : Shows which elements are positive infinity

isneginf : Shows which elements are negative infinity

isnan : Shows which elements are Not a Number

isfinite : Shows which elements are finite (not one of Not a Number, positive infinity and negative infinity)

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity. Also that positive infinity is not equivalent to negative infinity. But infinity is equivalent to positive infinity.

Examples

```
>>> import numpy as np
>>> np.inf
inf
>>> np.array([1]) / 0.
array([inf])
```

numpy.**nan**

IEEE 754 floating point representation of Not a Number (NaN).

Returns

y : A floating point representation of Not a Number.

See Also

isnan : Shows which elements are Not a Number.

isfinite : Shows which elements are finite (not one of Not a Number, positive infinity and negative infinity)

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity.

Examples

```
>>> import numpy as np
>>> np.nan
nan
>>> np.log(-1)
np.float64(nan)
>>> np.log([-1, 1, 2])
array([       nan, 0.        , 0.69314718])
```

numpy.**newaxis**

A convenient alias for None, useful for indexing arrays.

Examples

```
>>> import numpy as np
>>> np.newaxis is None
True
>>> x = np.arange(3)
>>> x
array([0, 1, 2])
>>> x[:, np.newaxis]
array([[0],
[1],
[2]])
>>> x[:, np.newaxis, np.newaxis]
array([[[0]],
[[1]],
[[2]]])
>>> x[:, np.newaxis] * x
array([[0, 0, 0],
    [0, 1, 2],
    [0, 2, 4]])
```

Outer product, same as `outer(x, y)`:

```
>>> y = np.arange(3, 6)
>>> x[:, np.newaxis] * y
array([[ 0,  0,  0],
       [ 3,  4,  5],
       [ 6,  8, 10]])
```

`x[np.newaxis, :]` is equivalent to `x[np.newaxis]` and `x[None]`:

```
>>> x[np.newaxis, :].shape
(1, 3)
>>> x[np.newaxis].shape
(1, 3)
>>> x[None].shape
(1, 3)
>>> x[:, np.newaxis].shape
(3, 1)
```

`numpy.pi`

`pi = 3.14159265358979323846264 33...`

References

https://en.wikipedia.org/wiki/Pi

1.4.2 Array creation routines

See also:

Array creation

From shape or value

empty(shape[, dtype, order, device, like])	Return a new array of given shape and type, without initializing entries.
empty_like(prototype[, dtype, order, subok, ...])	Return a new array with the same shape and type as a given array.
eye(N[, M, k, dtype, order, device, like])	Return a 2-D array with ones on the diagonal and zeros elsewhere.
identity(n[, dtype, like])	Return the identity array.
ones(shape[, dtype, order, device, like])	Return a new array of given shape and type, filled with ones.
ones_like(a[, dtype, order, subok, shape, ...])	Return an array of ones with the same shape and type as a given array.
zeros(shape[, dtype, order, like])	Return a new array of given shape and type, filled with zeros.
zeros_like(a[, dtype, order, subok, shape, ...])	Return an array of zeros with the same shape and type as a given array.
full(shape, fill_value[, dtype, order, ...])	Return a new array of given shape and type, filled with *fill_value*.
full_like(a, fill_value[, dtype, order, ...])	Return a full array with the same shape and type as a given array.

numpy.**empty**(*shape*, *dtype=float*, *order='C'*, ***, *device=None*, *like=None*)

Return a new array of given shape and type, without initializing entries.

Parameters

shape
[int or tuple of int] Shape of the empty array, e.g., `(2, 3)` or `2`.

dtype
[data-type, optional] Desired output data-type for the array, e.g, *numpy.int8*. Default is *numpy.float64*.

order
[{'C', 'F'}, optional, default: 'C'] Whether to store multi-dimensional data in row-major (C-style) or column-major (Fortran-style) order in memory.

device
[str, optional] The device on which to place the created array. Default: `None`. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] Array of uninitialized (arbitrary) data of the given shape, dtype, and order. Object arrays will be initialized to None.

See also:

empty_like
Return an empty array with shape and type of input.

ones
Return a new array setting values to one.

zeros
Return a new array setting values to zero.

full
Return a new array of given shape filled with value.

Notes

Unlike other array creation functions (e.g. *zeros*, *ones*, *full*), *empty* does not initialize the values of the array, and may therefore be marginally faster. However, the values stored in the newly allocated array are arbitrary. For reproducible behavior, be sure to set each element of the array before reading.

Examples

```
>>> import numpy as np
>>> np.empty([2, 2])
array([[ -9.74499359e+001,   6.69583040e-309],
       [  2.13182611e-314,   3.06959433e-309]])         #uninitialized
```

```
>>> np.empty([2, 2], dtype=int)
array([[-1073741821, -1067949133],
       [  496041986,    19249760]])                     #uninitialized
```

numpy.**empty_like**(*prototype*, *dtype=None*, *order='K'*, *subok=True*, *shape=None*, *, *device=None*)

Return a new array with the same shape and type as a given array.

Parameters

prototype
[array_like] The shape and data-type of *prototype* define these same attributes of the returned array.

dtype
[data-type, optional] Overrides the data type of the result.

order
[{'C', 'F', 'A', or 'K'}, optional] Overrides the memory layout of the result. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *prototype* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *prototype* as closely as possible.

subok
[bool, optional.] If True, then the newly created array will use the sub-class type of *prototype*, otherwise it will be a base-class array. Defaults to True.

shape
[int or sequence of ints, optional.] Overrides the shape of the result. If order='K' and the number of dimensions is unchanged, will try to keep order, otherwise, order='C' is implied.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

Returns

out
[ndarray] Array of uninitialized (arbitrary) data with the same shape and type as *prototype*.

See also:

ones_like
Return an array of ones with shape and type of input.

zeros_like
Return an array of zeros with shape and type of input.

full_like
Return a new array with shape of input filled with value.

empty
Return a new uninitialized array.

Notes

Unlike other array creation functions (e.g. *zeros_like*, *ones_like*, *full_like*), *empty_like* does not initialize the values of the array, and may therefore be marginally faster. However, the values stored in the newly allocated array are arbitrary. For reproducible behavior, be sure to set each element of the array before reading.

Examples

```
>>> import numpy as np
>>> a = ([1,2,3], [4,5,6])                         # a is array-like
>>> np.empty_like(a)
array([[-1073741821, -1073741821,           3],    # uninitialized
       [          0,           0, -1073741821]])
>>> a = np.array([[1., 2., 3.],[4.,5.,6.]])
>>> np.empty_like(a)
array([[ -2.00000715e+000,   1.48219694e-323,  -2.00000572e+000], # uninitialized
       [  4.38791518e-305,  -2.00000715e+000,   4.17269252e-309]])
```

numpy.**eye**(*N*, *M=None*, *k=0*, *dtype=<class 'float'>*, *order='C'*, ***, *device=None*, *like=None*)

Return a 2-D array with ones on the diagonal and zeros elsewhere.

Parameters

N
: [int] Number of rows in the output.

M
: [int, optional] Number of columns in the output. If None, defaults to *N*.

k
: [int, optional] Index of the diagonal: 0 (the default) refers to the main diagonal, a positive value refers to an upper diagonal, and a negative value to a lower diagonal.

dtype
: [data-type, optional] Data-type of the returned array.

order
: [{'C', 'F'}, optional] Whether the output should be stored in row-major (C-style) or column-major (Fortran-style) order in memory.

device
: [str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

  New in version 2.0.0.

like
: [array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

  New in version 1.20.0.

Returns

I
: [ndarray of shape (N,M)] An array where all elements are equal to zero, except for the *k*-th diagonal, whose values are equal to one.

See also:

identity
(almost) equivalent function

diag
diagonal 2-D array from a 1-D array specified by the user.

Examples

```
>>> import numpy as np
>>> np.eye(2, dtype=int)
array([[1, 0],
       [0, 1]])
>>> np.eye(3, k=1)
array([[0.,  1.,  0.],
       [0.,  0.,  1.],
       [0.,  0.,  0.]])
```

numpy.**identity**(*n*, *dtype=None*, *, *like=None*)

Return the identity array.

The identity array is a square array with ones on the main diagonal.

Parameters

n
[int] Number of rows (and columns) in *n* x *n* output.

dtype
[data-type, optional] Data-type of the output. Defaults to `float`.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] *n* x *n* array with its main diagonal set to one, and all other elements 0.

Examples

```
>>> import numpy as np
>>> np.identity(3)
array([[1.,  0.,  0.],
       [0.,  1.,  0.],
       [0.,  0.,  1.]])
```

numpy.**ones**(*shape*, *dtype=None*, *order='C'*, *, *device=None*, *like=None*)

Return a new array of given shape and type, filled with ones.

Parameters

shape
[int or sequence of ints] Shape of the new array, e.g., `(2, 3)` or `2`.

dtype
[data-type, optional] The desired data-type for the array, e.g., *numpy.int8*. Default is *numpy.float64*.

order
[{'C', 'F'}, optional, default: C] Whether to store multi-dimensional data in row-major (C-style) or column-major (Fortran-style) order in memory.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] Array of ones with the given shape, dtype, and order.

See also:

ones_like
Return an array of ones with shape and type of input.

empty
Return a new uninitialized array.

zeros
Return a new array setting values to zero.

full
Return a new array of given shape filled with value.

Examples

```
>>> import numpy as np
>>> np.ones(5)
array([1., 1., 1., 1., 1.])
```

```
>>> np.ones((5,), dtype=int)
array([1, 1, 1, 1, 1])
```

```
>>> np.ones((2, 1))
array([[1.],
       [1.]])
```

```
>>> s = (2,2)
>>> np.ones(s)
array([[1.,  1.],
       [1.,  1.]])
```

numpy.**ones_like**(*a*, *dtype=None*, *order='K'*, *subok=True*, *shape=None*, ***, *device=None*)

Return an array of ones with the same shape and type as a given array.

Parameters

a
[array_like] The shape and data-type of *a* define these same attributes of the returned array.

dtype
[data-type, optional] Overrides the data type of the result.

order
[{'C', 'F', 'A', or 'K'}, optional] Overrides the memory layout of the result. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible.

subok
[bool, optional.] If True, then the newly created array will use the sub-class type of *a*, otherwise it will be a base-class array. Defaults to True.

shape
[int or sequence of ints, optional.] Overrides the shape of the result. If order='K' and the number of dimensions is unchanged, will try to keep order, otherwise, order='C' is implied.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

Returns

out
[ndarray] Array of ones with the same shape and type as *a*.

See also:

empty_like
Return an empty array with shape and type of input.

zeros_like
Return an array of zeros with shape and type of input.

full_like
Return a new array with shape of input filled with value.

ones
Return a new array setting values to one.

Examples

```
>>> import numpy as np
>>> x = np.arange(6)
>>> x = x.reshape((2, 3))
>>> x
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.ones_like(x)
array([[1, 1, 1],
       [1, 1, 1]])
```

```
>>> y = np.arange(3, dtype=float)
>>> y
array([0., 1., 2.])
>>> np.ones_like(y)
array([1.,  1.,  1.])
```

numpy.**zeros**(*shape*, *dtype=float*, *order='C'*, ***, *like=None*)

Return a new array of given shape and type, filled with zeros.

Parameters

shape
[int or tuple of ints] Shape of the new array, e.g., `(2, 3)` or `2`.

dtype
[data-type, optional] The desired data-type for the array, e.g., *numpy.int8*. Default is *numpy.float64*.

order
[{'C', 'F'}, optional, default: 'C'] Whether to store multi-dimensional data in row-major (C-style) or column-major (Fortran-style) order in memory.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] Array of zeros with the given shape, dtype, and order.

See also:

zeros_like
Return an array of zeros with shape and type of input.

empty
Return a new uninitialized array.

ones
Return a new array setting values to one.

full
Return a new array of given shape filled with value.

Examples

```
>>> import numpy as np
>>> np.zeros(5)
array([ 0.,  0.,  0.,  0.,  0.])
```

```
>>> np.zeros((5,), dtype=int)
array([0, 0, 0, 0, 0])
```

```
>>> np.zeros((2, 1))
array([[ 0.],
       [ 0.]])
```

```
>>> s = (2,2)
>>> np.zeros(s)
array([[ 0.,  0.],
       [ 0.,  0.]])
```

```
>>> np.zeros((2,), dtype=[('x', 'i4'), ('y', 'i4')]) # custom dtype
array([(0, 0), (0, 0)],
      dtype=[('x', '<i4'), ('y', '<i4')])
```

numpy.**zeros_like**(*a*, *dtype=None*, *order='K'*, *subok=True*, *shape=None*, *, *device=None*)

Return an array of zeros with the same shape and type as a given array.

Parameters

a
: [array_like] The shape and data-type of *a* define these same attributes of the returned array.

dtype
: [data-type, optional] Overrides the data type of the result.

order
: [{'C', 'F', 'A', or 'K'}, optional] Overrides the memory layout of the result. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible.

subok
: [bool, optional.] If True, then the newly created array will use the sub-class type of *a*, otherwise it will be a base-class array. Defaults to True.

shape
: [int or sequence of ints, optional.] Overrides the shape of the result. If order='K' and the number of dimensions is unchanged, will try to keep order, otherwise, order='C' is implied.

device
: [str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

  New in version 2.0.0.

Returns

out
: [ndarray] Array of zeros with the same shape and type as *a*.

See also:

empty_like
Return an empty array with shape and type of input.

ones_like
Return an array of ones with shape and type of input.

full_like
Return a new array with shape of input filled with value.

zeros
Return a new array setting values to zero.

Examples

```
>>> import numpy as np
>>> x = np.arange(6)
>>> x = x.reshape((2, 3))
>>> x
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.zeros_like(x)
array([[0, 0, 0],
       [0, 0, 0]])
```

```
>>> y = np.arange(3, dtype=float)
>>> y
array([0., 1., 2.])
>>> np.zeros_like(y)
array([0.,  0.,  0.])
```

numpy.**full**(*shape*, *fill_value*, *dtype=None*, *order='C'*, ***, *device=None*, *like=None*)

Return a new array of given shape and type, filled with *fill_value*.

Parameters

shape
[int or sequence of ints] Shape of the new array, e.g., `(2, 3)` or `2`.

fill_value
[scalar or array_like] Fill value.

dtype
[data-type, optional]

The desired data-type for the array The default, None, means
`np.array(fill_value).dtype`.

order
[{'C', 'F'}, optional] Whether to store multidimensional data in C- or Fortran-contiguous (row- or column-wise) order in memory.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy

arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] Array of *fill_value* with the given shape, dtype, and order.

See also:

full_like
Return a new array with shape of input filled with value.

empty
Return a new uninitialized array.

ones
Return a new array setting values to one.

zeros
Return a new array setting values to zero.

Examples

```
>>> import numpy as np
>>> np.full((2, 2), np.inf)
array([[inf, inf],
       [inf, inf]])
>>> np.full((2, 2), 10)
array([[10, 10],
       [10, 10]])
```

```
>>> np.full((2, 2), [1, 2])
array([[1, 2],
       [1, 2]])
```

numpy.**full_like**(*a*, *fill_value*, *dtype=None*, *order='K'*, *subok=True*, *shape=None*, ***, *device=None*)

Return a full array with the same shape and type as a given array.

Parameters

a
[array_like] The shape and data-type of *a* define these same attributes of the returned array.

fill_value
[array_like] Fill value.

dtype
[data-type, optional] Overrides the data type of the result.

order
[{'C', 'F', 'A', or 'K'}, optional] Overrides the memory layout of the result. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible.

subok
[bool, optional.] If True, then the newly created array will use the sub-class type of *a*, otherwise it will be a base-class array. Defaults to True.

shape
[int or sequence of ints, optional.] Overrides the shape of the result. If order='K' and the number of dimensions is unchanged, will try to keep order, otherwise, order='C' is implied.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

Returns

out
[ndarray] Array of *fill_value* with the same shape and type as *a*.

See also:

empty_like
Return an empty array with shape and type of input.

ones_like
Return an array of ones with shape and type of input.

zeros_like
Return an array of zeros with shape and type of input.

full
Return a new array of given shape filled with value.

Examples

```
>>> import numpy as np
>>> x = np.arange(6, dtype=int)
>>> np.full_like(x, 1)
array([1, 1, 1, 1, 1, 1])
>>> np.full_like(x, 0.1)
array([0, 0, 0, 0, 0, 0])
>>> np.full_like(x, 0.1, dtype=np.double)
array([0.1, 0.1, 0.1, 0.1, 0.1, 0.1])
>>> np.full_like(x, np.nan, dtype=np.double)
array([nan, nan, nan, nan, nan, nan])
```

```
>>> y = np.arange(6, dtype=np.double)
>>> np.full_like(y, 0.1)
array([0.1, 0.1, 0.1, 0.1, 0.1, 0.1])
```

```
>>> y = np.zeros([2, 2, 3], dtype=int)
>>> np.full_like(y, [0, 0, 255])
array([[[  0,   0, 255],
        [  0,   0, 255]],
       [[  0,   0, 255],
        [  0,   0, 255]]])
```

From existing data

array(object[, dtype, copy, order, subok, ...])	Create an array.
asarray(a[, dtype, order, device, copy, like])	Convert the input to an array.
asanyarray(a[, dtype, order, device, copy, like])	Convert the input to an ndarray, but pass ndarray subclasses through.
ascontiguousarray(a[, dtype, like])	Return a contiguous array (ndim >= 1) in memory (C order).
asmatrix(data[, dtype])	Interpret the input as a matrix.
astype(x, dtype, /, *[, copy, device])	Copies an array to a specified data type.
copy(a[, order, subok])	Return an array copy of the given object.
frombuffer(buffer[, dtype, count, offset, like])	Interpret a buffer as a 1-dimensional array.
from_dlpack(x, /, *[, device, copy])	Create a NumPy array from an object implementing the `__dlpack__` protocol.
fromfile(file[, dtype, count, sep, offset, like])	Construct an array from data in a text or binary file.
fromfunction(function, shape, *[, dtype, like])	Construct an array by executing a function over each coordinate.
fromiter(iter, dtype[, count, like])	Create a new 1-dimensional array from an iterable object.
fromstring(string[, dtype, count, like])	A new 1-D array initialized from text data in a string.
loadtxt(fname[, dtype, comments, delimiter, ...])	Load data from a text file.

numpy.**array**(*object*, *dtype=None*, ***, *copy=True*, *order='K'*, *subok=False*, *ndmin=0*, *like=None*)

Create an array.

Parameters

object

[array_like] An array, any object exposing the array interface, an object whose `__array__` method returns an array, or any (nested) sequence. If object is a scalar, a 0-dimensional array containing object is returned.

dtype

[data-type, optional] The desired data-type for the array. If not given, NumPy will try to use a default `dtype` that can represent the values (by applying promotion rules when necessary.)

copy

[bool, optional] If `True` (default), then the array data is copied. If `None`, a copy will only be made if `__array__` returns a copy, if obj is a nested sequence, or if a copy is needed to satisfy any of the other requirements (`dtype`, `order`, etc.). Note that any copy of the data is shallow, i.e., for arrays with object dtype, the new array will point to the same objects. See Examples for *ndarray.copy*. For `False` it raises a `ValueError` if a copy cannot be avoided. Default: `True`.

order

[{'K', 'A', 'C', 'F'}, optional] Specify the memory layout of the array. If object is not an array, the newly created array will be in C order (row major) unless 'F' is specified, in which case it will be in Fortran order (column major). If object is an array the following holds.

order	no copy	copy=True
'K'	unchanged	F & C order preserved, otherwise most similar order
'A'	unchanged	F order if input is F and not C, otherwise C order
'C'	C order	C order
'F'	F order	F order

When `copy=None` and a copy is made for other reasons, the result is the same as if `copy=True`, with some exceptions for 'A', see the Notes section. The default order is 'K'.

subok
[bool, optional] If True, then sub-classes will be passed-through, otherwise the returned array will be forced to be a base-class array (default).

ndmin
[int, optional] Specifies the minimum number of dimensions that the resulting array should have. Ones will be prepended to the shape as needed to meet this requirement.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] An array object satisfying the specified requirements.

See also:

empty_like
Return an empty array with shape and type of input.

ones_like
Return an array of ones with shape and type of input.

zeros_like
Return an array of zeros with shape and type of input.

full_like
Return a new array with shape of input filled with value.

empty
Return a new uninitialized array.

ones
Return a new array setting values to one.

zeros
Return a new array setting values to zero.

full
Return a new array of given shape filled with value.

copy
Return an array copy of the given object.

Notes

When order is 'A' and `object` is an array in neither 'C' nor 'F' order, and a copy is forced by a change in dtype, then the order of the result is not necessarily 'C' as expected. This is likely a bug.

Examples

```
>>> import numpy as np
>>> np.array([1, 2, 3])
array([1, 2, 3])
```

Upcasting:

```
>>> np.array([1, 2, 3.0])
array([ 1.,  2.,  3.])
```

More than one dimension:

```
>>> np.array([[1, 2], [3, 4]])
array([[1, 2],
       [3, 4]])
```

Minimum dimensions 2:

```
>>> np.array([1, 2, 3], ndmin=2)
array([[1, 2, 3]])
```

Type provided:

```
>>> np.array([1, 2, 3], dtype=complex)
array([ 1.+0.j,  2.+0.j,  3.+0.j])
```

Data-type consisting of more than one element:

```
>>> x = np.array([(1,2),(3,4)],dtype=[('a','<i4'),('b','<i4')])
>>> x['a']
array([1, 3], dtype=int32)
```

Creating an array from sub-classes:

```
>>> np.array(np.asmatrix('1 2; 3 4'))
array([[1, 2],
       [3, 4]])
```

```
>>> np.array(np.asmatrix('1 2; 3 4'), subok=True)
matrix([[1, 2],
        [3, 4]])
```

numpy.**asarray**(*a*, *dtype=None*, *order=None*, ***, *device=None*, *copy=None*, *like=None*)

Convert the input to an array.

Parameters

a

[array_like] Input data, in any form that can be converted to an array. This includes lists, lists of tuples, tuples, tuples of tuples, tuples of lists and ndarrays.

dtype
[data-type, optional] By default, the data-type is inferred from the input data.

order
[{'C', 'F', 'A', 'K'}, optional] Memory layout. 'A' and 'K' depend on the order of input array a. 'C' row-major (C-style), 'F' column-major (Fortran-style) memory representation. 'A' (any) means 'F' if *a* is Fortran contiguous, 'C' otherwise 'K' (keep) preserve input order Defaults to 'K'.

device
[str, optional] The device on which to place the created array. Default: `None`. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

copy
[bool, optional] If `True`, then the object is copied. If `None` then the object is copied only if needed, i.e. if `__array__` returns a copy, if obj is a nested sequence, or if a copy is needed to satisfy any of the other requirements (`dtype`, `order`, etc.). For `False` it raises a `ValueError` if a copy cannot be avoided. Default: `None`.

New in version 2.0.0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] Array interpretation of `a`. No copy is performed if the input is already an ndarray with matching dtype and order. If `a` is a subclass of ndarray, a base class ndarray is returned.

See also:

asanyarray
Similar function which passes through subclasses.

ascontiguousarray
Convert input to a contiguous array.

asfortranarray
Convert input to an ndarray with column-major memory order.

asarray_chkfinite
Similar function which checks input for NaNs and Infs.

fromiter
Create an array from an iterator.

fromfunction
Construct an array by executing a function on grid positions.

Examples

Convert a list into an array:

```
>>> a = [1, 2]
>>> import numpy as np
>>> np.asarray(a)
array([1, 2])
```

Existing arrays are not copied:

```
>>> a = np.array([1, 2])
>>> np.asarray(a) is a
True
```

If *dtype* is set, array is copied only if dtype does not match:

```
>>> a = np.array([1, 2], dtype=np.float32)
>>> np.shares_memory(np.asarray(a, dtype=np.float32), a)
True
>>> np.shares_memory(np.asarray(a, dtype=np.float64), a)
False
```

Contrary to *asanyarray*, ndarray subclasses are not passed through:

```
>>> issubclass(np.recarray, np.ndarray)
True
>>> a = np.array([(1., 2), (3., 4)], dtype='f4,i4').view(np.recarray)
>>> np.asarray(a) is a
False
>>> np.asanyarray(a) is a
True
```

numpy.**asanyarray**(*a*, *dtype=None*, *order=None*, ***, *device=None*, *copy=None*, *like=None*)

Convert the input to an ndarray, but pass ndarray subclasses through.

Parameters

a
: [array_like] Input data, in any form that can be converted to an array. This includes scalars, lists, lists of tuples, tuples, tuples of tuples, tuples of lists, and ndarrays.

dtype
: [data-type, optional] By default, the data-type is inferred from the input data.

order
: [{'C', 'F', 'A', 'K'}, optional] Memory layout. 'A' and 'K' depend on the order of input array a. 'C' row-major (C-style), 'F' column-major (Fortran-style) memory representation. 'A' (any) means 'F' if *a* is Fortran contiguous, 'C' otherwise 'K' (keep) preserve input order Defaults to 'C'.

device
: [str, optional] The device on which to place the created array. Default: `None`. For Array-API interoperability only, so must be `"cpu"` if passed.

  New in version 2.1.0.

copy
: [bool, optional] If `True`, then the object is copied. If `None` then the object is copied only if needed, i.e. if `__array__` returns a copy, if obj is a nested sequence, or if a copy is

needed to satisfy any of the other requirements (`dtype`, `order`, etc.). For `False` it raises a `ValueError` if a copy cannot be avoided. Default: `None`.

New in version 2.1.0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray or an ndarray subclass] Array interpretation of *a*. If *a* is an ndarray or a subclass of ndarray, it is returned as-is and no copy is performed.

See also:

asarray
Similar function which always returns ndarrays.

ascontiguousarray
Convert input to a contiguous array.

asfortranarray
Convert input to an ndarray with column-major memory order.

asarray_chkfinite
Similar function which checks input for NaNs and Infs.

fromiter
Create an array from an iterator.

fromfunction
Construct an array by executing a function on grid positions.

Examples

Convert a list into an array:

```
>>> a = [1, 2]
>>> import numpy as np
>>> np.asanyarray(a)
array([1, 2])
```

Instances of *ndarray* subclasses are passed through as-is:

```
>>> a = np.array([(1., 2), (3., 4)], dtype='f4,i4').view(np.recarray)
>>> np.asanyarray(a) is a
True
```

numpy.**ascontiguousarray**(*a*, *dtype=None*, ***, *like=None*)

Return a contiguous array (ndim >= 1) in memory (C order).

Parameters

a
[array_like] Input array.

dtype
[str or dtype object, optional] Data-type of returned array.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] Contiguous array of same shape and content as *a*, with type `dtype` if specified.

See also:

asfortranarray
Convert input to an ndarray with column-major memory order.

require
Return an ndarray that satisfies requirements.

ndarray.flags
Information about the memory layout of the array.

Examples

Starting with a Fortran-contiguous array:

```
>>> import numpy as np
>>> x = np.ones((2, 3), order='F')
>>> x.flags['F_CONTIGUOUS']
True
```

Calling `ascontiguousarray` makes a C-contiguous copy:

```
>>> y = np.ascontiguousarray(x)
>>> y.flags['C_CONTIGUOUS']
True
>>> np.may_share_memory(x, y)
False
```

Now, starting with a C-contiguous array:

```
>>> x = np.ones((2, 3), order='C')
>>> x.flags['C_CONTIGUOUS']
True
```

Then, calling `ascontiguousarray` returns the same object:

```
>>> y = np.ascontiguousarray(x)
>>> x is y
True
```

Note: This function returns an array with at least one-dimension (1-d) so it will not preserve 0-d arrays.

numpy.**astype**(*x*, *dtype*, */*, ***, *copy=True*, *device=None*)

Copies an array to a specified data type.

This function is an Array API compatible alternative to *numpy.ndarray.astype*.

Parameters

x
[ndarray] Input NumPy array to cast. `array_likes` are explicitly not supported here.

dtype
[dtype] Data type of the result.

copy
[bool, optional] Specifies whether to copy an array when the specified dtype matches the data type of the input array `x`. If `True`, a newly allocated array must always be returned. If `False` and the specified dtype matches the data type of the input array, the input array must be returned; otherwise, a newly allocated array must be returned. Defaults to `True`.

device
[str, optional] The device on which to place the returned array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.1.0.

Returns

out
[ndarray] An array having the specified data type.

See also:

ndarray.astype

Examples

```
>>> import numpy as np
>>> arr = np.array([1, 2, 3]); arr
array([1, 2, 3])
>>> np.astype(arr, np.float64)
array([1., 2., 3.])
```

Non-copy case:

```
>>> arr = np.array([1, 2, 3])
>>> arr_noncpy = np.astype(arr, arr.dtype, copy=False)
>>> np.shares_memory(arr, arr_noncpy)
True
```

numpy.**copy**(*a*, *order='K'*, *subok=False*)

Return an array copy of the given object.

Parameters

a
[array_like] Input data.

order
: [{'C', 'F', 'A', 'K'}, optional] Controls the memory layout of the copy. 'C' means C-order, 'F' means F-order, 'A' means 'F' if *a* is Fortran contiguous, 'C' otherwise. 'K' means match the layout of *a* as closely as possible. (Note that this function and *ndarray.copy* are very similar, but have different default values for their order= arguments.)

subok
: [bool, optional] If True, then sub-classes will be passed-through, otherwise the returned array will be forced to be a base-class array (defaults to False).

Returns

arr
: [ndarray] Array interpretation of *a*.

See also:

ndarray.copy
: Preferred method for creating an array copy

Notes

This is equivalent to:

```
>>> np.array(a, copy=True)
```

The copy made of the data is shallow, i.e., for arrays with object dtype, the new array will point to the same objects. See Examples from *ndarray.copy*.

Examples

```
>>> import numpy as np
```

Create an array x, with a reference y and a copy z:

```
>>> x = np.array([1, 2, 3])
>>> y = x
>>> z = np.copy(x)
```

Note that, when we modify x, y changes, but not z:

```
>>> x[0] = 10
>>> x[0] == y[0]
True
>>> x[0] == z[0]
False
```

Note that, np.copy clears previously set WRITEABLE=False flag.

```
>>> a = np.array([1, 2, 3])
>>> a.flags["WRITEABLE"] = False
>>> b = np.copy(a)
>>> b.flags["WRITEABLE"]
True
>>> b[0] = 3
```

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```
>>> b
array([3, 2, 3])
```

numpy.**frombuffer**(*buffer*, *dtype=float*, *count=-1*, *offset=0*, *, *like=None*)

Interpret a buffer as a 1-dimensional array.

Parameters

buffer
[buffer_like] An object that exposes the buffer interface.

dtype
[data-type, optional] Data-type of the returned array; default: float.

count
[int, optional] Number of items to read. `-1` means all data in the buffer.

offset
[int, optional] Start reading the buffer from this offset (in bytes); default: 0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray]

See also:

ndarray.tobytes
Inverse of this operation, construct Python bytes from the raw data bytes in the array.

Notes

If the buffer has data that is not in machine byte-order, this should be specified as part of the data-type, e.g.:

```
>>> dt = np.dtype(int)
>>> dt = dt.newbyteorder('>')
>>> np.frombuffer(buf, dtype=dt)
```

The data of the resulting array will not be byteswapped, but will be interpreted correctly.

This function creates a view into the original object. This should be safe in general, but it may make sense to copy the result when the original object is mutable or untrusted.

Examples

```
>>> import numpy as np
>>> s = b'hello world'
>>> np.frombuffer(s, dtype='S1', count=5, offset=6)
array([b'w', b'o', b'r', b'l', b'd'], dtype='|S1')
```

```
>>> np.frombuffer(b'\x01\x02', dtype=np.uint8)
array([1, 2], dtype=uint8)
>>> np.frombuffer(b'\x01\x02\x03\x04\x05', dtype=np.uint8, count=3)
array([1, 2, 3], dtype=uint8)
```

numpy.**from_dlpack**(*x*, */*, ***, *device=None*, *copy=None*)

Create a NumPy array from an object implementing the `__dlpack__` protocol. Generally, the returned NumPy array is a read-only view of the input object. See [1] and [2] for more details.

Parameters

x
: [object] A Python object that implements the `__dlpack__` and `__dlpack_device__` methods.

device
: [device, optional] Device on which to place the created array. Default: `None`. Must be `"cpu"` if passed which may allow importing an array that is not already CPU available.

copy
: [bool, optional] Boolean indicating whether or not to copy the input. If `True`, the copy will be made. If `False`, the function will never copy, and will raise `BufferError` in case a copy is deemed necessary. Passing it requests a copy from the exporter who may or may not implement the capability. If `None`, the function will reuse the existing memory buffer if possible and copy otherwise. Default: `None`.

Returns

out
: [ndarray]

References

[1], [2]

Examples

```
>>> import torch
>>> x = torch.arange(10)
>>> # create a view of the torch tensor "x" in NumPy
>>> y = np.from_dlpack(x)
```

numpy.**fromfile**(*file*, *dtype=float*, *count=-1*, *sep=''*, *offset=0*, ***, *like=None*)

Construct an array from data in a text or binary file.

A highly efficient way of reading binary data with a known data-type, as well as parsing simply formatted text files. Data written using the *tofile* method can be read using this function.

Parameters

file
: [file or str or Path] Open file object or filename.

dtype
: [data-type] Data type of the returned array. For binary files, it is used to determine the size and byte-order of the items in the file. Most builtin numeric types are supported and extension types may be supported.

count
: [int] Number of items to read. `-1` means all items (i.e., the complete file).

sep
: [str] Separator between items if file is a text file. Empty ("") separator means the file should be treated as binary. Spaces (" ") in the separator match zero or more whitespace characters. A separator consisting only of spaces must match at least one whitespace.

offset
: [int] The offset (in bytes) from the file's current position. Defaults to 0. Only permitted for binary files.

like
: [array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

  New in version 1.20.0.

See also:

load, *save*
ndarray.tofile
loadtxt
: More flexible way of loading data from a text file.

Notes

Do not rely on the combination of *tofile* and *fromfile* for data storage, as the binary files generated are not platform independent. In particular, no byte-order or data-type information is saved. Data can be stored in the platform independent `.npy` format using *save* and *load* instead.

Examples

Construct an ndarray:

```
>>> import numpy as np
>>> dt = np.dtype([('time', [('min', np.int64), ('sec', np.int64)]),
...                ('temp', float)])
>>> x = np.zeros((1,), dtype=dt)
>>> x['time']['min'] = 10; x['temp'] = 98.25
>>> x
array([((10, 0), 98.25)],
      dtype=[('time', [('min', '<i8'), ('sec', '<i8')]), ('temp', '<f8')])
```

Save the raw data to disk:

```
>>> import tempfile
>>> fname = tempfile.mkstemp()[1]
>>> x.tofile(fname)
```

Read the raw data from disk:

```
>>> np.fromfile(fname, dtype=dt)
array([((10, 0), 98.25)],
      dtype=[('time', [('min', '<i8'), ('sec', '<i8')]), ('temp', '<f8')])
```

The recommended way to store and load data:

```
>>> np.save(fname, x)
>>> np.load(fname + '.npy')
array([((10, 0), 98.25)],
      dtype=[('time', [('min', '<i8'), ('sec', '<i8')]), ('temp', '<f8')])
```

numpy.**fromfunction**(*function*, *shape*, *, *dtype=<class 'float'>*, *like=None*, ***kwargs*)

Construct an array by executing a function over each coordinate.

The resulting array therefore has a value `fn(x, y, z)` at coordinate `(x, y, z)`.

Parameters

function
: [callable] The function is called with N parameters, where N is the rank of *shape*. Each parameter represents the coordinates of the array varying along a specific axis. For example, if *shape* were `(2, 2)`, then the parameters would be `array([[0, 0], [1, 1]])` and `array([[0, 1], [0, 1]])`

shape
: [(N,) tuple of ints] Shape of the output array, which also determines the shape of the coordinate arrays passed to *function*.

dtype
: [data-type, optional] Data-type of the coordinate arrays passed to *function*. By default, *dtype* is float.

like
: [array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

  New in version 1.20.0.

Returns

fromfunction
: [any] The result of the call to *function* is passed back directly. Therefore the shape of *fromfunction* is completely determined by *function*. If *function* returns a scalar value, the shape of *fromfunction* would not match the *shape* parameter.

See also:

indices*, *meshgrid

Notes

Keywords other than `dtype` and *like* are passed to *function*.

Examples

```
>>> import numpy as np
>>> np.fromfunction(lambda i, j: i, (2, 2), dtype=float)
array([[0., 0.],
       [1., 1.]])
```

```
>>> np.fromfunction(lambda i, j: j, (2, 2), dtype=float)
array([[0., 1.],
       [0., 1.]])
```

```
>>> np.fromfunction(lambda i, j: i == j, (3, 3), dtype=int)
array([[ True, False, False],
       [False,  True, False],
       [False, False,  True]])
```

```
>>> np.fromfunction(lambda i, j: i + j, (3, 3), dtype=int)
array([[0, 1, 2],
       [1, 2, 3],
       [2, 3, 4]])
```

numpy.**fromiter**(*iter*, *dtype*, *count=-1*, *, *like=None*)

Create a new 1-dimensional array from an iterable object.

Parameters

iter
[iterable object] An iterable object providing data for the array.

dtype
[data-type] The data-type of the returned array.

Changed in version 1.23: Object and subarray dtypes are now supported (note that the final result is not 1-D for a subarray dtype).

count
[int, optional] The number of items to read from *iterable*. The default is -1, which means all data is read.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] The output array.

Notes

Specify *count* to improve performance. It allows `fromiter` to pre-allocate the output array, instead of resizing it on demand.

Examples

```
>>> import numpy as np
>>> iterable = (x*x for x in range(5))
>>> np.fromiter(iterable, float)
array([  0.,   1.,   4.,   9.,  16.])
```

A carefully constructed subarray dtype will lead to higher dimensional results:

```
>>> iterable = ((x+1, x+2) for x in range(5))
>>> np.fromiter(iterable, dtype=np.dtype((int, 2)))
array([[1, 2],
       [2, 3],
       [3, 4],
       [4, 5],
       [5, 6]])
```

numpy.**fromstring**(*string*, *dtype=float*, *count=-1*, ***, *sep*, *like=None*)

A new 1-D array initialized from text data in a string.

Parameters

string
[str] A string containing the data.

dtype
[data-type, optional] The data type of the array; default: float. For binary input data, the data must be in exactly this format. Most builtin numeric types are supported and extension types may be supported.

count
[int, optional] Read this number of *dtype* elements from the data. If this is negative (the default), the count will be determined from the length of the data.

sep
[str, optional] The string separating numbers in the data; extra whitespace between elements is also ignored.

Deprecated since version 1.14: Passing `sep=''`, the default, is deprecated since it will trigger the deprecated binary mode of this function. This mode interprets `string` as binary bytes, rather than ASCII text with decimal numbers, an operation which is better spelt `frombuffer(string, dtype, count)`. If `string` contains unicode text, the binary mode of *fromstring* will first encode it into bytes using utf-8, which will not produce sane results.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

arr
[ndarray] The constructed array.

Raises

ValueError
If the string is not the correct size to satisfy the requested `dtype` and *count*.

See also:

frombuffer, ***fromfile***, ***fromiter***

Examples

```
>>> import numpy as np
>>> np.fromstring('1 2', dtype=int, sep=' ')
array([1, 2])
>>> np.fromstring('1, 2', dtype=int, sep=',')
array([1, 2])
```

numpy.**loadtxt**(*fname*, *dtype=<class 'float'>*, *comments='#'*, *delimiter=None*, *converters=None*, *skiprows=0*, *usecols=None*, *unpack=False*, *ndmin=0*, *encoding=None*, *max_rows=None*, ***, *quotechar=None*, *like=None*)

Load data from a text file.

Parameters

fname
[file, str, pathlib.Path, list of str, generator] File, filename, list, or generator to read. If the filename extension is `.gz` or `.bz2`, the file is first decompressed. Note that generators must return bytes or strings. The strings in a list or produced by a generator are treated as lines.

dtype
[data-type, optional] Data-type of the resulting array; default: float. If this is a structured data-type, the resulting array will be 1-dimensional, and each row will be interpreted as an element of the array. In this case, the number of columns used must match the number of fields in the data-type.

comments
[str or sequence of str or None, optional] The characters or list of characters used to indicate the start of a comment. None implies no comments. For backwards compatibility, byte strings will be decoded as 'latin1'. The default is '#'.

delimiter
[str, optional] The character used to separate the values. For backwards compatibility, byte strings will be decoded as 'latin1'. The default is whitespace.

Changed in version 1.23.0: Only single character delimiters are supported. Newline characters cannot be used as the delimiter.

converters
[dict or callable, optional] Converter functions to customize value parsing. If *converters* is callable, the function is applied to all columns, else it must be a dict that maps column number to a parser function. See examples for further details. Default: None.

Changed in version 1.23.0: The ability to pass a single callable to be applied to all columns was added.

skiprows
[int, optional] Skip the first *skiprows* lines, including comments; default: 0.

usecols
[int or sequence, optional] Which columns to read, with 0 being the first. For example, `usecols = (1,4,5)` will extract the 2nd, 5th and 6th columns. The default, None, results in all columns being read.

unpack
[bool, optional] If True, the returned array is transposed, so that arguments may be unpacked using `x, y, z = loadtxt(...)`. When used with a structured data-type, arrays are returned for each field. Default is False.

ndmin
[int, optional] The returned array will have at least *ndmin* dimensions. Otherwise mono-dimensional axes will be squeezed. Legal values: 0 (default), 1 or 2.

encoding
[str, optional] Encoding used to decode the inputfile. Does not apply to input streams. The special value 'bytes' enables backward compatibility workarounds that ensures you receive byte arrays as results if possible and passes 'latin1' encoded strings to converters. Override this value to receive unicode arrays and pass strings as input to converters. If set to None the system default is used. The default value is 'bytes'.

Changed in version 2.0: Before NumPy 2, the default was `'bytes'` for Python 2 compatibility. The default is now `None`.

max_rows
[int, optional] Read *max_rows* rows of content after *skiprows* lines. The default is to read all the rows. Note that empty rows containing no data such as empty lines and comment lines are not counted towards *max_rows*, while such lines are counted in *skiprows*.

Changed in version 1.23.0: Lines containing no data, including comment lines (e.g., lines starting with '#' or as specified via *comments*) are not counted towards *max_rows*.

quotechar
[unicode character or None, optional] The character used to denote the start and end of a quoted item. Occurrences of the delimiter or comment characters are ignored within a quoted item. The default value is `quotechar=None`, which means quoting support is disabled.

If two consecutive instances of *quotechar* are found within a quoted field, the first is treated as an escape character. See examples.

New in version 1.23.0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] Data read from the text file.

See also:

load, *fromstring*, *fromregex*
genfromtxt
: Load data with missing values handled as specified.

scipy.io.loadmat
: reads MATLAB data files

Notes

This function aims to be a fast reader for simply formatted files. The *genfromtxt* function provides more sophisticated handling of, e.g., lines with missing values.

Each row in the input text file must have the same number of values to be able to read all values. If all rows do not have same number of values, a subset of up to n columns (where n is the least number of values present in all rows) can be read by specifying the columns via *usecols*.

The strings produced by the Python float.hex method can be used as input for floats.

Examples

```
>>> import numpy as np
>>> from io import StringIO   # StringIO behaves like a file object
>>> c = StringIO("0 1\n2 3")
>>> np.loadtxt(c)
array([[0., 1.],
       [2., 3.]])
```

```
>>> d = StringIO("M 21 72\nF 35 58")
>>> np.loadtxt(d, dtype={'names': ('gender', 'age', 'weight'),
...                      'formats': ('S1', 'i4', 'f4')})
array([(b'M', 21, 72.), (b'F', 35, 58.)],
      dtype=[('gender', 'S1'), ('age', '<i4'), ('weight', '<f4')])
```

```
>>> c = StringIO("1,0,2\n3,0,4")
>>> x, y = np.loadtxt(c, delimiter=',', usecols=(0, 2), unpack=True)
>>> x
array([1., 3.])
>>> y
array([2., 4.])
```

The *converters* argument is used to specify functions to preprocess the text prior to parsing. *converters* can be a dictionary that maps preprocessing functions to each column:

```
>>> s = StringIO("1.618, 2.296\n3.141, 4.669\n")
>>> conv = {
...     0: lambda x: np.floor(float(x)),  # conversion fn for column 0
...     1: lambda x: np.ceil(float(x)),  # conversion fn for column 1
... }
>>> np.loadtxt(s, delimiter=",", converters=conv)
array([[1., 3.],
       [3., 5.]])
```

converters can be a callable instead of a dictionary, in which case it is applied to all columns:

```
>>> s = StringIO("0xDE 0xAD\n0xC0 0xDE")
>>> import functools
>>> conv = functools.partial(int, base=16)
>>> np.loadtxt(s, converters=conv)
array([[222., 173.],
       [192., 222.]])
```

This example shows how *converters* can be used to convert a field with a trailing minus sign into a negative number.

```
>>> s = StringIO("10.01 31.25-\n19.22 64.31\n17.57- 63.94")
>>> def conv(fld):
...     return -float(fld[:-1]) if fld.endswith("-") else float(fld)
...
>>> np.loadtxt(s, converters=conv)
array([[ 10.01, -31.25],
       [ 19.22,  64.31],
       [-17.57,  63.94]])
```

Using a callable as the converter can be particularly useful for handling values with different formatting, e.g. floats with underscores:

```
>>> s = StringIO("1 2.7 100_000")
>>> np.loadtxt(s, converters=float)
array([1.e+00, 2.7e+00, 1.e+05])
```

This idea can be extended to automatically handle values specified in many different formats, such as hex values:

```
>>> def conv(val):
...     try:
...         return float(val)
...     except ValueError:
...         return float.fromhex(val)
>>> s = StringIO("1, 2.5, 3_000, 0b4, 0x1.4000000000000p+2")
>>> np.loadtxt(s, delimiter=",", converters=conv)
array([1.0e+00, 2.5e+00, 3.0e+03, 1.8e+02, 5.0e+00])
```

Or a format where the - sign comes after the number:

```
>>> s = StringIO("10.01 31.25-\n19.22 64.31\n17.57- 63.94")
>>> conv = lambda x: -float(x[:-1]) if x.endswith("-") else float(x)
>>> np.loadtxt(s, converters=conv)
array([[ 10.01, -31.25],
       [ 19.22,  64.31],
       [-17.57,  63.94]])
```

Support for quoted fields is enabled with the *quotechar* parameter. Comment and delimiter characters are ignored when they appear within a quoted item delineated by *quotechar*:

```
>>> s = StringIO('"alpha, #42", 10.0\n"beta, #64", 2.0\n')
>>> dtype = np.dtype([("label", "U12"), ("value", float)])
>>> np.loadtxt(s, dtype=dtype, delimiter=",", quotechar='"')
array([('alpha, #42', 10.), ('beta, #64',  2.)],
      dtype=[('label', '<U12'), ('value', '<f8')])
```

Quoted fields can be separated by multiple whitespace characters:

```
>>> s = StringIO('"alpha, #42"       10.0\n"beta, #64" 2.0\n')
>>> dtype = np.dtype([("label", "U12"), ("value", float)])
>>> np.loadtxt(s, dtype=dtype, delimiter=None, quotechar='"')
array([('alpha, #42', 10.), ('beta, #64',  2.)],
      dtype=[('label', '<U12'), ('value', '<f8')])
```

Two consecutive quote characters within a quoted field are treated as a single escaped character:

```
>>> s = StringIO('"Hello, my name is ""Monty""!"')
>>> np.loadtxt(s, dtype="U", delimiter=",", quotechar='"')
array('Hello, my name is "Monty"!', dtype='<U26')
```

Read subset of columns when all rows do not contain equal number of values:

```
>>> d = StringIO("1 2\n2 4\n3 9 12\n4 16 20")
>>> np.loadtxt(d, usecols=(0, 1))
array([[ 1.,  2.],
       [ 2.,  4.],
       [ 3.,  9.],
       [ 4., 16.]])
```

Creating record arrays

Note: Please refer to *Record arrays* for record arrays.

rec.array(obj[, dtype, shape, offset, ...])	Construct a record array from a wide-variety of objects.
rec.fromarrays(arrayList[, dtype, shape, ...])	Create a record array from a (flat) list of arrays
rec.fromrecords(recList[, dtype, shape, ...])	Create a recarray from a list of records in text form.
rec.fromstring(datastring[, dtype, shape, ...])	Create a record array from binary data
rec.fromfile(fd[, dtype, shape, offset, ...])	Create an array from binary file data

Creating character arrays (`numpy.char`)

Note: *numpy.char* is used to create character arrays.

char.array(obj[, itemsize, copy, unicode, order])	Create a *chararray*.
char.asarray(obj[, itemsize, unicode, order])	Convert the input to a *chararray*, copying the data only if necessary.

Numerical ranges

arange([start,] stop[, step,][, dtype, ...])	Return evenly spaced values within a given interval.
linspace(start, stop[, num, endpoint, ...])	Return evenly spaced numbers over a specified interval.
logspace(start, stop[, num, endpoint, base, ...])	Return numbers spaced evenly on a log scale.
geomspace(start, stop[, num, endpoint, ...])	Return numbers spaced evenly on a log scale (a geometric progression).
meshgrid(*xi[, copy, sparse, indexing])	Return a tuple of coordinate matrices from coordinate vectors.
mgrid	An instance which returns a dense multi-dimensional "meshgrid".
ogrid	An instance which returns an open multi-dimensional "meshgrid".

numpy.**arange**([*start*,]*stop*, [*step*,]*dtype=None*, *, *device=None*, *like=None*)

Return evenly spaced values within a given interval.

`arange` can be called with a varying number of positional arguments:

- `arange(stop)`: Values are generated within the half-open interval `[0, stop)` (in other words, the interval including *start* but excluding *stop*).
- `arange(start, stop)`: Values are generated within the half-open interval `[start, stop)`.
- `arange(start, stop, step)` Values are generated within the half-open interval `[start, stop)`, with spacing between values given by `step`.

For integer arguments the function is roughly equivalent to the Python built-in `range`, but returns an ndarray rather than a `range` instance.

When using a non-integer step, such as 0.1, it is often better to use *numpy.linspace*.

See the Warning sections below for more information.

Parameters

start
: [integer or real, optional] Start of interval. The interval includes this value. The default start value is 0.

stop
: [integer or real] End of interval. The interval does not include this value, except in some cases where *step* is not an integer and floating point round-off affects the length of *out*.

step
: [integer or real, optional] Spacing between values. For any output *out*, this is the distance between two adjacent values, `out[i+1] - out[i]`. The default step size is 1. If *step* is specified as a position argument, *start* must also be given.

dtype
: [dtype, optional] The type of the output array. If *dtype* is not given, infer the data type from the other input arguments.

device
: [str, optional] The device on which to place the created array. Default: `None`. For Array-API interoperability only, so must be `"cpu"` if passed.

  New in version 2.0.0.

like
: [array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

  New in version 1.20.0.

Returns

arange
: [ndarray] Array of evenly spaced values.

  For floating point arguments, the length of the result is `ceil((stop - start)/step)`. Because of floating point overflow, this rule may result in the last element of *out* being greater than *stop*.

Warning: The length of the output might not be numerically stable.

Another stability issue is due to the internal implementation of *numpy.arange*. The actual step value used to populate the array is `dtype(start + step) - dtype(start)` and not *step*. Precision loss can occur here, due to casting or due to using floating points when *start* is much larger than *step*. This can lead to unexpected behaviour. For example:

```
>>> np.arange(0, 5, 0.5, dtype=int)
array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0])
>>> np.arange(-3, 3, 0.5, dtype=int)
array([-3, -2, -1,  0,  1,  2,  3,  4,  5,  6,  7,  8])
```

In such cases, the use of *numpy.linspace* should be preferred.

The built-in `range` generates Python built-in integers that have arbitrary size, while *numpy.arange* produces *numpy.int32* or *numpy.int64* numbers. This may result in incorrect results for large integer values:

```
>>> power = 40
>>> modulo = 10000
>>> x1 = [(n ** power) % modulo for n in range(8)]
>>> x2 = [(n ** power) % modulo for n in np.arange(8)]
>>> print(x1)
[0, 1, 7776, 8801, 6176, 625, 6576, 4001]  # correct
>>> print(x2)
[0, 1, 7776, 7185, 0, 5969, 4816, 3361]  # incorrect
```

See also:

numpy.linspace
: Evenly spaced numbers with careful handling of endpoints.

numpy.ogrid
: Arrays of evenly spaced numbers in N-dimensions.

numpy.mgrid
: Grid-shaped arrays of evenly spaced numbers in N-dimensions.

how-to-partition

Examples

```
>>> import numpy as np
>>> np.arange(3)
array([0, 1, 2])
>>> np.arange(3.0)
array([ 0.,  1.,  2.])
>>> np.arange(3,7)
array([3, 4, 5, 6])
>>> np.arange(3,7,2)
array([3, 5])
```

numpy.**linspace**(*start*, *stop*, *num=50*, *endpoint=True*, *retstep=False*, *dtype=None*, *axis=0*, ***, *device=None*)

Return evenly spaced numbers over a specified interval.

Returns *num* evenly spaced samples, calculated over the interval [*start*, *stop*].

The endpoint of the interval can optionally be excluded.

Changed in version 1.20.0: Values are rounded towards `-inf` instead of `0` when an integer `dtype` is specified. The old behavior can still be obtained with `np.linspace(start, stop, num).astype(int)`

Parameters

start
[array_like] The starting value of the sequence.

stop
[array_like] The end value of the sequence, unless *endpoint* is set to False. In that case, the sequence consists of all but the last of `num + 1` evenly spaced samples, so that *stop* is excluded. Note that the step size changes when *endpoint* is False.

num
[int, optional] Number of samples to generate. Default is 50. Must be non-negative.

endpoint
[bool, optional] If True, *stop* is the last sample. Otherwise, it is not included. Default is True.

retstep
[bool, optional] If True, return (*samples*, *step*), where *step* is the spacing between samples.

dtype
[dtype, optional] The type of the output array. If *dtype* is not given, the data type is inferred from *start* and *stop*. The inferred dtype will never be an integer; *float* is chosen even if the arguments would produce an array of integers.

axis
[int, optional] The axis in the result to store the samples. Relevant only if start or stop are array-like. By default (0), the samples will be along a new axis inserted at the beginning. Use -1 to get an axis at the end.

device
[str, optional] The device on which to place the created array. Default: None. For Array-API interoperability only, so must be `"cpu"` if passed.

New in version 2.0.0.

Returns

samples
[ndarray] There are *num* equally spaced samples in the closed interval `[start, stop]` or the half-open interval `[start, stop)` (depending on whether *endpoint* is True or False).

step
[float, optional] Only returned if *retstep* is True

Size of spacing between samples.

See also:

arange
Similar to `linspace`, but uses a step size (instead of the number of samples).

geomspace
Similar to `linspace`, but with numbers spaced evenly on a log scale (a geometric progression).

logspace
Similar to `geomspace`, but with the end points specified as logarithms.

how-to-partition

Examples

```
>>> import numpy as np
>>> np.linspace(2.0, 3.0, num=5)
array([2.  , 2.25, 2.5 , 2.75, 3.  ])
>>> np.linspace(2.0, 3.0, num=5, endpoint=False)
array([2. ,  2.2,  2.4,  2.6,  2.8])
>>> np.linspace(2.0, 3.0, num=5, retstep=True)
(array([2.  ,  2.25,  2.5 ,  2.75,  3.  ]), 0.25)
```

Graphical illustration:

```
>>> import matplotlib.pyplot as plt
>>> N = 8
>>> y = np.zeros(N)
>>> x1 = np.linspace(0, 10, N, endpoint=True)
>>> x2 = np.linspace(0, 10, N, endpoint=False)
>>> plt.plot(x1, y, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.plot(x2, y + 0.5, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.ylim([-0.5, 1])
(-0.5, 1)
>>> plt.show()
```

numpy.**logspace**(*start*, *stop*, *num=50*, *endpoint=True*, *base=10.0*, *dtype=None*, *axis=0*)

Return numbers spaced evenly on a log scale.

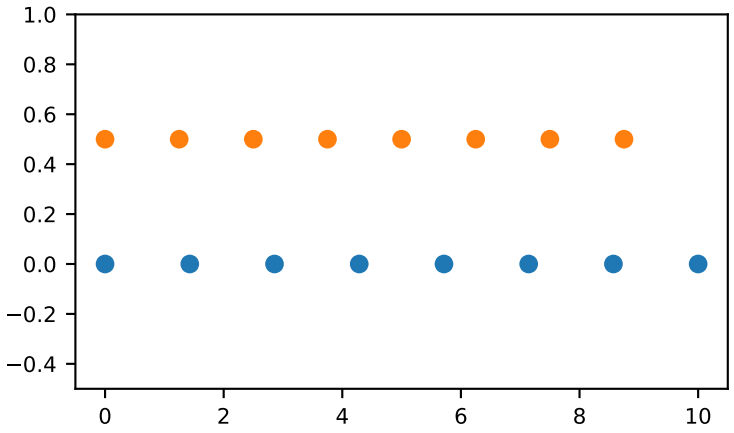
In linear space, the sequence starts at `base ** start` (*base* to the power of *start*) and ends with `base ** stop` (see *endpoint* below).

Changed in version 1.25.0: Non-scalar 'base` is now supported

Parameters

start
[array_like] `base ** start` is the starting value of the sequence.

stop
[array_like] `base ** stop` is the final value of the sequence, unless *endpoint* is False. In that case, `num + 1` values are spaced over the interval in log-space, of which all but the last (a sequence of length *num*) are returned.



num
: [integer, optional] Number of samples to generate. Default is 50.

endpoint
: [boolean, optional] If true, *stop* is the last sample. Otherwise, it is not included. Default is True.

base
: [array_like, optional] The base of the log space. The step size between the elements in `ln(samples) / ln(base)` (or `log_base(samples)`) is uniform. Default is 10.0.

dtype
: [dtype] The type of the output array. If `dtype` is not given, the data type is inferred from *start* and *stop*. The inferred type will never be an integer; *float* is chosen even if the arguments would produce an array of integers.

axis
: [int, optional] The axis in the result to store the samples. Relevant only if start, stop, or base are array-like. By default (0), the samples will be along a new axis inserted at the beginning. Use -1 to get an axis at the end.

Returns

samples
: [ndarray] *num* samples, equally spaced on a log scale.

See also:

arange
: Similar to linspace, with the step size specified instead of the number of samples. Note that, when used with a float endpoint, the endpoint may or may not be included.

linspace
: Similar to logspace, but with the samples uniformly distributed in linear space, instead of log space.

geomspace
: Similar to logspace, but with endpoints specified directly.

how-to-partition

Notes

If base is a scalar, logspace is equivalent to the code

```
>>> y = np.linspace(start, stop, num=num, endpoint=endpoint)
...
>>> power(base, y).astype(dtype)
...
```

Examples

```
>>> import numpy as np
>>> np.logspace(2.0, 3.0, num=4)
array([ 100.        ,  215.443469  ,  464.15888336, 1000.        ])
>>> np.logspace(2.0, 3.0, num=4, endpoint=False)
array([100.        ,  177.827941  ,  316.22776602,  562.34132519])
>>> np.logspace(2.0, 3.0, num=4, base=2.0)
array([4.        ,  5.0396842 ,  6.34960421,  8.        ])
>>> np.logspace(2.0, 3.0, num=4, base=[2.0, 3.0], axis=-1)
array([[ 4.        ,  5.0396842 ,  6.34960421,  8.        ],
       [ 9.        , 12.98024613, 18.72075441, 27.        ]])
```

Graphical illustration:

```
>>> import matplotlib.pyplot as plt
>>> N = 10
>>> x1 = np.logspace(0.1, 1, N, endpoint=True)
>>> x2 = np.logspace(0.1, 1, N, endpoint=False)
>>> y = np.zeros(N)
>>> plt.plot(x1, y, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.plot(x2, y + 0.5, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.ylim([-0.5, 1])
(-0.5, 1)
>>> plt.show()
```

numpy.**geomspace**(*start*, *stop*, *num=50*, *endpoint=True*, *dtype=None*, *axis=0*)

Return numbers spaced evenly on a log scale (a geometric progression).

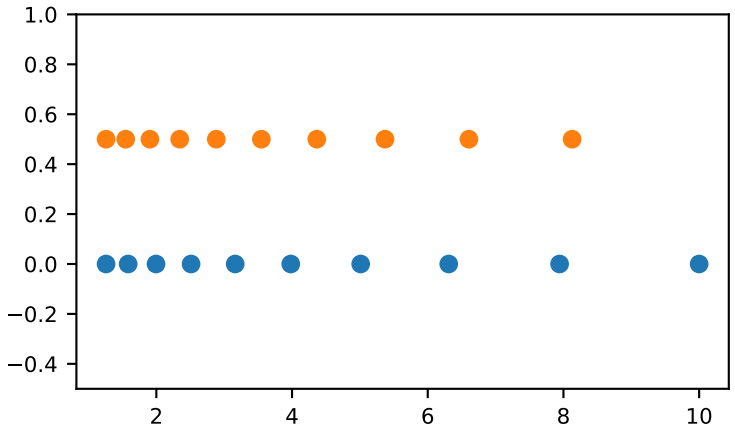
This is similar to *logspace*, but with endpoints specified directly. Each output sample is a constant multiple of the previous.

Parameters

start
: [array_like] The starting value of the sequence.

stop
: [array_like] The final value of the sequence, unless *endpoint* is False. In that case, `num + 1` values are spaced over the interval in log-space, of which all but the last (a sequence of length *num*) are returned.

num
: [integer, optional] Number of samples to generate. Default is 50.



endpoint
: [boolean, optional] If true, *stop* is the last sample. Otherwise, it is not included. Default is True.

dtype
: [dtype] The type of the output array. If `dtype` is not given, the data type is inferred from *start* and *stop*. The inferred dtype will never be an integer; *float* is chosen even if the arguments would produce an array of integers.

axis
: [int, optional] The axis in the result to store the samples. Relevant only if start or stop are array-like. By default (0), the samples will be along a new axis inserted at the beginning. Use -1 to get an axis at the end.

Returns

samples
: [ndarray] *num* samples, equally spaced on a log scale.

See also:

logspace
: Similar to geomspace, but with endpoints specified using log and base.

linspace
: Similar to geomspace, but with arithmetic instead of geometric progression.

arange
: Similar to linspace, with the step size specified instead of the number of samples.

how-to-partition

Notes

If the inputs or dtype are complex, the output will follow a logarithmic spiral in the complex plane. (There are an infinite number of spirals passing through two points; the output will follow the shortest such path.)

Examples

```
>>> import numpy as np
>>> np.geomspace(1, 1000, num=4)
array([    1.,    10.,   100.,  1000.])
>>> np.geomspace(1, 1000, num=3, endpoint=False)
array([   1.,   10.,  100.])
>>> np.geomspace(1, 1000, num=4, endpoint=False)
array([   1.        ,    5.62341325,   31.6227766 ,  177.827941  ])
>>> np.geomspace(1, 256, num=9)
array([   1.,    2.,    4.,    8.,   16.,   32.,   64.,  128.,  256.])
```

Note that the above may not produce exact integers:

```
>>> np.geomspace(1, 256, num=9, dtype=int)
array([  1,   2,   4,   7,  16,  32,  63, 127, 256])
>>> np.around(np.geomspace(1, 256, num=9)).astype(int)
array([  1,   2,   4,   8,  16,  32,  64, 128, 256])
```

Negative, decreasing, and complex inputs are allowed:

```
>>> np.geomspace(1000, 1, num=4)
array([1000.,  100.,   10.,    1.])
>>> np.geomspace(-1000, -1, num=4)
array([-1000.,  -100.,   -10.,    -1.])
>>> np.geomspace(1j, 1000j, num=4)  # Straight line
array([0.   +1.j, 0.  +10.j, 0. +100.j, 0.+1000.j])
>>> np.geomspace(-1+0j, 1+0j, num=5)  # Circle
array([-1.00000000e+00+1.22464680e-16j, -7.07106781e-01+7.07106781e-01j,
        6.12323400e-17+1.00000000e+00j,  7.07106781e-01+7.07106781e-01j,
        1.00000000e+00+0.00000000e+00j])
```

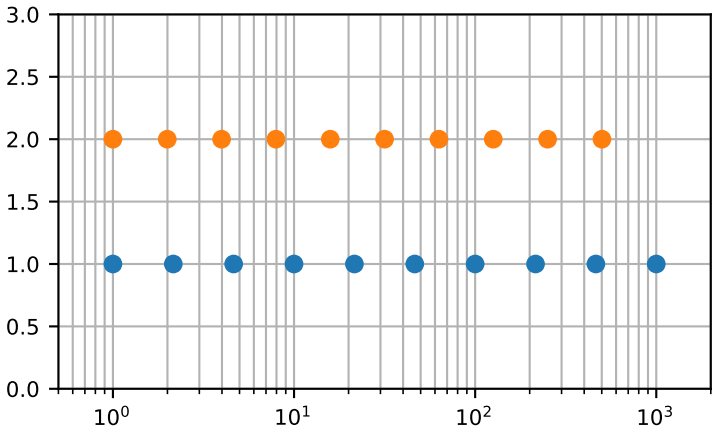
Graphical illustration of *endpoint* parameter:

```
>>> import matplotlib.pyplot as plt
>>> N = 10
>>> y = np.zeros(N)
>>> plt.semilogx(np.geomspace(1, 1000, N, endpoint=True), y + 1, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.semilogx(np.geomspace(1, 1000, N, endpoint=False), y + 2, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.axis([0.5, 2000, 0, 3])
[0.5, 2000, 0, 3]
>>> plt.grid(True, color='0.7', linestyle='-', which='both', axis='both')
>>> plt.show()
```

numpy.**meshgrid**(**xi*, *copy=True*, *sparse=False*, *indexing='xy'*)

Return a tuple of coordinate matrices from coordinate vectors.

Make N-D coordinate arrays for vectorized evaluations of N-D scalar/vector fields over N-D grids, given one-dimensional coordinate arrays x1, x2,…, xn.



Parameters

x1, x2,…, xn
[array_like] 1-D arrays representing the coordinates of a grid.

indexing
[{'xy', 'ij'}, optional] Cartesian ('xy', default) or matrix ('ij') indexing of output. See Notes for more details.

sparse
[bool, optional] If True the shape of the returned coordinate array for dimension *i* is reduced from `(N1, ..., Ni, ... Nn)` to `(1, ..., 1, Ni, 1, ..., 1)`. These sparse coordinate grids are intended to be use with basics.broadcasting. When all coordinates are used in an expression, broadcasting still leads to a fully-dimensonal result array.

Default is False.

copy
[bool, optional] If False, a view into the original arrays are returned in order to conserve memory. Default is True. Please note that `sparse=False, copy=False` will likely return non-contiguous arrays. Furthermore, more than one element of a broadcast array may refer to a single memory location. If you need to write to the arrays, make copies first.

Returns

X1, X2,…, XN
[tuple of ndarrays] For vectors *x1*, *x2*,…, *xn* with lengths `Ni=len(xi)`, returns `(N1, N2, N3,..., Nn)` shaped arrays if indexing='ij' or `(N2, N1, N3,..., Nn)` shaped arrays if indexing='xy' with the elements of *xi* repeated to fill the matrix along the first dimension for *x1*, the second for *x2* and so on.

See also:

mgrid
Construct a multi-dimensional "meshgrid" using indexing notation.

ogrid
Construct an open multi-dimensional "meshgrid" using indexing notation.

how-to-index

Notes

This function supports both indexing conventions through the indexing keyword argument. Giving the string 'ij' returns a meshgrid with matrix indexing, while 'xy' returns a meshgrid with Cartesian indexing. In the 2-D case with inputs of length M and N, the outputs are of shape (N, M) for 'xy' indexing and (M, N) for 'ij' indexing. In the 3-D case with inputs of length M, N and P, outputs are of shape (N, M, P) for 'xy' indexing and (M, N, P) for 'ij' indexing. The difference is illustrated by the following code snippet:

```
xv, yv = np.meshgrid(x, y, indexing='ij')
for i in range(nx):
    for j in range(ny):
        # treat xv[i,j], yv[i,j]

xv, yv = np.meshgrid(x, y, indexing='xy')
for i in range(nx):
    for j in range(ny):
        # treat xv[j,i], yv[j,i]
```

In the 1-D and 0-D case, the indexing and sparse keywords have no effect.

Examples

```
>>> import numpy as np
>>> nx, ny = (3, 2)
>>> x = np.linspace(0, 1, nx)
>>> y = np.linspace(0, 1, ny)
>>> xv, yv = np.meshgrid(x, y)
>>> xv
array([[0. , 0.5, 1. ],
       [0. , 0.5, 1. ]])
>>> yv
array([[0.,  0.,  0.],
       [1.,  1.,  1.]])
```

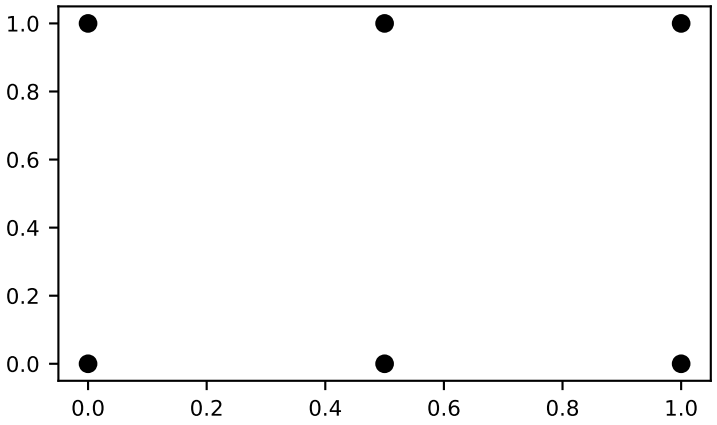
The result of *meshgrid* is a coordinate grid:

```
>>> import matplotlib.pyplot as plt
>>> plt.plot(xv, yv, marker='o', color='k', linestyle='none')
>>> plt.show()
```

You can create sparse output arrays to save memory and computation time.

```
>>> xv, yv = np.meshgrid(x, y, sparse=True)
>>> xv
array([[0. ,  0.5,  1. ]])
>>> yv
array([[0.],
       [1.]])
```

meshgrid is very useful to evaluate functions on a grid. If the function depends on all coordinates, both dense and sparse outputs can be used.




```
>>> x = np.linspace(-5, 5, 101)
>>> y = np.linspace(-5, 5, 101)
>>> # full coordinate arrays
>>> xx, yy = np.meshgrid(x, y)
>>> zz = np.sqrt(xx**2 + yy**2)
>>> xx.shape, yy.shape, zz.shape
((101, 101), (101, 101), (101, 101))
>>> # sparse coordinate arrays
>>> xs, ys = np.meshgrid(x, y, sparse=True)
>>> zs = np.sqrt(xs**2 + ys**2)
>>> xs.shape, ys.shape, zs.shape
((1, 101), (101, 1), (101, 101))
>>> np.array_equal(zz, zs)
True
```

```
>>> h = plt.contourf(x, y, zs)
>>> plt.axis('scaled')
>>> plt.colorbar()
>>> plt.show()
```

numpy.**mgrid = <numpy.lib._index_tricks_impl.MGridClass object>**

An instance which returns a dense multi-dimensional “meshgrid”.

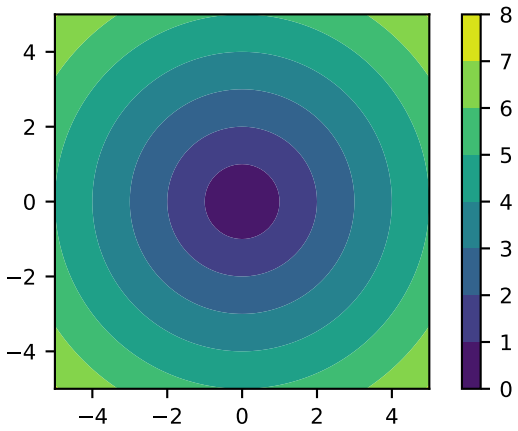
An instance which returns a dense (or fleshed out) mesh-grid when indexed, so that each returned argument has the same shape. The dimensions and number of the output arrays are equal to the number of indexing dimensions. If the step length is not a complex number, then the stop is not inclusive.

However, if the step length is a **complex number** (e.g. 5j), then the integer part of its magnitude is interpreted as specifying the number of points to create between the start and stop values, where the stop value **is inclusive**.

Returns

mesh-grid
[ndarray] A single array, containing a set of *ndarray*s all of the same dimensions. stacked along the first axis.

See also:



ogrid
: like *mgrid* but returns open (not fleshed out) mesh grids

meshgrid
: return coordinate matrices from coordinate vectors

r_
: array concatenator

how-to-partition

Examples

```
>>> import numpy as np
>>> np.mgrid[0:5, 0:5]
array([[[0, 0, 0, 0, 0],
        [1, 1, 1, 1, 1],
        [2, 2, 2, 2, 2],
        [3, 3, 3, 3, 3],
        [4, 4, 4, 4, 4]],
       [[0, 1, 2, 3, 4],
        [0, 1, 2, 3, 4],
        [0, 1, 2, 3, 4],
        [0, 1, 2, 3, 4],
        [0, 1, 2, 3, 4]]])
>>> np.mgrid[-1:1:5j]
array([-1. , -0.5,  0. ,  0.5,  1. ])
```

```
>>> np.mgrid[0:4].shape
(4,)
>>> np.mgrid[0:4, 0:5].shape
(2, 4, 5)
>>> np.mgrid[0:4, 0:5, 0:6].shape
(3, 4, 5, 6)
```

numpy.**ogrid = <numpy.lib._index_tricks_impl.OGridClass object>**

An instance which returns an open multi-dimensional "meshgrid".

An instance which returns an open (i.e. not fleshed out) mesh-grid when indexed, so that only one dimension of each returned array is greater than 1. The dimension and number of the output arrays are equal to the number of indexing dimensions. If the step length is not a complex number, then the stop is not inclusive.

However, if the step length is a **complex number** (e.g. 5j), then the integer part of its magnitude is interpreted as specifying the number of points to create between the start and stop values, where the stop value **is inclusive**.

Returns

mesh-grid
[ndarray or tuple of ndarrays] If the input is a single slice, returns an array. If the input is multiple slices, returns a tuple of arrays, with only one dimension not equal to 1.

See also:

mgrid
like *ogrid* but returns dense (or fleshed out) mesh grids

meshgrid
return coordinate matrices from coordinate vectors

r_
array concatenator

how-to-partition

Examples

```
>>> from numpy import ogrid
>>> ogrid[-1:1:5j]
array([-1. , -0.5,  0. ,  0.5,  1. ])
>>> ogrid[0:5, 0:5]
(array([[0],
        [1],
        [2],
        [3],
        [4]]),
 array([[0, 1, 2, 3, 4]]))
```

Building matrices

diag(v[, k])	Extract a diagonal or construct a diagonal array.
diagflat(v[, k])	Create a two-dimensional array with the flattened input as a diagonal.
tri(N[, M, k, dtype, like])	An array with ones at and below the given diagonal and zeros elsewhere.
tril(m[, k])	Lower triangle of an array.
triu(m[, k])	Upper triangle of an array.
vander(x[, N, increasing])	Generate a Vandermonde matrix.

numpy.**diag**(*v*, *k=0*)

Extract a diagonal or construct a diagonal array.

See the more detailed documentation for `numpy.diagonal` if you use this function to extract a diagonal and wish to write to the resulting array; whether it returns a copy or a view depends on what version of numpy you are using.

Parameters

v
[array_like] If *v* is a 2-D array, return a copy of its *k*-th diagonal. If *v* is a 1-D array, return a 2-D array with *v* on the *k*-th diagonal.

k
[int, optional] Diagonal in question. The default is 0. Use *k>0* for diagonals above the main diagonal, and *k<0* for diagonals below the main diagonal.

Returns

out
[ndarray] The extracted diagonal or constructed diagonal array.

See also:

diagonal
Return specified diagonals.

diagflat
Create a 2-D array with the flattened input as a diagonal.

trace
Sum along diagonals.

triu
Upper triangle of an array.

tril
Lower triangle of an array.

Examples

```
>>> import numpy as np
>>> x = np.arange(9).reshape((3,3))
>>> x
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
```

```
>>> np.diag(x)
array([0, 4, 8])
>>> np.diag(x, k=1)
array([1, 5])
>>> np.diag(x, k=-1)
array([3, 7])
```

```
>>> np.diag(np.diag(x))
array([[0, 0, 0],
       [0, 4, 0],
       [0, 0, 8]])
```

numpy.**diagflat**(*v*, *k=0*)

Create a two-dimensional array with the flattened input as a diagonal.

Parameters

v
[array_like] Input data, which is flattened and set as the *k*-th diagonal of the output.

k
[int, optional] Diagonal to set; 0, the default, corresponds to the "main" diagonal, a positive (negative) *k* giving the number of the diagonal above (below) the main.

Returns

out
[ndarray] The 2-D output array.

See also:

diag
MATLAB work-alike for 1-D and 2-D arrays.

diagonal
Return specified diagonals.

trace
Sum along diagonals.

Examples

```
>>> import numpy as np
>>> np.diagflat([[1,2], [3,4]])
array([[1, 0, 0, 0],
       [0, 2, 0, 0],
       [0, 0, 3, 0],
       [0, 0, 0, 4]])
```

```
>>> np.diagflat([1,2], 1)
array([[0, 1, 0],
       [0, 0, 2],
       [0, 0, 0]])
```

numpy.**tri**(*N*, *M=None*, *k=0*, *dtype=<class 'float'>*, ***, *like=None*)

An array with ones at and below the given diagonal and zeros elsewhere.

Parameters

N
[int] Number of rows in the array.

M
[int, optional] Number of columns in the array. By default, *M* is taken equal to *N*.

k
[int, optional] The sub-diagonal at and below which the array is filled. $k = 0$ is the main diagonal, while $k < 0$ is below it, and $k > 0$ is above. The default is 0.

dtype
[dtype, optional] Data type of the returned array. The default is float.

like
: [array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

  New in version 1.20.0.

Returns

tri
: [ndarray of shape (N, M)] Array with its lower triangle filled with ones and zero elsewhere; in other words `T[i,j] == 1` for `j <= i + k`, 0 otherwise.

Examples

```
>>> import numpy as np
>>> np.tri(3, 5, 2, dtype=int)
array([[1, 1, 1, 0, 0],
       [1, 1, 1, 1, 0],
       [1, 1, 1, 1, 1]])
```

```
>>> np.tri(3, 5, -1)
array([[0.,  0.,  0.,  0.,  0.],
       [1.,  0.,  0.,  0.,  0.],
       [1.,  1.,  0.,  0.,  0.]])
```

numpy.**tril**(*m*, *k=0*)

Lower triangle of an array.

Return a copy of an array with elements above the *k*-th diagonal zeroed. For arrays with `ndim` exceeding 2, *tril* will apply to the final two axes.

Parameters

m
: [array_like, shape (…, M, N)] Input array.

k
: [int, optional] Diagonal above which to zero elements. *k = 0* (the default) is the main diagonal, *k < 0* is below it and *k > 0* is above.

Returns

tril
: [ndarray, shape (…, M, N)] Lower triangle of *m*, of same shape and data-type as *m*.

See also:

triu
: same thing, only for the upper triangle

Examples

```
>>> import numpy as np
>>> np.tril([[1,2,3],[4,5,6],[7,8,9],[10,11,12]], -1)
array([[ 0,  0,  0],
       [ 4,  0,  0],
       [ 7,  8,  0],
       [10, 11, 12]])
```

```
>>> np.tril(np.arange(3*4*5).reshape(3, 4, 5))
array([[[ 0,  0,  0,  0,  0],
        [ 5,  6,  0,  0,  0],
        [10, 11, 12,  0,  0],
        [15, 16, 17, 18,  0]],
       [[20,  0,  0,  0,  0],
        [25, 26,  0,  0,  0],
        [30, 31, 32,  0,  0],
        [35, 36, 37, 38,  0]],
       [[40,  0,  0,  0,  0],
        [45, 46,  0,  0,  0],
        [50, 51, 52,  0,  0],
        [55, 56, 57, 58,  0]]])
```

numpy.**triu**(*m*, *k=0*)

Upper triangle of an array.

Return a copy of an array with the elements below the *k*-th diagonal zeroed. For arrays with `ndim` exceeding 2, *triu* will apply to the final two axes.

Please refer to the documentation for *tril* for further details.

See also:

tril
lower triangle of an array

Examples

```
>>> import numpy as np
>>> np.triu([[1,2,3],[4,5,6],[7,8,9],[10,11,12]], -1)
array([[ 1,  2,  3],
       [ 4,  5,  6],
       [ 0,  8,  9],
       [ 0,  0, 12]])
```

```
>>> np.triu(np.arange(3*4*5).reshape(3, 4, 5))
array([[[ 0,  1,  2,  3,  4],
        [ 0,  6,  7,  8,  9],
        [ 0,  0, 12, 13, 14],
        [ 0,  0,  0, 18, 19]],
       [[20, 21, 22, 23, 24],
        [ 0, 26, 27, 28, 29],
        [ 0,  0, 32, 33, 34],
        [ 0,  0,  0, 38, 39]],
       [[40, 41, 42, 43, 44],
```

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```
        [ 0, 46, 47, 48, 49],
        [ 0,  0, 52, 53, 54],
        [ 0,  0,  0, 58, 59]]])
```

numpy.**vander**(*x*, *N=None*, *increasing=False*)

Generate a Vandermonde matrix.

The columns of the output matrix are powers of the input vector. The order of the powers is determined by the *increasing* boolean argument. Specifically, when *increasing* is False, the *i*-th output column is the input vector raised element-wise to the power of `N - i - 1`. Such a matrix with a geometric progression in each row is named for Alexandre- Theophile Vandermonde.

Parameters

x
: [array_like] 1-D input array.

N
: [int, optional] Number of columns in the output. If *N* is not specified, a square array is returned (`N = len(x)`).

increasing
: [bool, optional] Order of the powers of the columns. If True, the powers increase from left to right, if False (the default) they are reversed.

Returns

out
: [ndarray] Vandermonde matrix. If *increasing* is False, the first column is `x^(N-1)`, the second `x^(N-2)` and so forth. If *increasing* is True, the columns are `x^0, x^1, ..., x^(N-1)`.

See also:

polynomial.polynomial.polyvander

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 3, 5])
>>> N = 3
>>> np.vander(x, N)
array([[ 1,  1,  1],
       [ 4,  2,  1],
       [ 9,  3,  1],
       [25,  5,  1]])
```

```
>>> np.column_stack([x**(N-1-i) for i in range(N)])
array([[ 1,  1,  1],
       [ 4,  2,  1],
       [ 9,  3,  1],
       [25,  5,  1]])
```

```
>>> x = np.array([1, 2, 3, 5])
>>> np.vander(x)
array([[  1,   1,   1,   1],
```

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```
       [  8,   4,   2,   1],
       [ 27,   9,   3,   1],
       [125,  25,   5,   1]])
>>> np.vander(x, increasing=True)
array([[  1,   1,   1,   1],
       [  1,   2,   4,   8],
       [  1,   3,   9,  27],
       [  1,   5,  25, 125]])
```

The determinant of a square Vandermonde matrix is the product of the differences between the values of the input vector:

```
>>> np.linalg.det(np.vander(x))
48.000000000000043 # may vary
>>> (5-3)*(5-2)*(5-1)*(3-2)*(3-1)*(2-1)
48
```

The matrix class

bmat(obj[, ldict, gdict])	Build a matrix object from a string, nested sequence, or array.

1.4.3 Array manipulation routines

Basic operations

copyto(dst, src[, casting, where])	Copies values from one array to another, broadcasting as necessary.
ndim(a)	Return the number of dimensions of an array.
shape(a)	Return the shape of an array.
size(a[, axis])	Return the number of elements along a given axis.

numpy.**copyto**(*dst*, *src*, *casting='same_kind'*, *where=True*)

Copies values from one array to another, broadcasting as necessary.

Raises a TypeError if the *casting* rule is violated, and if *where* is provided, it selects which elements to copy.

Parameters

dst
[ndarray] The array into which values are copied.

src
[array_like] The array from which values are copied.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur when copying.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.

- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

where
[array_like of bool, optional] A boolean array which is broadcasted to match the dimensions of *dst*, and selects elements to copy from *src* to *dst* wherever it contains the value True.

Examples

```
>>> import numpy as np
>>> A = np.array([4, 5, 6])
>>> B = [1, 2, 3]
>>> np.copyto(A, B)
>>> A
array([1, 2, 3])
```

```
>>> A = np.array([[1, 2, 3], [4, 5, 6]])
>>> B = [[4, 5, 6], [7, 8, 9]]
>>> np.copyto(A, B)
>>> A
array([[4, 5, 6],
       [7, 8, 9]])
```

numpy.**ndim**(*a*)

Return the number of dimensions of an array.

Parameters

a
[array_like] Input array. If it is not already an ndarray, a conversion is attempted.

Returns

number_of_dimensions
[int] The number of dimensions in *a*. Scalars are zero-dimensional.

See also:

ndarray.ndim
equivalent method

shape
dimensions of array

ndarray.shape
dimensions of array

Examples

```
>>> import numpy as np
>>> np.ndim([[1,2,3],[4,5,6]])
2
>>> np.ndim(np.array([[1,2,3],[4,5,6]]))
2
>>> np.ndim(1)
0
```

numpy.**shape**(*a*)

Return the shape of an array.

Parameters

a
[array_like] Input array.

Returns

shape
[tuple of ints] The elements of the shape tuple give the lengths of the corresponding array dimensions.

See also:

len
`len(a)` is equivalent to `np.shape(a)[0]` for N-D arrays with `N>=1`.

ndarray.shape
Equivalent array method.

Examples

```
>>> import numpy as np
>>> np.shape(np.eye(3))
(3, 3)
>>> np.shape([[1, 3]])
(1, 2)
>>> np.shape([0])
(1,)
>>> np.shape(0)
()
```

```
>>> a = np.array([(1, 2), (3, 4), (5, 6)],
...              dtype=[('x', 'i4'), ('y', 'i4')])
>>> np.shape(a)
(3,)
>>> a.shape
(3,)
```

numpy.**size**(*a*, *axis=None*)

Return the number of elements along a given axis.

Parameters

a
[array_like] Input data.

axis
[int, optional] Axis along which the elements are counted. By default, give the total number of elements.

Returns

element_count
[int] Number of elements along the specified axis.

See also:

shape
dimensions of array

ndarray.shape
dimensions of array

ndarray.size
number of elements in array

Examples

```
>>> import numpy as np
>>> a = np.array([[1,2,3],[4,5,6]])
>>> np.size(a)
6
>>> np.size(a,1)
3
>>> np.size(a,0)
2
```

Changing array shape

reshape(a, /[, shape, order, newshape, copy])	Gives a new shape to an array without changing its data.
ravel(a[, order])	Return a contiguous flattened array.
ndarray.flat	A 1-D iterator over the array.
ndarray.flatten([order])	Return a copy of the array collapsed into one dimension.

numpy.**reshape**(*a*, */*, *shape=None*, *order='C'*, ***, *newshape=None*, *copy=None*)

Gives a new shape to an array without changing its data.

Parameters

a
[array_like] Array to be reshaped.

shape
[int or tuple of ints] The new shape should be compatible with the original shape. If an integer, then the result will be a 1-D array of that length. One shape dimension can be -1. In this case, the value is inferred from the length of the array and remaining dimensions.

order
[{'C', 'F', 'A'}, optional] Read the elements of `a` using this index order, and place the elements into the reshaped array using this index order. 'C' means to read / write the elements using C-like index order, with the last axis index changing fastest, back to the first axis index changing

slowest. 'F' means to read / write the elements using Fortran-like index order, with the first index changing fastest, and the last index changing slowest. Note that the 'C' and 'F' options take no account of the memory layout of the underlying array, and only refer to the order of indexing. 'A' means to read / write the elements in Fortran-like index order if `a` is Fortran *contiguous* in memory, C-like order otherwise.

newshape
[int or tuple of ints] Deprecated since version 2.1: Replaced by `shape` argument. Retained for backward compatibility.

copy
[bool, optional] If `True`, then the array data is copied. If `None`, a copy will only be made if it's required by `order`. For `False` it raises a `ValueError` if a copy cannot be avoided. Default: `None`.

Returns

reshaped_array
[ndarray] This will be a new view object if possible; otherwise, it will be a copy. Note there is no guarantee of the *memory layout* (C- or Fortran- contiguous) of the returned array.

See also:

ndarray.reshape
Equivalent method.

Notes

It is not always possible to change the shape of an array without copying the data.

The `order` keyword gives the index ordering both for *fetching* the values from `a`, and then *placing* the values into the output array. For example, let's say you have an array:

```
>>> a = np.arange(6).reshape((3, 2))
>>> a
array([[0, 1],
       [2, 3],
       [4, 5]])
```

You can think of reshaping as first raveling the array (using the given index order), then inserting the elements from the raveled array into the new array using the same kind of index ordering as was used for the raveling.

```
>>> np.reshape(a, (2, 3)) # C-like index ordering
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.reshape(np.ravel(a), (2, 3)) # equivalent to C ravel then C reshape
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.reshape(a, (2, 3), order='F') # Fortran-like index ordering
array([[0, 4, 3],
       [2, 1, 5]])
>>> np.reshape(np.ravel(a, order='F'), (2, 3), order='F')
array([[0, 4, 3],
       [2, 1, 5]])
```

Examples

```
>>> import numpy as np
>>> a = np.array([[1,2,3], [4,5,6]])
>>> np.reshape(a, 6)
array([1, 2, 3, 4, 5, 6])
>>> np.reshape(a, 6, order='F')
array([1, 4, 2, 5, 3, 6])
```

```
>>> np.reshape(a, (3,-1))       # the unspecified value is inferred to be 2
array([[1, 2],
       [3, 4],
       [5, 6]])
```

numpy.**ravel**(*a*, *order='C'*)

Return a contiguous flattened array.

A 1-D array, containing the elements of the input, is returned. A copy is made only if needed.

As of NumPy 1.10, the returned array will have the same type as the input array. (for example, a masked array will be returned for a masked array input)

Parameters

a
: [array_like] Input array. The elements in *a* are read in the order specified by *order*, and packed as a 1-D array.

order
: [{'C','F', 'A', 'K'}, optional] The elements of *a* are read using this index order. 'C' means to index the elements in row-major, C-style order, with the last axis index changing fastest, back to the first axis index changing slowest. 'F' means to index the elements in column-major, Fortran-style order, with the first index changing fastest, and the last index changing slowest. Note that the 'C' and 'F' options take no account of the memory layout of the underlying array, and only refer to the order of axis indexing. 'A' means to read the elements in Fortran-like index order if *a* is Fortran *contiguous* in memory, C-like order otherwise. 'K' means to read the elements in the order they occur in memory, except for reversing the data when strides are negative. By default, 'C' index order is used.

Returns

y
: [array_like] y is a contiguous 1-D array of the same subtype as *a*, with shape `(a.size,)`. Note that matrices are special cased for backward compatibility, if *a* is a matrix, then y is a 1-D ndarray.

See also:

ndarray.flat
: 1-D iterator over an array.

ndarray.flatten
: 1-D array copy of the elements of an array in row-major order.

ndarray.reshape
: Change the shape of an array without changing its data.

Notes

In row-major, C-style order, in two dimensions, the row index varies the slowest, and the column index the quickest. This can be generalized to multiple dimensions, where row-major order implies that the index along the first axis varies slowest, and the index along the last quickest. The opposite holds for column-major, Fortran-style index ordering.

When a view is desired in as many cases as possible, `arr.reshape(-1)` may be preferable. However, `ravel` supports `K` in the optional `order` argument while `reshape` does not.

Examples

It is equivalent to `reshape(-1, order=order)`.

```
>>> import numpy as np
>>> x = np.array([[1, 2, 3], [4, 5, 6]])
>>> np.ravel(x)
array([1, 2, 3, 4, 5, 6])
```

```
>>> x.reshape(-1)
array([1, 2, 3, 4, 5, 6])
```

```
>>> np.ravel(x, order='F')
array([1, 4, 2, 5, 3, 6])
```

When `order` is 'A', it will preserve the array's 'C' or 'F' ordering:

```
>>> np.ravel(x.T)
array([1, 4, 2, 5, 3, 6])
>>> np.ravel(x.T, order='A')
array([1, 2, 3, 4, 5, 6])
```

When `order` is 'K', it will preserve orderings that are neither 'C' nor 'F', but won't reverse axes:

```
>>> a = np.arange(3)[::-1]; a
array([2, 1, 0])
>>> a.ravel(order='C')
array([2, 1, 0])
>>> a.ravel(order='K')
array([2, 1, 0])
```

```
>>> a = np.arange(12).reshape(2,3,2).swapaxes(1,2); a
array([[[ 0,  2,  4],
        [ 1,  3,  5]],
       [[ 6,  8, 10],
        [ 7,  9, 11]]])
>>> a.ravel(order='C')
array([ 0,  2,  4,  1,  3,  5,  6,  8, 10,  7,  9, 11])
>>> a.ravel(order='K')
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11])
```

Transpose-like operations

moveaxis(a, source, destination)	Move axes of an array to new positions.
rollaxis(a, axis[, start])	Roll the specified axis backwards, until it lies in a given position.
swapaxes(a, axis1, axis2)	Interchange two axes of an array.
ndarray.T	View of the transposed array.
transpose(a[, axes])	Returns an array with axes transposed.
permute_dims(a[, axes])	Returns an array with axes transposed.
matrix_transpose(x, /)	Transposes a matrix (or a stack of matrices) `x`.

numpy.**moveaxis**(*a*, *source*, *destination*)

Move axes of an array to new positions.

Other axes remain in their original order.

Parameters

a
[np.ndarray] The array whose axes should be reordered.

source
[int or sequence of int] Original positions of the axes to move. These must be unique.

destination
[int or sequence of int] Destination positions for each of the original axes. These must also be unique.

Returns

result
[np.ndarray] Array with moved axes. This array is a view of the input array.

See also:

transpose
Permute the dimensions of an array.

swapaxes
Interchange two axes of an array.

Examples

```
>>> import numpy as np
>>> x = np.zeros((3, 4, 5))
>>> np.moveaxis(x, 0, -1).shape
(4, 5, 3)
>>> np.moveaxis(x, -1, 0).shape
(5, 3, 4)
```

These all achieve the same result:

```
>>> np.transpose(x).shape
(5, 4, 3)
>>> np.swapaxes(x, 0, -1).shape
(5, 4, 3)
```

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```
>>> np.moveaxis(x, [0, 1], [-1, -2]).shape
(5, 4, 3)
>>> np.moveaxis(x, [0, 1, 2], [-1, -2, -3]).shape
(5, 4, 3)
```

numpy.**rollaxis**(*a*, *axis*, *start=0*)

Roll the specified axis backwards, until it lies in a given position.

This function continues to be supported for backward compatibility, but you should prefer *moveaxis*. The *moveaxis* function was added in NumPy 1.11.

Parameters

a
[ndarray] Input array.

axis
[int] The axis to be rolled. The positions of the other axes do not change relative to one another.

start
[int, optional] When `start <= axis`, the axis is rolled back until it lies in this position. When `start > axis`, the axis is rolled until it lies before this position. The default, 0, results in a "complete" roll. The following table describes how negative values of `start` are interpreted:

`start`	Normalized `start`
`-(arr.ndim+1)`	raise `AxisError`
`-arr.ndim`	0
⋮	⋮
`-1`	`arr.ndim-1`
`0`	`0`
⋮	⋮
`arr.ndim`	`arr.ndim`
`arr.ndim + 1`	raise `AxisError`

Returns

res
[ndarray] For NumPy >= 1.10.0 a view of *a* is always returned. For earlier NumPy versions a view of *a* is returned only if the order of the axes is changed, otherwise the input array is returned.

See also:

moveaxis
Move array axes to new positions.

roll
Roll the elements of an array by a number of positions along a given axis.

Examples

```
>>> import numpy as np
>>> a = np.ones((3,4,5,6))
>>> np.rollaxis(a, 3, 1).shape
(3, 6, 4, 5)
>>> np.rollaxis(a, 2).shape
(5, 3, 4, 6)
>>> np.rollaxis(a, 1, 4).shape
(3, 5, 6, 4)
```

numpy.**swapaxes**(*a*, *axis1*, *axis2*)

Interchange two axes of an array.

Parameters

a
: [array_like] Input array.

axis1
: [int] First axis.

axis2
: [int] Second axis.

Returns

a_swapped
: [ndarray] For NumPy >= 1.10.0, if *a* is an ndarray, then a view of *a* is returned; otherwise a new array is created. For earlier NumPy versions a view of *a* is returned only if the order of the axes is changed, otherwise the input array is returned.

Examples

```
>>> import numpy as np
>>> x = np.array([[1,2,3]])
>>> np.swapaxes(x,0,1)
array([[1],
       [2],
       [3]])
```

```
>>> x = np.array([[[0,1],[2,3]],[[4,5],[6,7]]])
>>> x
array([[[0, 1],
        [2, 3]],
       [[4, 5],
        [6, 7]]])
```

```
>>> np.swapaxes(x,0,2)
array([[[0, 4],
        [2, 6]],
       [[1, 5],
        [3, 7]]])
```

numpy.**transpose**(*a*, *axes=None*)

Returns an array with axes transposed.

For a 1-D array, this returns an unchanged view of the original array, as a transposed vector is simply the same vector. To convert a 1-D array into a 2-D column vector, an additional dimension must be added, e.g., `np.atleast_2d(a).T` achieves this, as does `a[:, np.newaxis]`. For a 2-D array, this is the standard matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided, then `transpose(a).shape == a.shape[::-1]`.

Parameters

a
[array_like] Input array.

axes
[tuple or list of ints, optional] If specified, it must be a tuple or list which contains a permutation of [0, 1, …, N-1] where N is the number of axes of *a*. Negative indices can also be used to specify axes. The i-th axis of the returned array will correspond to the axis numbered `axes[i]` of the input. If not specified, defaults to `range(a.ndim)[::-1]`, which reverses the order of the axes.

Returns

p
[ndarray] *a* with its axes permuted. A view is returned whenever possible.

See also:

ndarray.transpose
Equivalent method.

moveaxis
Move axes of an array to new positions.

argsort
Return the indices that would sort an array.

Notes

Use `transpose(a, argsort(axes))` to invert the transposition of tensors when using the *axes* keyword argument.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> np.transpose(a)
array([[1, 3],
       [2, 4]])
```

```
>>> a = np.array([1, 2, 3, 4])
>>> a
array([1, 2, 3, 4])
>>> np.transpose(a)
array([1, 2, 3, 4])
```

```
>>> a = np.ones((1, 2, 3))
>>> np.transpose(a, (1, 0, 2)).shape
(2, 1, 3)
```

```
>>> a = np.ones((2, 3, 4, 5))
>>> np.transpose(a).shape
(5, 4, 3, 2)
```

```
>>> a = np.arange(3*4*5).reshape((3, 4, 5))
>>> np.transpose(a, (-1, 0, -2)).shape
(5, 3, 4)
```

numpy.**permute_dims**(*a*, *axes=None*)

Returns an array with axes transposed.

For a 1-D array, this returns an unchanged view of the original array, as a transposed vector is simply the same vector. To convert a 1-D array into a 2-D column vector, an additional dimension must be added, e.g., `np.atleast_2d(a).T` achieves this, as does `a[:, np.newaxis]`. For a 2-D array, this is the standard matrix transpose. For an n-D array, if axes are given, their order indicates how the axes are permuted (see Examples). If axes are not provided, then `transpose(a).shape == a.shape[::-1]`.

Parameters

a
: [array_like] Input array.

axes
: [tuple or list of ints, optional] If specified, it must be a tuple or list which contains a permutation of [0, 1, …, N-1] where N is the number of axes of *a*. Negative indices can also be used to specify axes. The i-th axis of the returned array will correspond to the axis numbered `axes[i]` of the input. If not specified, defaults to `range(a.ndim)[::-1]`, which reverses the order of the axes.

Returns

p
: [ndarray] *a* with its axes permuted. A view is returned whenever possible.

See also:

ndarray.transpose
: Equivalent method.

moveaxis
: Move axes of an array to new positions.

argsort
: Return the indices that would sort an array.

Notes

Use `transpose(a, argsort(axes))` to invert the transposition of tensors when using the *axes* keyword argument.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> a
array([[1, 2],
       [3, 4]])
>>> np.transpose(a)
array([[1, 3],
       [2, 4]])
```

```
>>> a = np.array([1, 2, 3, 4])
>>> a
array([1, 2, 3, 4])
>>> np.transpose(a)
array([1, 2, 3, 4])
```

```
>>> a = np.ones((1, 2, 3))
>>> np.transpose(a, (1, 0, 2)).shape
(2, 1, 3)
```

```
>>> a = np.ones((2, 3, 4, 5))
>>> np.transpose(a).shape
(5, 4, 3, 2)
```

```
>>> a = np.arange(3*4*5).reshape((3, 4, 5))
>>> np.transpose(a, (-1, 0, -2)).shape
(5, 3, 4)
```

numpy.**matrix_transpose**(*x*, */*)

Transposes a matrix (or a stack of matrices) `x`.

This function is Array API compatible.

Parameters

x
[array_like] Input array having shape (…, M, N) and whose two innermost dimensions form `MxN` matrices.

Returns

out
[ndarray] An array containing the transpose for each matrix and having shape (…, N, M).

See also:

transpose
Generic transpose method.

Examples

```
>>> import numpy as np
>>> np.matrix_transpose([[1, 2], [3, 4]])
array([[1, 3],
       [2, 4]])
```

```
>>> np.matrix_transpose([[[1, 2], [3, 4]], [[5, 6], [7, 8]]])
array([[[1, 3],
        [2, 4]],
       [[5, 7],
        [6, 8]]])
```

Changing number of dimensions

atleast_1d(*arys)	Convert inputs to arrays with at least one dimension.
atleast_2d(*arys)	View inputs as arrays with at least two dimensions.
atleast_3d(*arys)	View inputs as arrays with at least three dimensions.
broadcast	Produce an object that mimics broadcasting.
broadcast_to(array, shape[, subok])	Broadcast an array to a new shape.
broadcast_arrays(*args[, subok])	Broadcast any number of arrays against each other.
expand_dims(a, axis)	Expand the shape of an array.
squeeze(a[, axis])	Remove axes of length one from *a*.

numpy.**atleast_1d**(**arys*)

Convert inputs to arrays with at least one dimension.

Scalar inputs are converted to 1-dimensional arrays, whilst higher-dimensional inputs are preserved.

Parameters

arys1, arys2, …
[array_like] One or more input arrays.

Returns

ret
[ndarray] An array, or tuple of arrays, each with `a.ndim >= 1`. Copies are made only if necessary.

See also:

atleast_2d, ***atleast_3d***

Examples

```
>>> import numpy as np
>>> np.atleast_1d(1.0)
array([1.])
```

```
>>> x = np.arange(9.0).reshape(3,3)
>>> np.atleast_1d(x)
array([[0., 1., 2.],
       [3., 4., 5.],
       [6., 7., 8.]])
>>> np.atleast_1d(x) is x
True
```

```
>>> np.atleast_1d(1, [3, 4])
(array([1]), array([3, 4]))
```

numpy.**atleast_2d**(**arys*)

View inputs as arrays with at least two dimensions.

Parameters

arys1, arys2, …
[array_like] One or more array-like sequences. Non-array inputs are converted to arrays. Arrays that already have two or more dimensions are preserved.

Returns

res, res2, …
[ndarray] An array, or tuple of arrays, each with `a.ndim >= 2`. Copies are avoided where possible, and views with two or more dimensions are returned.

See also:

atleast_1d, *atleast_3d*

Examples

```
>>> import numpy as np
>>> np.atleast_2d(3.0)
array([[3.]])
```

```
>>> x = np.arange(3.0)
>>> np.atleast_2d(x)
array([[0., 1., 2.]])
>>> np.atleast_2d(x).base is x
True
```

```
>>> np.atleast_2d(1, [1, 2], [[1, 2]])
(array([[1]]), array([[1, 2]]), array([[1, 2]]))
```

numpy.**atleast_3d**(**arys*)

View inputs as arrays with at least three dimensions.

Parameters

arys1, arys2, …
[array_like] One or more array-like sequences. Non-array inputs are converted to arrays. Arrays that already have three or more dimensions are preserved.

Returns

res1, res2, …
[ndarray] An array, or tuple of arrays, each with `a.ndim >= 3`. Copies are avoided where possible, and views with three or more dimensions are returned. For example, a 1-D array of shape `(N,)` becomes a view of shape `(1, N, 1)`, and a 2-D array of shape `(M, N)` becomes a view of shape `(M, N, 1)`.

See also:

atleast_1d*, *atleast_2d

Examples

```
>>> import numpy as np
>>> np.atleast_3d(3.0)
array([[[3.]]])
```

```
>>> x = np.arange(3.0)
>>> np.atleast_3d(x).shape
(1, 3, 1)
```

```
>>> x = np.arange(12.0).reshape(4,3)
>>> np.atleast_3d(x).shape
(4, 3, 1)
>>> np.atleast_3d(x).base is x.base  # x is a reshape, so not base itself
True
```

```
>>> for arr in np.atleast_3d([1, 2], [[1, 2]], [[[1, 2]]]):
...     print(arr, arr.shape)
...
[[[1]
  [2]]] (1, 2, 1)
[[[1]
  [2]]] (1, 2, 1)
[[[1 2]]] (1, 1, 2)
```

numpy.**broadcast_to**(*array*, *shape*, *subok=False*)

Broadcast an array to a new shape.

Parameters

array
[array_like] The array to broadcast.

shape
[tuple or int] The shape of the desired array. A single integer `i` is interpreted as `(i,)`.

subok
[bool, optional] If True, then sub-classes will be passed-through, otherwise the returned array will be forced to be a base-class array (default).

Returns

broadcast
: [array] A readonly view on the original array with the given shape. It is typically not contiguous. Furthermore, more than one element of a broadcasted array may refer to a single memory location.

Raises

ValueError
: If the array is not compatible with the new shape according to NumPy's broadcasting rules.

See also:

broadcast
broadcast_arrays
broadcast_shapes

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 3])
>>> np.broadcast_to(x, (3, 3))
array([[1, 2, 3],
       [1, 2, 3],
       [1, 2, 3]])
```

numpy.**broadcast_arrays**(**args*, *subok=False*)

Broadcast any number of arrays against each other.

Parameters

***args**
: [array_likes] The arrays to broadcast.

subok
: [bool, optional] If True, then sub-classes will be passed-through, otherwise the returned arrays will be forced to be a base-class array (default).

Returns

broadcasted
: [tuple of arrays] These arrays are views on the original arrays. They are typically not contiguous. Furthermore, more than one element of a broadcasted array may refer to a single memory location. If you need to write to the arrays, make copies first. While you can set the `writable` flag True, writing to a single output value may end up changing more than one location in the output array.

  Deprecated since version 1.17: The output is currently marked so that if written to, a deprecation warning will be emitted. A future version will set the `writable` flag False so writing to it will raise an error.

See also:

broadcast
broadcast_to
broadcast_shapes

Examples

```
>>> import numpy as np
>>> x = np.array([[1,2,3]])
>>> y = np.array([[4],[5]])
>>> np.broadcast_arrays(x, y)
(array([[1, 2, 3],
        [1, 2, 3]]),
 array([[4, 4, 4],
        [5, 5, 5]]))
```

Here is a useful idiom for getting contiguous copies instead of non-contiguous views.

```
>>> [np.array(a) for a in np.broadcast_arrays(x, y)]
[array([[1, 2, 3],
        [1, 2, 3]]),
 array([[4, 4, 4],
        [5, 5, 5]])]
```

numpy.**expand_dims**(*a*, *axis*)

Expand the shape of an array.

Insert a new axis that will appear at the *axis* position in the expanded array shape.

Parameters

a
: [array_like] Input array.

axis
: [int or tuple of ints] Position in the expanded axes where the new axis (or axes) is placed.

  Deprecated since version 1.13.0: Passing an axis where `axis > a.ndim` will be treated as `axis == a.ndim`, and passing `axis < -a.ndim - 1` will be treated as `axis == 0`. This behavior is deprecated.

Returns

result
: [ndarray] View of *a* with the number of dimensions increased.

See also:

squeeze
: The inverse operation, removing singleton dimensions

reshape
: Insert, remove, and combine dimensions, and resize existing ones

atleast_1d, ***atleast_2d***, ***atleast_3d***

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2])
>>> x.shape
(2,)
```

The following is equivalent to `x[np.newaxis, :]` or `x[np.newaxis]`:

```
>>> y = np.expand_dims(x, axis=0)
>>> y
array([[1, 2]])
>>> y.shape
(1, 2)
```

The following is equivalent to `x[:, np.newaxis]`:

```
>>> y = np.expand_dims(x, axis=1)
>>> y
array([[1],
       [2]])
>>> y.shape
(2, 1)
```

`axis` may also be a tuple:

```
>>> y = np.expand_dims(x, axis=(0, 1))
>>> y
array([[[1, 2]]])
```

```
>>> y = np.expand_dims(x, axis=(2, 0))
>>> y
array([[[1],
        [2]]])
```

Note that some examples may use `None` instead of `np.newaxis`. These are the same objects:

```
>>> np.newaxis is None
True
```

`numpy.`**`squeeze`**(*a*, *axis=None*)

Remove axes of length one from *a*.

Parameters

a
: [array_like] Input data.

axis
: [None or int or tuple of ints, optional] Selects a subset of the entries of length one in the shape. If an axis is selected with shape entry greater than one, an error is raised.

Returns

squeezed
: [ndarray] The input array, but with all or a subset of the dimensions of length 1 removed. This is always *a* itself or a view into *a*. Note that if all axes are squeezed, the result is a 0d array and not a scalar.

Raises

ValueError
If *axis* is not None, and an axis being squeezed is not of length 1

See also:

expand_dims
The inverse operation, adding entries of length one

reshape
Insert, remove, and combine dimensions, and resize existing ones

Examples

```
>>> import numpy as np
>>> x = np.array([[[0], [1], [2]]])
>>> x.shape
(1, 3, 1)
>>> np.squeeze(x).shape
(3,)
>>> np.squeeze(x, axis=0).shape
(3, 1)
>>> np.squeeze(x, axis=1).shape
Traceback (most recent call last):
...
ValueError: cannot select an axis to squeeze out which has size
not equal to one
>>> np.squeeze(x, axis=2).shape
(1, 3)
>>> x = np.array([[1234]])
>>> x.shape
(1, 1)
>>> np.squeeze(x)
array(1234)  # 0d array
>>> np.squeeze(x).shape
()
>>> np.squeeze(x)[()]
1234
```

Changing kind of array

asarray(a[, dtype, order, device, copy, like])	Convert the input to an array.
asanyarray(a[, dtype, order, device, copy, like])	Convert the input to an ndarray, but pass ndarray subclasses through.
asmatrix(data[, dtype])	Interpret the input as a matrix.
asfortranarray(a[, dtype, like])	Return an array (ndim >= 1) laid out in Fortran order in memory.
ascontiguousarray(a[, dtype, like])	Return a contiguous array (ndim >= 1) in memory (C order).
asarray_chkfinite(a[, dtype, order])	Convert the input to an array, checking for NaNs or Infs.
require(a[, dtype, requirements, like])	Return an ndarray of the provided type that satisfies requirements.

numpy.**asfortranarray**(*a*, *dtype=None*, ***, *like=None*)

Return an array (ndim >= 1) laid out in Fortran order in memory.

Parameters

a
[array_like] Input array.

dtype
[str or dtype object, optional] By default, the data-type is inferred from the input data.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] The input *a* in Fortran, or column-major, order.

See also:

ascontiguousarray
Convert input to a contiguous (C order) array.

asanyarray
Convert input to an ndarray with either row or column-major memory order.

require
Return an ndarray that satisfies requirements.

ndarray.flags
Information about the memory layout of the array.

Examples

Starting with a C-contiguous array:

```
>>> import numpy as np
>>> x = np.ones((2, 3), order='C')
>>> x.flags['C_CONTIGUOUS']
True
```

Calling `asfortranarray` makes a Fortran-contiguous copy:

```
>>> y = np.asfortranarray(x)
>>> y.flags['F_CONTIGUOUS']
True
>>> np.may_share_memory(x, y)
False
```

Now, starting with a Fortran-contiguous array:

```
>>> x = np.ones((2, 3), order='F')
>>> x.flags['F_CONTIGUOUS']
True
```

Then, calling `asfortranarray` returns the same object:

```
>>> y = np.asfortranarray(x)
>>> x is y
True
```

Note: This function returns an array with at least one-dimension (1-d) so it will not preserve 0-d arrays.

numpy.**asarray_chkfinite**(*a*, *dtype=None*, *order=None*)

Convert the input to an array, checking for NaNs or Infs.

Parameters

a
[array_like] Input data, in any form that can be converted to an array. This includes lists, lists of tuples, tuples, tuples of tuples, tuples of lists and ndarrays. Success requires no NaNs or Infs.

dtype
[data-type, optional] By default, the data-type is inferred from the input data.

order
[{'C', 'F', 'A', 'K'}, optional] Memory layout. 'A' and 'K' depend on the order of input array a. 'C' row-major (C-style), 'F' column-major (Fortran-style) memory representation. 'A' (any) means 'F' if *a* is Fortran contiguous, 'C' otherwise 'K' (keep) preserve input order Defaults to 'C'.

Returns

out
[ndarray] Array interpretation of *a*. No copy is performed if the input is already an ndarray. If *a* is a subclass of ndarray, a base class ndarray is returned.

Raises

ValueError
Raises ValueError if *a* contains NaN (Not a Number) or Inf (Infinity).

See also:

asarray
Create and array.

asanyarray
Similar function which passes through subclasses.

ascontiguousarray
Convert input to a contiguous array.

asfortranarray
Convert input to an ndarray with column-major memory order.

fromiter
Create an array from an iterator.

fromfunction
Construct an array by executing a function on grid positions.

Examples

```
>>> import numpy as np
```

Convert a list into an array. If all elements are finite, then `asarray_chkfinite` is identical to `asarray`.

```
>>> a = [1, 2]
>>> np.asarray_chkfinite(a, dtype=float)
array([1., 2.])
```

Raises ValueError if array_like contains Nans or Infs.

```
>>> a = [1, 2, np.inf]
>>> try:
...     np.asarray_chkfinite(a)
... except ValueError:
...     print('ValueError')
...
ValueError
```

numpy.**require**(*a*, *dtype=None*, *requirements=None*, ***, *like=None*)

Return an ndarray of the provided type that satisfies requirements.

This function is useful to be sure that an array with the correct flags is returned for passing to compiled code (perhaps through ctypes).

Parameters

a
[array_like] The object to be converted to a type-and-requirement-satisfying array.

dtype
[data-type] The required data-type. If None preserve the current dtype. If your application requires the data to be in native byteorder, include a byteorder specification as a part of the dtype specification.

requirements
[str or sequence of str] The requirements list can be any of the following

- 'F_CONTIGUOUS' ('F') - ensure a Fortran-contiguous array
- 'C_CONTIGUOUS' ('C') - ensure a C-contiguous array
- 'ALIGNED' ('A') - ensure a data-type aligned array
- 'WRITEABLE' ('W') - ensure a writable array
- 'OWNDATA' ('O') - ensure an array that owns its own data
- 'ENSUREARRAY', ('E') - ensure a base array, instead of a subclass

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] Array with specified requirements and type if given.

See also:

asarray
Convert input to an ndarray.

asanyarray
Convert to an ndarray, but pass through ndarray subclasses.

ascontiguousarray
Convert input to a contiguous array.

asfortranarray
Convert input to an ndarray with column-major memory order.

ndarray.flags
Information about the memory layout of the array.

Notes

The returned array will be guaranteed to have the listed requirements by making a copy if needed.

Examples

```
>>> import numpy as np
>>> x = np.arange(6).reshape(2,3)
>>> x.flags
  C_CONTIGUOUS : True
  F_CONTIGUOUS : False
  OWNDATA : False
  WRITEABLE : True
  ALIGNED : True
  WRITEBACKIFCOPY : False
```

```
>>> y = np.require(x, dtype=np.float32, requirements=['A', 'O', 'W', 'F'])
>>> y.flags
  C_CONTIGUOUS : False
  F_CONTIGUOUS : True
  OWNDATA : True
  WRITEABLE : True
  ALIGNED : True
  WRITEBACKIFCOPY : False
```

Joining arrays

concatenate([axis, out, dtype, casting])	Join a sequence of arrays along an existing axis.
concat([axis, out, dtype, casting])	Join a sequence of arrays along an existing axis.
stack(arrays[, axis, out, dtype, casting])	Join a sequence of arrays along a new axis.
block(arrays)	Assemble an nd-array from nested lists of blocks.
vstack(tup, *[, dtype, casting])	Stack arrays in sequence vertically (row wise).
hstack(tup, *[, dtype, casting])	Stack arrays in sequence horizontally (column wise).
dstack(tup)	Stack arrays in sequence depth wise (along third axis).
column_stack(tup)	Stack 1-D arrays as columns into a 2-D array.

numpy.**concatenate**(*(a1, a2, ...)*, *axis=0*, *out=None*, *dtype=None*, *casting="same_kind"*)

Join a sequence of arrays along an existing axis.

Parameters

a1, a2, …
[sequence of array_like] The arrays must have the same shape, except in the dimension corresponding to *axis* (the first, by default).

axis
[int, optional] The axis along which the arrays will be joined. If axis is None, arrays are flattened before use. Default is 0.

out
[ndarray, optional] If provided, the destination to place the result. The shape must be correct, matching that of what concatenate would have returned if no out argument were specified.

dtype
[str or dtype] If provided, the destination array will have this dtype. Cannot be provided together with *out*.

New in version 1.20.0.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'same_kind'. For a description of the options, please see casting.

New in version 1.20.0.

Returns

res
[ndarray] The concatenated array.

See also:

ma.concatenate
Concatenate function that preserves input masks.

array_split
Split an array into multiple sub-arrays of equal or near-equal size.

split
Split array into a list of multiple sub-arrays of equal size.

hsplit
Split array into multiple sub-arrays horizontally (column wise).

vsplit
Split array into multiple sub-arrays vertically (row wise).

dsplit
Split array into multiple sub-arrays along the 3rd axis (depth).

stack
Stack a sequence of arrays along a new axis.

block
Assemble arrays from blocks.

hstack
Stack arrays in sequence horizontally (column wise).

vstack
Stack arrays in sequence vertically (row wise).

dstack
Stack arrays in sequence depth wise (along third dimension).

column_stack
Stack 1-D arrays as columns into a 2-D array.

Notes

When one or more of the arrays to be concatenated is a MaskedArray, this function will return a MaskedArray object instead of an ndarray, but the input masks are *not* preserved. In cases where a MaskedArray is expected as input, use the ma.concatenate function from the masked array module instead.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> b = np.array([[5, 6]])
>>> np.concatenate((a, b), axis=0)
array([[1, 2],
       [3, 4],
       [5, 6]])
>>> np.concatenate((a, b.T), axis=1)
array([[1, 2, 5],
       [3, 4, 6]])
>>> np.concatenate((a, b), axis=None)
array([1, 2, 3, 4, 5, 6])
```

This function will not preserve masking of MaskedArray inputs.

```
>>> a = np.ma.arange(3)
>>> a[1] = np.ma.masked
>>> b = np.arange(2, 5)
>>> a
masked_array(data=[0, --, 2],
             mask=[False,  True, False],
       fill_value=999999)
>>> b
array([2, 3, 4])
>>> np.concatenate([a, b])
```

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```
masked_array(data=[0, 1, 2, 2, 3, 4],
             mask=False,
       fill_value=999999)
>>> np.ma.concatenate([a, b])
masked_array(data=[0, --, 2, 2, 3, 4],
             mask=[False,  True, False, False, False, False],
       fill_value=999999)
```

numpy.**concat**(*(a1, a2, ...)*, *axis=0*, *out=None*, *dtype=None*, *casting="same_kind"*)

Join a sequence of arrays along an existing axis.

Parameters

a1, a2, …
[sequence of array_like] The arrays must have the same shape, except in the dimension corresponding to *axis* (the first, by default).

axis
[int, optional] The axis along which the arrays will be joined. If axis is None, arrays are flattened before use. Default is 0.

out
[ndarray, optional] If provided, the destination to place the result. The shape must be correct, matching that of what concatenate would have returned if no out argument were specified.

dtype
[str or dtype] If provided, the destination array will have this dtype. Cannot be provided together with *out*.

New in version 1.20.0.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'same_kind'. For a description of the options, please see casting.

New in version 1.20.0.

Returns

res
[ndarray] The concatenated array.

See also:

ma.concatenate
Concatenate function that preserves input masks.

array_split
Split an array into multiple sub-arrays of equal or near-equal size.

split
Split array into a list of multiple sub-arrays of equal size.

hsplit
Split array into multiple sub-arrays horizontally (column wise).

vsplit
Split array into multiple sub-arrays vertically (row wise).

dsplit
Split array into multiple sub-arrays along the 3rd axis (depth).

stack
Stack a sequence of arrays along a new axis.

block
Assemble arrays from blocks.

hstack
Stack arrays in sequence horizontally (column wise).

vstack
Stack arrays in sequence vertically (row wise).

dstack
Stack arrays in sequence depth wise (along third dimension).

column_stack
Stack 1-D arrays as columns into a 2-D array.

Notes

When one or more of the arrays to be concatenated is a MaskedArray, this function will return a MaskedArray object instead of an ndarray, but the input masks are *not* preserved. In cases where a MaskedArray is expected as input, use the ma.concatenate function from the masked array module instead.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> b = np.array([[5, 6]])
>>> np.concatenate((a, b), axis=0)
array([[1, 2],
       [3, 4],
       [5, 6]])
>>> np.concatenate((a, b.T), axis=1)
array([[1, 2, 5],
       [3, 4, 6]])
>>> np.concatenate((a, b), axis=None)
array([1, 2, 3, 4, 5, 6])
```

This function will not preserve masking of MaskedArray inputs.

```
>>> a = np.ma.arange(3)
>>> a[1] = np.ma.masked
>>> b = np.arange(2, 5)
>>> a
masked_array(data=[0, --, 2],
             mask=[False,  True, False],
       fill_value=999999)
>>> b
array([2, 3, 4])
>>> np.concatenate([a, b])
masked_array(data=[0, 1, 2, 2, 3, 4],
             mask=False,
       fill_value=999999)
>>> np.ma.concatenate([a, b])
masked_array(data=[0, --, 2, 2, 3, 4],
```

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```
             mask=[False,  True, False, False, False, False],
       fill_value=999999)
```

numpy.**stack**(*arrays*, *axis=0*, *out=None*, ***, *dtype=None*, *casting='same_kind'*)

Join a sequence of arrays along a new axis.

The `axis` parameter specifies the index of the new axis in the dimensions of the result. For example, if `axis=0` it will be the first dimension and if `axis=-1` it will be the last dimension.

Parameters

arrays
[sequence of ndarrays] Each array must have the same shape. In the case of a single ndarray array_like input, it will be treated as a sequence of arrays; i.e., each element along the zeroth axis is treated as a separate array.

axis
[int, optional] The axis in the result array along which the input arrays are stacked.

out
[ndarray, optional] If provided, the destination to place the result. The shape must be correct, matching that of what stack would have returned if no out argument were specified.

dtype
[str or dtype] If provided, the destination array will have this dtype. Cannot be provided together with *out*.

New in version 1.24.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'same_kind'.

New in version 1.24.

Returns

stacked
[ndarray] The stacked array has one more dimension than the input arrays.

See also:

concatenate
Join a sequence of arrays along an existing axis.

block
Assemble an nd-array from nested lists of blocks.

split
Split array into a list of multiple sub-arrays of equal size.

unstack
Split an array into a tuple of sub-arrays along an axis.

Examples

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> arrays = [rng.normal(size=(3,4)) for _ in range(10)]
>>> np.stack(arrays, axis=0).shape
(10, 3, 4)
```

```
>>> np.stack(arrays, axis=1).shape
(3, 10, 4)
```

```
>>> np.stack(arrays, axis=2).shape
(3, 4, 10)
```

```
>>> a = np.array([1, 2, 3])
>>> b = np.array([4, 5, 6])
>>> np.stack((a, b))
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> np.stack((a, b), axis=-1)
array([[1, 4],
       [2, 5],
       [3, 6]])
```

numpy.**block**(*arrays*)

Assemble an nd-array from nested lists of blocks.

Blocks in the innermost lists are concatenated (see *concatenate*) along the last dimension (-1), then these are concatenated along the second-last dimension (-2), and so on until the outermost list is reached.

Blocks can be of any dimension, but will not be broadcasted using the normal rules. Instead, leading axes of size 1 are inserted, to make `block.ndim` the same for all blocks. This is primarily useful for working with scalars, and means that code like `np.block([v, 1])` is valid, where `v.ndim == 1`.

When the nested list is two levels deep, this allows block matrices to be constructed from their components.

Parameters

arrays
[nested list of array_like or scalars (but not tuples)] If passed a single ndarray or scalar (a nested list of depth 0), this is returned unmodified (and not copied).

Elements shapes must match along the appropriate axes (without broadcasting), but leading 1s will be prepended to the shape as necessary to make the dimensions match.

Returns

block_array
[ndarray] The array assembled from the given blocks.

The dimensionality of the output is equal to the greatest of:

- the dimensionality of all the inputs
- the depth to which the input list is nested

Raises

ValueError

- If list depths are mismatched - for instance, `[[a, b], c]` is illegal, and should be spelt `[[a, b], [c]]`
- If lists are empty - for instance, `[[a, b], []]`

See also:

concatenate
Join a sequence of arrays along an existing axis.

stack
Join a sequence of arrays along a new axis.

vstack
Stack arrays in sequence vertically (row wise).

hstack
Stack arrays in sequence horizontally (column wise).

dstack
Stack arrays in sequence depth wise (along third axis).

column_stack
Stack 1-D arrays as columns into a 2-D array.

vsplit
Split an array into multiple sub-arrays vertically (row-wise).

unstack
Split an array into a tuple of sub-arrays along an axis.

Notes

When called with only scalars, `np.block` is equivalent to an ndarray call. So `np.block([[1, 2], [3, 4]])` is equivalent to `np.array([[1, 2], [3, 4]])`.

This function does not enforce that the blocks lie on a fixed grid. `np.block([[a, b], [c, d]])` is not restricted to arrays of the form:

```
AAAbb
AAAbb
cccDD
```

But is also allowed to produce, for some `a, b, c, d`:

```
AAAbb
AAAbb
cDDDD
```

Since concatenation happens along the last axis first, *`block`* is *not* capable of producing the following directly:

```
AAAbb
cccbb
cccDD
```

Matlab's "square bracket stacking", `[A, B, ...; p, q, ...]`, is equivalent to `np.block([[A, B, ...], [p, q, ...]])`.

Examples

The most common use of this function is to build a block matrix:

```
>>> import numpy as np
>>> A = np.eye(2) * 2
>>> B = np.eye(3) * 3
>>> np.block([
...     [A,               np.zeros((2, 3))],
...     [np.ones((3, 2)), B               ]
... ])
array([[2., 0., 0., 0., 0.],
       [0., 2., 0., 0., 0.],
       [1., 1., 3., 0., 0.],
       [1., 1., 0., 3., 0.],
       [1., 1., 0., 0., 3.]])
```

With a list of depth 1, *block* can be used as *hstack*:

```
>>> np.block([1, 2, 3])              # hstack([1, 2, 3])
array([1, 2, 3])
```

```
>>> a = np.array([1, 2, 3])
>>> b = np.array([4, 5, 6])
>>> np.block([a, b, 10])             # hstack([a, b, 10])
array([ 1,  2,  3,  4,  5,  6, 10])
```

```
>>> A = np.ones((2, 2), int)
>>> B = 2 * A
>>> np.block([A, B])                 # hstack([A, B])
array([[1, 1, 2, 2],
       [1, 1, 2, 2]])
```

With a list of depth 2, *block* can be used in place of *vstack*:

```
>>> a = np.array([1, 2, 3])
>>> b = np.array([4, 5, 6])
>>> np.block([[a], [b]])             # vstack([a, b])
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> A = np.ones((2, 2), int)
>>> B = 2 * A
>>> np.block([[A], [B]])             # vstack([A, B])
array([[1, 1],
       [1, 1],
       [2, 2],
       [2, 2]])
```

It can also be used in place of *atleast_1d* and *atleast_2d*:

```
>>> a = np.array(0)
>>> b = np.array([1])
>>> np.block([a])                    # atleast_1d(a)
array([0])
>>> np.block([b])                    # atleast_1d(b)
array([1])
```

```
>>> np.block([[a]])                  # atleast_2d(a)
array([[0]])
>>> np.block([[b]])                  # atleast_2d(b)
array([[1]])
```

numpy.**vstack**(*tup*, *, *dtype=None*, *casting='same_kind'*)

Stack arrays in sequence vertically (row wise).

This is equivalent to concatenation along the first axis after 1-D arrays of shape *(N,)* have been reshaped to *(1,N)*. Rebuilds arrays divided by *vsplit*.

This function makes most sense for arrays with up to 3 dimensions. For instance, for pixel-data with a height (first axis), width (second axis), and r/g/b channels (third axis). The functions *concatenate*, *stack* and *block* provide more general stacking and concatenation operations.

Parameters

tup
[sequence of ndarrays] The arrays must have the same shape along all but the first axis. 1-D arrays must have the same length. In the case of a single array_like input, it will be treated as a sequence of arrays; i.e., each element along the zeroth axis is treated as a separate array.

dtype
[str or dtype] If provided, the destination array will have this dtype. Cannot be provided together with *out*.

New in version 1.24.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'same_kind'.

New in version 1.24.

Returns

stacked
[ndarray] The array formed by stacking the given arrays, will be at least 2-D.

See also:

concatenate
Join a sequence of arrays along an existing axis.

stack
Join a sequence of arrays along a new axis.

block
Assemble an nd-array from nested lists of blocks.

hstack
Stack arrays in sequence horizontally (column wise).

dstack
Stack arrays in sequence depth wise (along third axis).

column_stack
Stack 1-D arrays as columns into a 2-D array.

vsplit
Split an array into multiple sub-arrays vertically (row-wise).

unstack
: Split an array into a tuple of sub-arrays along an axis.

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2, 3])
>>> b = np.array([4, 5, 6])
>>> np.vstack((a,b))
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> a = np.array([[1], [2], [3]])
>>> b = np.array([[4], [5], [6]])
>>> np.vstack((a,b))
array([[1],
       [2],
       [3],
       [4],
       [5],
       [6]])
```

numpy.**hstack**(*tup*, ***, *dtype=None*, *casting='same_kind'*)

Stack arrays in sequence horizontally (column wise).

This is equivalent to concatenation along the second axis, except for 1-D arrays where it concatenates along the first axis. Rebuilds arrays divided by *hsplit*.

This function makes most sense for arrays with up to 3 dimensions. For instance, for pixel-data with a height (first axis), width (second axis), and r/g/b channels (third axis). The functions *concatenate*, *stack* and *block* provide more general stacking and concatenation operations.

Parameters

tup
: [sequence of ndarrays] The arrays must have the same shape along all but the second axis, except 1-D arrays which can be any length. In the case of a single array_like input, it will be treated as a sequence of arrays; i.e., each element along the zeroth axis is treated as a separate array.

dtype
: [str or dtype] If provided, the destination array will have this dtype. Cannot be provided together with *out*.

  New in version 1.24.

casting
: [{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur. Defaults to 'same_kind'.

  New in version 1.24.

Returns

stacked
: [ndarray] The array formed by stacking the given arrays.

See also:

concatenate
: Join a sequence of arrays along an existing axis.

stack
: Join a sequence of arrays along a new axis.

block
: Assemble an nd-array from nested lists of blocks.

vstack
: Stack arrays in sequence vertically (row wise).

dstack
: Stack arrays in sequence depth wise (along third axis).

column_stack
: Stack 1-D arrays as columns into a 2-D array.

hsplit
: Split an array into multiple sub-arrays horizontally (column-wise).

unstack
: Split an array into a tuple of sub-arrays along an axis.

Examples

```
>>> import numpy as np
>>> a = np.array((1,2,3))
>>> b = np.array((4,5,6))
>>> np.hstack((a,b))
array([1, 2, 3, 4, 5, 6])
>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[4],[5],[6]])
>>> np.hstack((a,b))
array([[1, 4],
       [2, 5],
       [3, 6]])
```

numpy.**dstack**(*tup*)

Stack arrays in sequence depth wise (along third axis).

This is equivalent to concatenation along the third axis after 2-D arrays of shape *(M,N)* have been reshaped to *(M,N,1)* and 1-D arrays of shape *(N,)* have been reshaped to *(1,N,1)*. Rebuilds arrays divided by *dsplit*.

This function makes most sense for arrays with up to 3 dimensions. For instance, for pixel-data with a height (first axis), width (second axis), and r/g/b channels (third axis). The functions *concatenate*, *stack* and *block* provide more general stacking and concatenation operations.

Parameters

tup
: [sequence of arrays] The arrays must have the same shape along all but the third axis. 1-D or 2-D arrays must have the same shape.

Returns

stacked
: [ndarray] The array formed by stacking the given arrays, will be at least 3-D.

See also:

concatenate
Join a sequence of arrays along an existing axis.

stack
Join a sequence of arrays along a new axis.

block
Assemble an nd-array from nested lists of blocks.

vstack
Stack arrays in sequence vertically (row wise).

hstack
Stack arrays in sequence horizontally (column wise).

column_stack
Stack 1-D arrays as columns into a 2-D array.

dsplit
Split array along third axis.

Examples

```
>>> import numpy as np
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.dstack((a,b))
array([[[1, 2],
        [2, 3],
        [3, 4]]])
```

```
>>> a = np.array([[1],[2],[3]])
>>> b = np.array([[2],[3],[4]])
>>> np.dstack((a,b))
array([[[1, 2]],
       [[2, 3]],
       [[3, 4]]])
```

numpy.**column_stack**(*tup*)

Stack 1-D arrays as columns into a 2-D array.

Take a sequence of 1-D arrays and stack them as columns to make a single 2-D array. 2-D arrays are stacked as-is, just like with *hstack*. 1-D arrays are turned into 2-D columns first.

Parameters

tup
[sequence of 1-D or 2-D arrays.] Arrays to stack. All of them must have the same first dimension.

Returns

stacked
[2-D array] The array formed by stacking the given arrays.

See also:

stack, ***hstack***, ***vstack***, ***concatenate***

Examples

```
>>> import numpy as np
>>> a = np.array((1,2,3))
>>> b = np.array((2,3,4))
>>> np.column_stack((a,b))
array([[1, 2],
       [2, 3],
       [3, 4]])
```

Splitting arrays

split(ary, indices_or_sections[, axis])	Split an array into multiple sub-arrays as views into *ary*.
array_split(ary, indices_or_sections[, axis])	Split an array into multiple sub-arrays.
dsplit(ary, indices_or_sections)	Split array into multiple sub-arrays along the 3rd axis (depth).
hsplit(ary, indices_or_sections)	Split an array into multiple sub-arrays horizontally (column-wise).
vsplit(ary, indices_or_sections)	Split an array into multiple sub-arrays vertically (row-wise).
unstack(x, /, *[, axis])	Split an array into a sequence of arrays along the given axis.

numpy.**split**(*ary*, *indices_or_sections*, *axis=0*)

Split an array into multiple sub-arrays as views into *ary*.

Parameters

ary
[ndarray] Array to be divided into sub-arrays.

indices_or_sections
[int or 1-D array] If *indices_or_sections* is an integer, N, the array will be divided into N equal arrays along *axis*. If such a split is not possible, an error is raised.

If *indices_or_sections* is a 1-D array of sorted integers, the entries indicate where along *axis* the array is split. For example, `[2, 3]` would, for `axis=0`, result in

- ary[:2]
- ary[2:3]
- ary[3:]

If an index exceeds the dimension of the array along *axis*, an empty sub-array is returned correspondingly.

axis
[int, optional] The axis along which to split, default is 0.

Returns

sub-arrays
[list of ndarrays] A list of sub-arrays as views into *ary*.

Raises

ValueError
If *indices_or_sections* is given as an integer, but a split does not result in equal division.

See also:

array_split
Split an array into multiple sub-arrays of equal or near-equal size. Does not raise an exception if an equal division cannot be made.

hsplit
Split array into multiple sub-arrays horizontally (column-wise).

vsplit
Split array into multiple sub-arrays vertically (row wise).

dsplit
Split array into multiple sub-arrays along the 3rd axis (depth).

concatenate
Join a sequence of arrays along an existing axis.

stack
Join a sequence of arrays along a new axis.

hstack
Stack arrays in sequence horizontally (column wise).

vstack
Stack arrays in sequence vertically (row wise).

dstack
Stack arrays in sequence depth wise (along third dimension).

Examples

```
>>> import numpy as np
>>> x = np.arange(9.0)
>>> np.split(x, 3)
[array([0.,  1.,  2.]), array([3.,  4.,  5.]), array([6.,  7.,  8.])]
```

```
>>> x = np.arange(8.0)
>>> np.split(x, [3, 5, 6, 10])
[array([0.,  1.,  2.]),
 array([3.,  4.]),
 array([5.]),
 array([6.,  7.]),
 array([], dtype=float64)]
```

numpy.**array_split**(*ary*, *indices_or_sections*, *axis=0*)

Split an array into multiple sub-arrays.

Please refer to the `split` documentation. The only difference between these functions is that `array_split` allows *indices_or_sections* to be an integer that does *not* equally divide the axis. For an array of length l that should be split into n sections, it returns l % n sub-arrays of size l//n + 1 and the rest of size l//n.

See also:

split
Split array into multiple sub-arrays of equal size.

Examples

```
>>> import numpy as np
>>> x = np.arange(8.0)
>>> np.array_split(x, 3)
[array([0.,  1.,  2.]), array([3.,  4.,  5.]), array([6.,  7.])]
```

```
>>> x = np.arange(9)
>>> np.array_split(x, 4)
[array([0, 1, 2]), array([3, 4]), array([5, 6]), array([7, 8])]
```

numpy.**dsplit**(*ary*, *indices_or_sections*)

Split array into multiple sub-arrays along the 3rd axis (depth).

Please refer to the *split* documentation. *dsplit* is equivalent to *split* with `axis=2`, the array is always split along the third axis provided the array dimension is greater than or equal to 3.

See also:

split
Split an array into multiple sub-arrays of equal size.

Examples

```
>>> import numpy as np
>>> x = np.arange(16.0).reshape(2, 2, 4)
>>> x
array([[[ 0.,   1.,   2.,   3.],
        [ 4.,   5.,   6.,   7.]],
       [[ 8.,   9.,  10.,  11.],
        [12.,  13.,  14.,  15.]]])
>>> np.dsplit(x, 2)
[array([[[ 0.,  1.],
        [ 4.,  5.]],
       [[ 8.,  9.],
        [12., 13.]]]), array([[[ 2.,  3.],
        [ 6.,  7.]],
       [[10., 11.],
        [14., 15.]]])]
>>> np.dsplit(x, np.array([3, 6]))
[array([[[ 0.,   1.,   2.],
        [ 4.,   5.,   6.]],
       [[ 8.,   9.,  10.],
        [12.,  13.,  14.]]]),
 array([[[ 3.],
        [ 7.]],
       [[11.],
        [15.]]]),
array([], shape=(2, 2, 0), dtype=float64)]
```

numpy.**hsplit**(*ary*, *indices_or_sections*)

Split an array into multiple sub-arrays horizontally (column-wise).

Please refer to the *split* documentation. *hsplit* is equivalent to *split* with `axis=1`, the array is always split along the second axis except for 1-D arrays, where it is split at `axis=0`.

See also:

split
Split an array into multiple sub-arrays of equal size.

Examples

```
>>> import numpy as np
>>> x = np.arange(16.0).reshape(4, 4)
>>> x
array([[ 0.,   1.,   2.,   3.],
       [ 4.,   5.,   6.,   7.],
       [ 8.,   9.,  10.,  11.],
       [12.,  13.,  14.,  15.]])
>>> np.hsplit(x, 2)
[array([[  0.,   1.],
       [  4.,   5.],
       [  8.,   9.],
       [12.,  13.]]),
 array([[  2.,   3.],
       [  6.,   7.],
       [10.,  11.],
       [14.,  15.]])]
>>> np.hsplit(x, np.array([3, 6]))
[array([[ 0.,   1.,   2.],
       [ 4.,   5.,   6.],
       [ 8.,   9.,  10.],
       [12.,  13.,  14.]]),
 array([[ 3.],
       [ 7.],
       [11.],
       [15.]]),
 array([], shape=(4, 0), dtype=float64)]
```

With a higher dimensional array the split is still along the second axis.

```
>>> x = np.arange(8.0).reshape(2, 2, 2)
>>> x
array([[[0.,  1.],
        [2.,  3.]],
       [[4.,  5.],
        [6.,  7.]]])
>>> np.hsplit(x, 2)
[array([[[0.,  1.]],
       [[4.,  5.]]]),
 array([[[2.,  3.]],
       [[6.,  7.]]])]
```

With a 1-D array, the split is along axis 0.

```
>>> x = np.array([0, 1, 2, 3, 4, 5])
>>> np.hsplit(x, 2)
[array([0, 1, 2]), array([3, 4, 5])]
```

numpy.**vsplit**(*ary*, *indices_or_sections*)
Split an array into multiple sub-arrays vertically (row-wise).

Please refer to the `split` documentation. `vsplit` is equivalent to `split` with *axis=0* (default), the array is always split along the first axis regardless of the array dimension.

See also:

split
Split an array into multiple sub-arrays of equal size.

Examples

```
>>> import numpy as np
>>> x = np.arange(16.0).reshape(4, 4)
>>> x
array([[ 0.,   1.,   2.,   3.],
       [ 4.,   5.,   6.,   7.],
       [ 8.,   9.,  10.,  11.],
       [12.,  13.,  14.,  15.]])
>>> np.vsplit(x, 2)
[array([[0., 1., 2., 3.],
        [4., 5., 6., 7.]]),
 array([[ 8.,  9., 10., 11.],
        [12., 13., 14., 15.]])]
>>> np.vsplit(x, np.array([3, 6]))
[array([[ 0.,  1.,  2.,  3.],
        [ 4.,  5.,  6.,  7.],
        [ 8.,  9., 10., 11.]]),
 array([[12., 13., 14., 15.]]),
 array([], shape=(0, 4), dtype=float64)]
```

With a higher dimensional array the split is still along the first axis.

```
>>> x = np.arange(8.0).reshape(2, 2, 2)
>>> x
array([[[0.,  1.],
        [2.,  3.]],
       [[4.,  5.],
        [6.,  7.]]])
>>> np.vsplit(x, 2)
[array([[[0., 1.],
         [2., 3.]]]),
 array([[[4., 5.],
         [6., 7.]]])]
```

numpy.**unstack**(*x*, */*, ***, *axis=0*)

Split an array into a sequence of arrays along the given axis.

The `axis` parameter specifies the dimension along which the array will be split. For example, if `axis=0` (the default) it will be the first dimension and if `axis=-1` it will be the last dimension.

The result is a tuple of arrays split along `axis`.

New in version 2.1.0.

Parameters

x
[ndarray] The array to be unstacked.

axis
[int, optional] Axis along which the array will be split. Default: `0`.

Returns

unstacked
[tuple of ndarrays] The unstacked arrays.

See also:

stack
Join a sequence of arrays along a new axis.

concatenate
Join a sequence of arrays along an existing axis.

block
Assemble an nd-array from nested lists of blocks.

split
Split array into a list of multiple sub-arrays of equal size.

Notes

`unstack` serves as the reverse operation of *stack*, i.e., `stack(unstack(x, axis=axis), axis=axis) == x`.

This function is equivalent to `tuple(np.moveaxis(x, axis, 0))`, since iterating on an array iterates along the first axis.

Examples

```
>>> arr = np.arange(24).reshape((2, 3, 4))
>>> np.unstack(arr)
(array([[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]]),
 array([[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]]))
>>> np.unstack(arr, axis=1)
(array([[ 0,  1,  2,  3],
        [12, 13, 14, 15]]),
 array([[ 4,  5,  6,  7],
        [16, 17, 18, 19]]),
 array([[ 8,  9, 10, 11],
        [20, 21, 22, 23]]))
>>> arr2 = np.stack(np.unstack(arr, axis=1), axis=1)
>>> arr2.shape
(2, 3, 4)
>>> np.all(arr == arr2)
np.True_
```

Tiling arrays

tile(A, reps)	Construct an array by repeating A the number of times given by reps.
repeat(a, repeats[, axis])	Repeat each element of an array after themselves

numpy.**tile**(*A*, *reps*)

Construct an array by repeating A the number of times given by reps.

If *reps* has length `d`, the result will have dimension of `max(d, A.ndim)`.

If `A.ndim < d`, *A* is promoted to be d-dimensional by prepending new axes. So a shape (3,) array is promoted to (1, 3) for 2-D replication, or shape (1, 1, 3) for 3-D replication. If this is not the desired behavior, promote *A* to d-dimensions manually before calling this function.

If `A.ndim > d`, *reps* is promoted to *A*.ndim by prepending 1's to it. Thus for an *A* of shape (2, 3, 4, 5), a *reps* of (2, 2) is treated as (1, 1, 2, 2).

Note : Although tile may be used for broadcasting, it is strongly recommended to use numpy's broadcasting operations and functions.

Parameters

A
[array_like] The input array.

reps
[array_like] The number of repetitions of *A* along each axis.

Returns

c
[ndarray] The tiled output array.

See also:

repeat
Repeat elements of an array.

broadcast_to
Broadcast an array to a new shape

Examples

```
>>> import numpy as np
>>> a = np.array([0, 1, 2])
>>> np.tile(a, 2)
array([0, 1, 2, 0, 1, 2])
>>> np.tile(a, (2, 2))
array([[0, 1, 2, 0, 1, 2],
       [0, 1, 2, 0, 1, 2]])
>>> np.tile(a, (2, 1, 2))
array([[[0, 1, 2, 0, 1, 2]],
       [[0, 1, 2, 0, 1, 2]]])
```

```
>>> b = np.array([[1, 2], [3, 4]])
>>> np.tile(b, 2)
array([[1, 2, 1, 2],
       [3, 4, 3, 4]])
>>> np.tile(b, (2, 1))
array([[1, 2],
       [3, 4],
       [1, 2],
       [3, 4]])
```

```
>>> c = np.array([1,2,3,4])
>>> np.tile(c,(4,1))
array([[1, 2, 3, 4],
       [1, 2, 3, 4],
       [1, 2, 3, 4],
       [1, 2, 3, 4]])
```

numpy.**repeat**(*a*, *repeats*, *axis=None*)

Repeat each element of an array after themselves

Parameters

a
[array_like] Input array.

repeats
[int or array of ints] The number of repetitions for each element. *repeats* is broadcasted to fit the shape of the given axis.

axis
[int, optional] The axis along which to repeat values. By default, use the flattened input array, and return a flat output array.

Returns

repeated_array
[ndarray] Output array which has the same shape as *a*, except along the given axis.

See also:

tile
Tile an array.

unique
Find the unique elements of an array.

Examples

```
>>> import numpy as np
>>> np.repeat(3, 4)
array([3, 3, 3, 3])
>>> x = np.array([[1,2],[3,4]])
>>> np.repeat(x, 2)
array([1, 1, 2, 2, 3, 3, 4, 4])
>>> np.repeat(x, 3, axis=1)
array([[1, 1, 1, 2, 2, 2],
       [3, 3, 3, 4, 4, 4]])
```

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```
>>> np.repeat(x, [1, 2], axis=0)
array([[1, 2],
       [3, 4],
       [3, 4]])
```

Adding and removing elements

delete(arr, obj[, axis])	Return a new array with sub-arrays along an axis deleted.
insert(arr, obj, values[, axis])	Insert values along the given axis before the given indices.
append(arr, values[, axis])	Append values to the end of an array.
resize(a, new_shape)	Return a new array with the specified shape.
trim_zeros(filt[, trim, axis])	Remove values along a dimension which are zero along all other.
unique(ar[, return_index, return_inverse, ...])	Find the unique elements of an array.
pad(array, pad_width[, mode])	Pad an array.

numpy.**delete**(*arr*, *obj*, *axis=None*)

Return a new array with sub-arrays along an axis deleted. For a one dimensional array, this returns those entries not returned by *arr[obj]*.

Parameters

arr
[array_like] Input array.

obj
[slice, int, array-like of ints or bools] Indicate indices of sub-arrays to remove along the specified axis.

Changed in version 1.19.0: Boolean indices are now treated as a mask of elements to remove, rather than being cast to the integers 0 and 1.

axis
[int, optional] The axis along which to delete the subarray defined by *obj*. If *axis* is None, *obj* is applied to the flattened array.

Returns

out
[ndarray] A copy of *arr* with the elements specified by *obj* removed. Note that *delete* does not occur in-place. If *axis* is None, *out* is a flattened array.

See also:

insert
Insert elements into an array.

append
Append elements at the end of an array.

Notes

Often it is preferable to use a boolean mask. For example:

```
>>> arr = np.arange(12) + 1
>>> mask = np.ones(len(arr), dtype=bool)
>>> mask[[0,2,4]] = False
>>> result = arr[mask,...]
```

Is equivalent to `np.delete(arr, [0,2,4], axis=0)`, but allows further use of *mask*.

Examples

```
>>> import numpy as np
>>> arr = np.array([[1,2,3,4], [5,6,7,8], [9,10,11,12]])
>>> arr
array([[ 1,  2,  3,  4],
       [ 5,  6,  7,  8],
       [ 9, 10, 11, 12]])
>>> np.delete(arr, 1, 0)
array([[ 1,  2,  3,  4],
       [ 9, 10, 11, 12]])
```

```
>>> np.delete(arr, np.s_[::2], 1)
array([[ 2,  4],
       [ 6,  8],
       [10, 12]])
>>> np.delete(arr, [1,3,5], None)
array([ 1,  3,  5,  7,  8,  9, 10, 11, 12])
```

numpy.**insert**(*arr*, *obj*, *values*, *axis=None*)

Insert values along the given axis before the given indices.

Parameters

arr
: [array_like] Input array.

obj
: [slice, int, array-like of ints or bools] Object that defines the index or indices before which *values* is inserted.

  Changed in version 2.1.2: Boolean indices are now treated as a mask of elements to insert, rather than being cast to the integers 0 and 1.

  Support for multiple insertions when *obj* is a single scalar or a sequence with one element (similar to calling insert multiple times).

values
: [array_like] Values to insert into *arr*. If the type of *values* is different from that of *arr*, *values* is converted to the type of *arr*. *values* should be shaped so that `arr[...,obj,...] = values` is legal.

axis
: [int, optional] Axis along which to insert *values*. If *axis* is None then *arr* is flattened first.

Returns

out
: [ndarray] A copy of *arr* with *values* inserted. Note that `insert` does not occur in-place: a new array is returned. If *axis* is None, *out* is a flattened array.

See also:

append
: Append elements at the end of an array.

concatenate
: Join a sequence of arrays along an existing axis.

delete
: Delete elements from an array.

Notes

Note that for higher dimensional inserts `obj=0` behaves very different from `obj=[0]` just like `arr[:,0,:] = values` is different from `arr[:,[0],:] = values`. This is because of the difference between basic and advanced indexing.

Examples

```
>>> import numpy as np
>>> a = np.arange(6).reshape(3, 2)
>>> a
array([[0, 1],
       [2, 3],
       [4, 5]])
>>> np.insert(a, 1, 6)
array([0, 6, 1, 2, 3, 4, 5])
>>> np.insert(a, 1, 6, axis=1)
array([[0, 6, 1],
       [2, 6, 3],
       [4, 6, 5]])
```

Difference between sequence and scalars, showing how `obj=[1]` behaves different from `obj=1`:

```
>>> np.insert(a, [1], [[7],[8],[9]], axis=1)
array([[0, 7, 1],
       [2, 8, 3],
       [4, 9, 5]])
>>> np.insert(a, 1, [[7],[8],[9]], axis=1)
array([[0, 7, 8, 9, 1],
       [2, 7, 8, 9, 3],
       [4, 7, 8, 9, 5]])
>>> np.array_equal(np.insert(a, 1, [7, 8, 9], axis=1),
...                np.insert(a, [1], [[7],[8],[9]], axis=1))
True
```

```
>>> b = a.flatten()
>>> b
array([0, 1, 2, 3, 4, 5])
>>> np.insert(b, [2, 2], [6, 7])
array([0, 1, 6, 7, 2, 3, 4, 5])
```

```
>>> np.insert(b, slice(2, 4), [7, 8])
array([0, 1, 7, 2, 8, 3, 4, 5])
```

```
>>> np.insert(b, [2, 2], [7.13, False]) # type casting
array([0, 1, 7, 0, 2, 3, 4, 5])
```

```
>>> x = np.arange(8).reshape(2, 4)
>>> idx = (1, 3)
>>> np.insert(x, idx, 999, axis=1)
array([[  0, 999,   1,   2, 999,   3],
       [  4, 999,   5,   6, 999,   7]])
```

numpy.**append**(*arr*, *values*, *axis=None*)

Append values to the end of an array.

Parameters

arr
[array_like] Values are appended to a copy of this array.

values
[array_like] These values are appended to a copy of *arr*. It must be of the correct shape (the same shape as *arr*, excluding *axis*). If *axis* is not specified, *values* can be any shape and will be flattened before use.

axis
[int, optional] The axis along which *values* are appended. If *axis* is not given, both *arr* and *values* are flattened before use.

Returns

append
[ndarray] A copy of *arr* with *values* appended to *axis*. Note that *append* does not occur in-place: a new array is allocated and filled. If *axis* is None, *out* is a flattened array.

See also:

insert
Insert elements into an array.

delete
Delete elements from an array.

Examples

```
>>> import numpy as np
>>> np.append([1, 2, 3], [[4, 5, 6], [7, 8, 9]])
array([1, 2, 3, ..., 7, 8, 9])
```

When *axis* is specified, *values* must have the correct shape.

```
>>> np.append([[1, 2, 3], [4, 5, 6]], [[7, 8, 9]], axis=0)
array([[1, 2, 3],
       [4, 5, 6],
       [7, 8, 9]])
```

```
>>> np.append([[1, 2, 3], [4, 5, 6]], [7, 8, 9], axis=0)
Traceback (most recent call last):
    ...
ValueError: all the input arrays must have same number of dimensions, but
the array at index 0 has 2 dimension(s) and the array at index 1 has 1
dimension(s)
```

```
>>> a = np.array([1, 2], dtype=int)
>>> c = np.append(a, [])
>>> c
array([1., 2.])
>>> c.dtype
float64
```

Default dtype for empty ndarrays is *float64* thus making the output of dtype *float64* when appended with dtype *int64*

numpy.**resize**(*a*, *new_shape*)

Return a new array with the specified shape.

If the new array is larger than the original array, then the new array is filled with repeated copies of *a*. Note that this behavior is different from a.resize(new_shape) which fills with zeros instead of repeated copies of *a*.

Parameters

a
[array_like] Array to be resized.

new_shape
[int or tuple of int] Shape of resized array.

Returns

reshaped_array
[ndarray] The new array is formed from the data in the old array, repeated if necessary to fill out the required number of elements. The data are repeated iterating over the array in C-order.

See also:

numpy.reshape
Reshape an array without changing the total size.

numpy.pad
Enlarge and pad an array.

numpy.repeat
Repeat elements of an array.

ndarray.resize
resize an array in-place.

Notes

When the total size of the array does not change *reshape* should be used. In most other cases either indexing (to reduce the size) or padding (to increase the size) may be a more appropriate solution.

Warning: This functionality does **not** consider axes separately, i.e. it does not apply interpolation/extrapolation. It fills the return array with the required number of elements, iterating over *a* in C-order, disregarding axes (and cycling back from the start if the new shape is larger). This functionality is therefore not suitable to resize images, or data where each axis represents a separate and distinct entity.

Examples

```
>>> import numpy as np
>>> a = np.array([[0,1],[2,3]])
>>> np.resize(a,(2,3))
array([[0, 1, 2],
       [3, 0, 1]])
>>> np.resize(a,(1,4))
array([[0, 1, 2, 3]])
>>> np.resize(a,(2,4))
array([[0, 1, 2, 3],
       [0, 1, 2, 3]])
```

numpy.**trim_zeros**(*filt*, *trim='fb'*, *axis=None*)

Remove values along a dimension which are zero along all other.

Parameters

filt
[array_like] Input array.

trim
[{“fb”, “f”, “b”}, optional] A string with ‘f’ representing trim from front and ‘b’ to trim from back. By default, zeros are trimmed on both sides. Front and back refer to the edges of a dimension, with “front” refering to the side with the lowest index 0, and “back” refering to the highest index (or index -1).

axis
[int or sequence, optional] If None, *filt* is cropped such, that the smallest bounding box is returned that still contains all values which are not zero. If an axis is specified, *filt* will be sliced in that dimension only on the sides specified by *trim*. The remaining area will be the smallest that still contains all values wich are not zero.

Returns

trimmed
[ndarray or sequence] The result of trimming the input. The number of dimensions and the input data type are preserved.

Notes

For all-zero arrays, the first axis is trimmed first.

Examples

```
>>> import numpy as np
>>> a = np.array((0, 0, 0, 1, 2, 3, 0, 2, 1, 0))
>>> np.trim_zeros(a)
array([1, 2, 3, 0, 2, 1])
```

```
>>> np.trim_zeros(a, trim='b')
array([0, 0, 0, ..., 0, 2, 1])
```

Multiple dimensions are supported.

```
>>> b = np.array([[0, 0, 2, 3, 0, 0],
...               [0, 1, 0, 3, 0, 0],
...               [0, 0, 0, 0, 0, 0]])
>>> np.trim_zeros(b)
array([[0, 2, 3],
       [1, 0, 3]])
```

```
>>> np.trim_zeros(b, axis=-1)
array([[0, 2, 3],
       [1, 0, 3],
       [0, 0, 0]])
```

The input data type is preserved, list/tuple in means list/tuple out.

```
>>> np.trim_zeros([0, 1, 2, 0])
[1, 2]
```

numpy.**unique**(*ar*, *return_index=False*, *return_inverse=False*, *return_counts=False*, *axis=None*, ***, *equal_nan=True*)

Find the unique elements of an array.

Returns the sorted unique elements of an array. There are three optional outputs in addition to the unique elements:

- the indices of the input array that give the unique values
- the indices of the unique array that reconstruct the input array
- the number of times each unique value comes up in the input array

Parameters

ar
: [array_like] Input array. Unless *axis* is specified, this will be flattened if it is not already 1-D.

return_index
: [bool, optional] If True, also return the indices of *ar* (along the specified axis, if provided, or in the flattened array) that result in the unique array.

return_inverse
: [bool, optional] If True, also return the indices of the unique array (for the specified axis, if provided) that can be used to reconstruct *ar*.

return_counts
[bool, optional] If True, also return the number of times each unique item appears in *ar*.

axis
[int or None, optional] The axis to operate on. If None, *ar* will be flattened. If an integer, the subarrays indexed by the given axis will be flattened and treated as the elements of a 1-D array with the dimension of the given axis, see the notes for more details. Object arrays or structured arrays that contain objects are not supported if the *axis* kwarg is used. The default is None.

equal_nan
[bool, optional] If True, collapses multiple NaN values in the return array into one.

New in version 1.24.

Returns

unique
[ndarray] The sorted unique values.

unique_indices
[ndarray, optional] The indices of the first occurrences of the unique values in the original array. Only provided if *return_index* is True.

unique_inverse
[ndarray, optional] The indices to reconstruct the original array from the unique array. Only provided if *return_inverse* is True.

unique_counts
[ndarray, optional] The number of times each of the unique values comes up in the original array. Only provided if *return_counts* is True.

See also:

repeat
Repeat elements of an array.

sort
Return a sorted copy of an array.

Notes

When an axis is specified the subarrays indexed by the axis are sorted. This is done by making the specified axis the first dimension of the array (move the axis to the first dimension to keep the order of the other axes) and then flattening the subarrays in C order. The flattened subarrays are then viewed as a structured type with each element given a label, with the effect that we end up with a 1-D array of structured types that can be treated in the same way as any other 1-D array. The result is that the flattened subarrays are sorted in lexicographic order starting with the first element.

Changed in version 1.21: Like np.sort, NaN will sort to the end of the values. For complex arrays all NaN values are considered equivalent (no matter whether the NaN is in the real or imaginary part). As the representant for the returned array the smallest one in the lexicographical order is chosen - see np.sort for how the lexicographical order is defined for complex arrays.

Changed in version 2.0: For multi-dimensional inputs, `unique_inverse` is reshaped such that the input can be reconstructed using `np.take(unique, unique_inverse, axis=axis)`. The result is now not 1-dimensional when `axis=None`.

Note that in NumPy 2.0.0 a higher dimensional array was returned also when `axis` was not `None`. This was reverted, but `inverse.reshape(-1)` can be used to ensure compatibility with both versions.

Examples

```
>>> import numpy as np
>>> np.unique([1, 1, 2, 2, 3, 3])
array([1, 2, 3])
>>> a = np.array([[1, 1], [2, 3]])
>>> np.unique(a)
array([1, 2, 3])
```

Return the unique rows of a 2D array

```
>>> a = np.array([[1, 0, 0], [1, 0, 0], [2, 3, 4]])
>>> np.unique(a, axis=0)
array([[1, 0, 0], [2, 3, 4]])
```

Return the indices of the original array that give the unique values:

```
>>> a = np.array(['a', 'b', 'b', 'c', 'a'])
>>> u, indices = np.unique(a, return_index=True)
>>> u
array(['a', 'b', 'c'], dtype='<U1')
>>> indices
array([0, 1, 3])
>>> a[indices]
array(['a', 'b', 'c'], dtype='<U1')
```

Reconstruct the input array from the unique values and inverse:

```
>>> a = np.array([1, 2, 6, 4, 2, 3, 2])
>>> u, indices = np.unique(a, return_inverse=True)
>>> u
array([1, 2, 3, 4, 6])
>>> indices
array([0, 1, 4, 3, 1, 2, 1])
>>> u[indices]
array([1, 2, 6, 4, 2, 3, 2])
```

Reconstruct the input values from the unique values and counts:

```
>>> a = np.array([1, 2, 6, 4, 2, 3, 2])
>>> values, counts = np.unique(a, return_counts=True)
>>> values
array([1, 2, 3, 4, 6])
>>> counts
array([1, 3, 1, 1, 1])
>>> np.repeat(values, counts)
array([1, 2, 2, 2, 3, 4, 6])    # original order not preserved
```

numpy.**pad**(*array*, *pad_width*, *mode='constant'*, ***kwargs*)

Pad an array.

Parameters

array
[array_like of rank N] The array to pad.

pad_width
[{sequence, array_like, int}] Number of values padded to the edges of each axis.

`((before_1, after_1), ... (before_N, after_N))` unique pad widths for each axis. `(before, after)` or `((before, after),)` yields same before and after pad for each axis. `(pad,)` or `int` is a shortcut for before = after = pad width for all axes.

mode
[str or function, optional] One of the following string values or a user supplied function.

'constant' (default)
Pads with a constant value.

'edge'
Pads with the edge values of array.

'linear_ramp'
Pads with the linear ramp between end_value and the array edge value.

'maximum'
Pads with the maximum value of all or part of the vector along each axis.

'mean'
Pads with the mean value of all or part of the vector along each axis.

'median'
Pads with the median value of all or part of the vector along each axis.

'minimum'
Pads with the minimum value of all or part of the vector along each axis.

'reflect'
Pads with the reflection of the vector mirrored on the first and last values of the vector along each axis.

'symmetric'
Pads with the reflection of the vector mirrored along the edge of the array.

'wrap'
Pads with the wrap of the vector along the axis. The first values are used to pad the end and the end values are used to pad the beginning.

'empty'
Pads with undefined values.

<function>
Padding function, see Notes.

stat_length
[sequence or int, optional] Used in 'maximum', 'mean', 'median', and 'minimum'. Number of values at edge of each axis used to calculate the statistic value.

`((before_1, after_1), ... (before_N, after_N))` unique statistic lengths for each axis.

`(before, after)` or `((before, after),)` yields same before and after statistic lengths for each axis.

`(stat_length,)` or `int` is a shortcut for `before = after = statistic` length for all axes.

Default is `None`, to use the entire axis.

constant_values
[sequence or scalar, optional] Used in 'constant'. The values to set the padded values for each axis.

`((before_1, after_1), ... (before_N, after_N))` unique pad constants for each axis.

`(before, after)` or `((before, after),)` yields same before and after constants for each axis.

`(constant,)` or `constant` is a shortcut for `before = after = constant` for all axes.

Default is 0.

end_values
[sequence or scalar, optional] Used in 'linear_ramp'. The values used for the ending value of the linear_ramp and that will form the edge of the padded array.

`((before_1, after_1), ... (before_N, after_N))` unique end values for each axis.

`(before, after)` or `((before, after),)` yields same before and after end values for each axis.

`(constant,)` or `constant` is a shortcut for `before = after = constant` for all axes.

Default is 0.

reflect_type
[{'even', 'odd'}, optional] Used in 'reflect', and 'symmetric'. The 'even' style is the default with an unaltered reflection around the edge value. For the 'odd' style, the extended part of the array is created by subtracting the reflected values from two times the edge value.

Returns

pad
[ndarray] Padded array of rank equal to *array* with shape increased according to *pad_width*.

Notes

For an array with rank greater than 1, some of the padding of later axes is calculated from padding of previous axes. This is easiest to think about with a rank 2 array where the corners of the padded array are calculated by using padded values from the first axis.

The padding function, if used, should modify a rank 1 array in-place. It has the following signature:

```
padding_func(vector, iaxis_pad_width, iaxis, kwargs)
```

where

vector
[ndarray] A rank 1 array already padded with zeros. Padded values are vector[:iaxis_pad_width[0]] and vector[-iaxis_pad_width[1]:].

iaxis_pad_width
[tuple] A 2-tuple of ints, iaxis_pad_width[0] represents the number of values padded at the beginning of vector where iaxis_pad_width[1] represents the number of values padded at the end of vector.

iaxis
[int] The axis currently being calculated.

kwargs
[dict] Any keyword arguments the function requires.

Examples

```
>>> import numpy as np
>>> a = [1, 2, 3, 4, 5]
>>> np.pad(a, (2, 3), 'constant', constant_values=(4, 6))
array([4, 4, 1, ..., 6, 6, 6])
```

```
>>> np.pad(a, (2, 3), 'edge')
array([1, 1, 1, ..., 5, 5, 5])
```

```
>>> np.pad(a, (2, 3), 'linear_ramp', end_values=(5, -4))
array([ 5,  3,  1,  2,  3,  4,  5,  2, -1, -4])
```

```
>>> np.pad(a, (2,), 'maximum')
array([5, 5, 1, 2, 3, 4, 5, 5, 5])
```

```
>>> np.pad(a, (2,), 'mean')
array([3, 3, 1, 2, 3, 4, 5, 3, 3])
```

```
>>> np.pad(a, (2,), 'median')
array([3, 3, 1, 2, 3, 4, 5, 3, 3])
```

```
>>> a = [[1, 2], [3, 4]]
>>> np.pad(a, ((3, 2), (2, 3)), 'minimum')
array([[1, 1, 1, 2, 1, 1, 1],
       [1, 1, 1, 2, 1, 1, 1],
       [1, 1, 1, 2, 1, 1, 1],
       [1, 1, 1, 2, 1, 1, 1],
       [3, 3, 3, 4, 3, 3, 3],
       [1, 1, 1, 2, 1, 1, 1],
       [1, 1, 1, 2, 1, 1, 1]])
```

```
>>> a = [1, 2, 3, 4, 5]
>>> np.pad(a, (2, 3), 'reflect')
array([3, 2, 1, 2, 3, 4, 5, 4, 3, 2])
```

```
>>> np.pad(a, (2, 3), 'reflect', reflect_type='odd')
array([-1,  0,  1,  2,  3,  4,  5,  6,  7,  8])
```

```
>>> np.pad(a, (2, 3), 'symmetric')
array([2, 1, 1, 2, 3, 4, 5, 5, 4, 3])
```

```
>>> np.pad(a, (2, 3), 'symmetric', reflect_type='odd')
array([0, 1, 1, 2, 3, 4, 5, 5, 6, 7])
```

```
>>> np.pad(a, (2, 3), 'wrap')
array([4, 5, 1, 2, 3, 4, 5, 1, 2, 3])
```

```
>>> def pad_with(vector, pad_width, iaxis, kwargs):
...     pad_value = kwargs.get('padder', 10)
...     vector[:pad_width[0]] = pad_value
...     vector[-pad_width[1]:] = pad_value
>>> a = np.arange(6)
>>> a = a.reshape((2, 3))
>>> np.pad(a, 2, pad_with)
array([[10, 10, 10, 10, 10, 10, 10],
       [10, 10, 10, 10, 10, 10, 10],
       [10, 10,  0,  1,  2, 10, 10],
       [10, 10,  3,  4,  5, 10, 10],
       [10, 10, 10, 10, 10, 10, 10],
       [10, 10, 10, 10, 10, 10, 10]])
>>> np.pad(a, 2, pad_with, padder=100)
array([[100, 100, 100, 100, 100, 100, 100],
       [100, 100, 100, 100, 100, 100, 100],
       [100, 100,   0,   1,   2, 100, 100],
       [100, 100,   3,   4,   5, 100, 100],
       [100, 100, 100, 100, 100, 100, 100],
       [100, 100, 100, 100, 100, 100, 100]])
```

Rearranging elements

flip(m[, axis])	Reverse the order of elements in an array along the given axis.
fliplr(m)	Reverse the order of elements along axis 1 (left/right).
flipud(m)	Reverse the order of elements along axis 0 (up/down).
roll(a, shift[, axis])	Roll array elements along a given axis.
rot90(m[, k, axes])	Rotate an array by 90 degrees in the plane specified by axes.

numpy.**flip**(*m*, *axis=None*)

Reverse the order of elements in an array along the given axis.

The shape of the array is preserved, but the elements are reordered.

Parameters

m
[array_like] Input array.

axis
[None or int or tuple of ints, optional] Axis or axes along which to flip over. The default, axis=None, will flip over all of the axes of the input array. If axis is negative it counts from the last to the first axis.

If axis is a tuple of ints, flipping is performed on all of the axes specified in the tuple.

Returns

out
[array_like] A view of *m* with the entries of axis reversed. Since a view is returned, this operation is done in constant time.

See also:

flipud
Flip an array vertically (axis=0).

fliplr
Flip an array horizontally (axis=1).

Notes

flip(m, 0) is equivalent to flipud(m).

flip(m, 1) is equivalent to fliplr(m).

flip(m, n) corresponds to `m[...,::-1,...]` with `::-1` at position n.

flip(m) corresponds to `m[::-1,::-1,...,::-1]` with `::-1` at all positions.

flip(m, (0, 1)) corresponds to `m[::-1,::-1,...]` with `::-1` at position 0 and position 1.

Examples

```
>>> import numpy as np
>>> A = np.arange(8).reshape((2,2,2))
>>> A
array([[[0, 1],
        [2, 3]],
       [[4, 5],
        [6, 7]]])
>>> np.flip(A, 0)
array([[[4, 5],
        [6, 7]],
       [[0, 1],
        [2, 3]]])
>>> np.flip(A, 1)
array([[[2, 3],
        [0, 1]],
       [[6, 7],
        [4, 5]]])
>>> np.flip(A)
array([[[7, 6],
        [5, 4]],
       [[3, 2],
        [1, 0]]])
>>> np.flip(A, (0, 2))
array([[[5, 4],
        [7, 6]],
       [[1, 0],
        [3, 2]]])
>>> rng = np.random.default_rng()
>>> A = rng.normal(size=(3,4,5))
>>> np.all(np.flip(A,2) == A[:,:,::-1,...])
True
```

numpy.**fliplr**(*m*)

Reverse the order of elements along axis 1 (left/right).

For a 2-D array, this flips the entries in each row in the left/right direction. Columns are preserved, but appear in a different order than before.

Parameters

m
[array_like] Input array, must be at least 2-D.

Returns

f
[ndarray] A view of *m* with the columns reversed. Since a view is returned, this operation is $\mathcal{O}(1)$.

See also:

flipud
Flip array in the up/down direction.

flip
Flip array in one or more dimensions.

rot90
Rotate array counterclockwise.

Notes

Equivalent to `m[:,::-1]` or `np.flip(m, axis=1)`. Requires the array to be at least 2-D.

Examples

```
>>> import numpy as np
>>> A = np.diag([1.,2.,3.])
>>> A
array([[1.,  0.,  0.],
       [0.,  2.,  0.],
       [0.,  0.,  3.]])
>>> np.fliplr(A)
array([[0.,  0.,  1.],
       [0.,  2.,  0.],
       [3.,  0.,  0.]])
```

```
>>> rng = np.random.default_rng()
>>> A = rng.normal(size=(2,3,5))
>>> np.all(np.fliplr(A) == A[:,::-1,...])
True
```

numpy.**flipud**(*m*)

Reverse the order of elements along axis 0 (up/down).

For a 2-D array, this flips the entries in each column in the up/down direction. Rows are preserved, but appear in a different order than before.

Parameters

m
[array_like] Input array.

Returns

out
[array_like] A view of *m* with the rows reversed. Since a view is returned, this operation is $\mathcal{O}(1)$.

See also:

fliplr
Flip array in the left/right direction.

flip
Flip array in one or more dimensions.

rot90
Rotate array counterclockwise.

Notes

Equivalent to `m[::-1, ...]` or `np.flip(m, axis=0)`. Requires the array to be at least 1-D.

Examples

```
>>> import numpy as np
>>> A = np.diag([1.0, 2, 3])
>>> A
array([[1.,  0.,  0.],
       [0.,  2.,  0.],
       [0.,  0.,  3.]])
>>> np.flipud(A)
array([[0.,  0.,  3.],
       [0.,  2.,  0.],
       [1.,  0.,  0.]])
```

```
>>> rng = np.random.default_rng()
>>> A = rng.normal(size=(2,3,5))
>>> np.all(np.flipud(A) == A[::-1,...])
True
```

```
>>> np.flipud([1,2])
array([2, 1])
```

`numpy.`**`roll`**(*a*, *shift*, *axis=None*)

Roll array elements along a given axis.

Elements that roll beyond the last position are re-introduced at the first.

Parameters

a
[array_like] Input array.

shift
[int or tuple of ints] The number of places by which elements are shifted. If a tuple, then *axis* must be a tuple of the same size, and each of the given axes is shifted by the corresponding number. If an int while *axis* is a tuple of ints, then the same value is used for all given axes.

axis
: [int or tuple of ints, optional] Axis or axes along which elements are shifted. By default, the array is flattened before shifting, after which the original shape is restored.

Returns

res
: [ndarray] Output array, with the same shape as *a*.

See also:

rollaxis
: Roll the specified axis backwards, until it lies in a given position.

Notes

Supports rolling over multiple dimensions simultaneously.

Examples

```
>>> import numpy as np
>>> x = np.arange(10)
>>> np.roll(x, 2)
array([8, 9, 0, 1, 2, 3, 4, 5, 6, 7])
>>> np.roll(x, -2)
array([2, 3, 4, 5, 6, 7, 8, 9, 0, 1])
```

```
>>> x2 = np.reshape(x, (2, 5))
>>> x2
array([[0, 1, 2, 3, 4],
       [5, 6, 7, 8, 9]])
>>> np.roll(x2, 1)
array([[9, 0, 1, 2, 3],
       [4, 5, 6, 7, 8]])
>>> np.roll(x2, -1)
array([[1, 2, 3, 4, 5],
       [6, 7, 8, 9, 0]])
>>> np.roll(x2, 1, axis=0)
array([[5, 6, 7, 8, 9],
       [0, 1, 2, 3, 4]])
>>> np.roll(x2, -1, axis=0)
array([[5, 6, 7, 8, 9],
       [0, 1, 2, 3, 4]])
>>> np.roll(x2, 1, axis=1)
array([[4, 0, 1, 2, 3],
       [9, 5, 6, 7, 8]])
>>> np.roll(x2, -1, axis=1)
array([[1, 2, 3, 4, 0],
       [6, 7, 8, 9, 5]])
>>> np.roll(x2, (1, 1), axis=(1, 0))
array([[9, 5, 6, 7, 8],
       [4, 0, 1, 2, 3]])
>>> np.roll(x2, (2, 1), axis=(1, 0))
array([[8, 9, 5, 6, 7],
       [3, 4, 0, 1, 2]])
```

numpy.**rot90**(*m*, *k=1*, *axes=(0, 1)*)

Rotate an array by 90 degrees in the plane specified by axes.

Rotation direction is from the first towards the second axis. This means for a 2D array with the default *k* and *axes*, the rotation will be counterclockwise.

Parameters

m
[array_like] Array of two or more dimensions.

k
[integer] Number of times the array is rotated by 90 degrees.

axes
[(2,) array_like] The array is rotated in the plane defined by the axes. Axes must be different.

Returns

y
[ndarray] A rotated view of *m*.

See also:

flip
Reverse the order of elements in an array along the given axis.

fliplr
Flip an array horizontally.

flipud
Flip an array vertically.

Notes

`rot90(m, k=1, axes=(1,0))` is the reverse of `rot90(m, k=1, axes=(0,1))`

`rot90(m, k=1, axes=(1,0))` is equivalent to `rot90(m, k=-1, axes=(0,1))`

Examples

```
>>> import numpy as np
>>> m = np.array([[1,2],[3,4]], int)
>>> m
array([[1, 2],
       [3, 4]])
>>> np.rot90(m)
array([[2, 4],
       [1, 3]])
>>> np.rot90(m, 2)
array([[4, 3],
       [2, 1]])
>>> m = np.arange(8).reshape((2,2,2))
>>> np.rot90(m, 1, (1,2))
array([[[1, 3],
        [0, 2]],
       [[5, 7],
        [4, 6]]])
```

1.4.4 Bit-wise operations

Elementwise bit operations

bitwise_and(x1, x2, /[, out, where, ...])	Compute the bit-wise AND of two arrays element-wise.
bitwise_or(x1, x2, /[, out, where, casting, ...])	Compute the bit-wise OR of two arrays element-wise.
bitwise_xor(x1, x2, /[, out, where, ...])	Compute the bit-wise XOR of two arrays element-wise.
invert(x, /[, out, where, casting, order, ...])	Compute bit-wise inversion, or bit-wise NOT, element-wise.
bitwise_invert(x, /[, out, where, casting, ...])	Compute bit-wise inversion, or bit-wise NOT, element-wise.
left_shift(x1, x2, /[, out, where, casting, ...])	Shift the bits of an integer to the left.
bitwise_left_shift(x1, x2, /[, out, where, ...])	Shift the bits of an integer to the left.
right_shift(x1, x2, /[, out, where, ...])	Shift the bits of an integer to the right.
bitwise_right_shift(x1, x2, /[, out, where, ...])	Shift the bits of an integer to the right.

numpy.**bitwise_and**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'bitwise_and'>**

Compute the bit-wise AND of two arrays element-wise.

Computes the bit-wise AND of the underlying binary representation of the integers in the input arrays. This ufunc implements the C/Python operator `&`.

Parameters

x1, x2
[array_like] Only integer and boolean types are handled. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Result. This is a scalar if both *x1* and *x2* are scalars.

See also:

logical_and
bitwise_or
bitwise_xor
binary_repr
Return the binary representation of the input number as a string.

Examples

```
>>> import numpy as np
```

The number 13 is represented by `00001101`. Likewise, 17 is represented by `00010001`. The bit-wise AND of 13 and 17 is therefore `000000001`, or 1:

```
>>> np.bitwise_and(13, 17)
1
```

```
>>> np.bitwise_and(14, 13)
12
>>> np.binary_repr(12)
'1100'
>>> np.bitwise_and([14,3], 13)
array([12,  1])
```

```
>>> np.bitwise_and([11,7], [4,25])
array([0, 1])
>>> np.bitwise_and(np.array([2,5,255]), np.array([3,14,16]))
array([ 2,  4, 16])
>>> np.bitwise_and([True, True], [False, True])
array([False,  True])
```

The `&` operator can be used as a shorthand for `np.bitwise_and` on ndarrays.

```
>>> x1 = np.array([2, 5, 255])
>>> x2 = np.array([3, 14, 16])
>>> x1 & x2
array([ 2,  4, 16])
```

numpy.**bitwise_or**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'bitwise_or'>**

Compute the bit-wise OR of two arrays element-wise.

Computes the bit-wise OR of the underlying binary representation of the integers in the input arrays. This ufunc implements the C/Python operator `|`.

Parameters

x1, x2
: [array_like] Only integer and boolean types are handled. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Result. This is a scalar if both *x1* and *x2* are scalars.

See also:

logical_or
bitwise_and
bitwise_xor
binary_repr
Return the binary representation of the input number as a string.

Examples

```
>>> import numpy as np
```

The number 13 has the binary representation `00001101`. Likewise, 16 is represented by `00010000`. The bitwise OR of 13 and 16 is then `00011101`, or 29:

```
>>> np.bitwise_or(13, 16)
29
>>> np.binary_repr(29)
'11101'
```

```
>>> np.bitwise_or(32, 2)
34
>>> np.bitwise_or([33, 4], 1)
array([33,  5])
>>> np.bitwise_or([33, 4], [1, 2])
array([33,  6])
```

```
>>> np.bitwise_or(np.array([2, 5, 255]), np.array([4, 4, 4]))
array([  6,   5, 255])
>>> np.array([2, 5, 255]) | np.array([4, 4, 4])
array([  6,   5, 255])
>>> np.bitwise_or(np.array([2, 5, 255, 2147483647], dtype=np.int32),
...               np.array([4, 4, 4, 2147483647], dtype=np.int32))
array([         6,          5,        255, 2147483647], dtype=int32)
>>> np.bitwise_or([True, True], [False, True])
array([ True,  True])
```

The `|` operator can be used as a shorthand for `np.bitwise_or` on ndarrays.

```
>>> x1 = np.array([2, 5, 255])
>>> x2 = np.array([4, 4, 4])
>>> x1 | x2
array([  6,   5, 255])
```

numpy.**bitwise_xor**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'bitwise_xor'>**

Compute the bit-wise XOR of two arrays element-wise.

Computes the bit-wise XOR of the underlying binary representation of the integers in the input arrays. This ufunc implements the C/Python operator `^`.

Parameters

x1, x2
: [array_like] Only integer and boolean types are handled. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Result. This is a scalar if both *x1* and *x2* are scalars.

See also:

logical_xor
bitwise_and
bitwise_or
binary_repr
: Return the binary representation of the input number as a string.

Examples

```
>>> import numpy as np
```

The number 13 is represented by `00001101`. Likewise, 17 is represented by `00010001`. The bit-wise XOR of 13 and 17 is therefore `00011100`, or 28:

```
>>> np.bitwise_xor(13, 17)
28
>>> np.binary_repr(28)
'11100'
```

```
>>> np.bitwise_xor(31, 5)
26
>>> np.bitwise_xor([31,3], 5)
array([26,  6])
```

```
>>> np.bitwise_xor([31,3], [5,6])
array([26,  5])
>>> np.bitwise_xor([True, True], [False, True])
array([ True, False])
```

The ^ operator can be used as a shorthand for `np.bitwise_xor` on ndarrays.

```
>>> x1 = np.array([True, True])
>>> x2 = np.array([False, True])
>>> x1 ^ x2
array([ True, False])
```

numpy.**invert**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'invert'>**

Compute bit-wise inversion, or bit-wise NOT, element-wise.

Computes the bit-wise NOT of the underlying binary representation of the integers in the input arrays. This ufunc implements the C/Python operator ~.

For signed integer inputs, the bit-wise NOT of the absolute value is returned. In a two's-complement system, this operation effectively flips all the bits, resulting in a representation that corresponds to the negative of the input plus one. This is the most common method of representing signed integers on computers [1]. A N-bit two's-complement system can represent every integer in the range -2^{N-1} to $+2^{N-1}-1$.

Parameters

x
: [array_like] Only integer and boolean types are handled.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Result. This is a scalar if *x* is a scalar.

See also:

bitwise_and*, *bitwise_or*, *bitwise_xor
logical_not
binary_repr
: Return the binary representation of the input number as a string.

Notes

`numpy.bitwise_not` is an alias for *invert*:

```
>>> np.bitwise_not is np.invert
True
```

References

[1]

Examples

```
>>> import numpy as np
```

We've seen that 13 is represented by `00001101`. The invert or bit-wise NOT of 13 is then:

```
>>> x = np.invert(np.array(13, dtype=np.uint8))
>>> x
np.uint8(242)
>>> np.binary_repr(x, width=8)
'11110010'
```

The result depends on the bit-width:

```
>>> x = np.invert(np.array(13, dtype=np.uint16))
>>> x
np.uint16(65522)
>>> np.binary_repr(x, width=16)
'1111111111110010'
```

When using signed integer types, the result is the bit-wise NOT of the unsigned type, interpreted as a signed integer:

```
>>> np.invert(np.array([13], dtype=np.int8))
array([-14], dtype=int8)
>>> np.binary_repr(-14, width=8)
'11110010'
```

Booleans are accepted as well:

```
>>> np.invert(np.array([True, False]))
array([False,  True])
```

The ~ operator can be used as a shorthand for `np.invert` on ndarrays.

```
>>> x1 = np.array([True, False])
>>> ~x1
array([False,  True])
```

numpy.**bitwise_invert**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'invert'>**

Compute bit-wise inversion, or bit-wise NOT, element-wise.

Computes the bit-wise NOT of the underlying binary representation of the integers in the input arrays. This ufunc implements the C/Python operator ~.

For signed integer inputs, the bit-wise NOT of the absolute value is returned. In a two's-complement system, this operation effectively flips all the bits, resulting in a representation that corresponds to the negative of the input plus one. This is the most common method of representing signed integers on computers [1]. A N-bit two's-complement system can represent every integer in the range -2^{N-1} to $+2^{N-1} - 1$.

Parameters

x
: [array_like] Only integer and boolean types are handled.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Result. This is a scalar if *x* is a scalar.

See also:

bitwise_and*, *bitwise_or*, *bitwise_xor
logical_not
binary_repr
: Return the binary representation of the input number as a string.

Notes

`numpy.bitwise_not` is an alias for *invert*:

```
>>> np.bitwise_not is np.invert
True
```

References

[1]

Examples

```
>>> import numpy as np
```

We've seen that 13 is represented by `00001101`. The invert or bit-wise NOT of 13 is then:

```
>>> x = np.invert(np.array(13, dtype=np.uint8))
>>> x
np.uint8(242)
>>> np.binary_repr(x, width=8)
'11110010'
```

The result depends on the bit-width:

```
>>> x = np.invert(np.array(13, dtype=np.uint16))
>>> x
np.uint16(65522)
>>> np.binary_repr(x, width=16)
'1111111111110010'
```

When using signed integer types, the result is the bit-wise NOT of the unsigned type, interpreted as a signed integer:

```
>>> np.invert(np.array([13], dtype=np.int8))
array([-14], dtype=int8)
>>> np.binary_repr(-14, width=8)
'11110010'
```

Booleans are accepted as well:

```
>>> np.invert(np.array([True, False]))
array([False,  True])
```

The ~ operator can be used as a shorthand for `np.invert` on ndarrays.

```
>>> x1 = np.array([True, False])
>>> ~x1
array([False,  True])
```

numpy.**left_shift**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'left_shift'>**

Shift the bits of an integer to the left.

Bits are shifted to the left by appending *x2* 0s at the right of *x1*. Since the internal representation of numbers is in binary format, this operation is equivalent to multiplying *x1* by `2**x2`.

Parameters

x1
: [array_like of integer type] Input values.

x2
: [array_like of integer type] Number of zeros to append to *x1*. Has to be non-negative. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None,

a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[array of integer type] Return *x1* with bits shifted *x2* times to the left. This is a scalar if both *x1* and *x2* are scalars.

See also:

right_shift
Shift the bits of an integer to the right.

binary_repr
Return the binary representation of the input number as a string.

Examples

```
>>> import numpy as np
>>> np.binary_repr(5)
'101'
>>> np.left_shift(5, 2)
20
>>> np.binary_repr(20)
'10100'
```

```
>>> np.left_shift(5, [1,2,3])
array([10, 20, 40])
```

Note that the dtype of the second argument may change the dtype of the result and can lead to unexpected results in some cases (see Casting Rules):

```
>>> a = np.left_shift(np.uint8(255), np.int64(1))  # Expect 254
>>> print(a, type(a)) # Unexpected result due to upcasting
510 <class 'numpy.int64'>
>>> b = np.left_shift(np.uint8(255), np.uint8(1))
>>> print(b, type(b))
254 <class 'numpy.uint8'>
```

The << operator can be used as a shorthand for `np.left_shift` on ndarrays.

```
>>> x1 = 5
>>> x2 = np.array([1, 2, 3])
>>> x1 << x2
array([10, 20, 40])
```

numpy.**bitwise_left_shift**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'left_shift'>**

Shift the bits of an integer to the left.

Bits are shifted to the left by appending *x2* 0s at the right of *x1*. Since the internal representation of numbers is in binary format, this operation is equivalent to multiplying *x1* by `2**x2`.

Parameters

x1
[array_like of integer type] Input values.

x2
[array_like of integer type] Number of zeros to append to *x1*. Has to be non-negative. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[array of integer type] Return *x1* with bits shifted *x2* times to the left. This is a scalar if both *x1* and *x2* are scalars.

See also:

right_shift
Shift the bits of an integer to the right.

binary_repr
Return the binary representation of the input number as a string.

Examples

```
>>> import numpy as np
>>> np.binary_repr(5)
'101'
>>> np.left_shift(5, 2)
20
>>> np.binary_repr(20)
'10100'
```

```
>>> np.left_shift(5, [1,2,3])
array([10, 20, 40])
```

Note that the dtype of the second argument may change the dtype of the result and can lead to unexpected results in some cases (see Casting Rules):

```
>>> a = np.left_shift(np.uint8(255), np.int64(1))  # Expect 254
>>> print(a, type(a)) # Unexpected result due to upcasting
510 <class 'numpy.int64'>
>>> b = np.left_shift(np.uint8(255), np.uint8(1))
>>> print(b, type(b))
254 <class 'numpy.uint8'>
```

The << operator can be used as a shorthand for `np.left_shift` on ndarrays.

```
>>> x1 = 5
>>> x2 = np.array([1, 2, 3])
>>> x1 << x2
array([10, 20, 40])
```

numpy.**right_shift**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'right_shift'>**

Shift the bits of an integer to the right.

Bits are shifted to the right *x2*. Because the internal representation of numbers is in binary format, this operation is equivalent to dividing *x1* by `2**x2`.

Parameters

x1
: [array_like, int] Input values.

x2
: [array_like, int] Number of bits to remove at the right of *x1*. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray, int] Return *x1* with bits shifted *x2* times to the right. This is a scalar if both *x1* and *x2* are scalars.

See also:

left_shift
: Shift the bits of an integer to the left.

binary_repr
Return the binary representation of the input number as a string.

Examples

```
>>> import numpy as np
>>> np.binary_repr(10)
'1010'
>>> np.right_shift(10, 1)
5
>>> np.binary_repr(5)
'101'
```

```
>>> np.right_shift(10, [1,2,3])
array([5, 2, 1])
```

The >> operator can be used as a shorthand for `np.right_shift` on ndarrays.

```
>>> x1 = 10
>>> x2 = np.array([1,2,3])
>>> x1 >> x2
array([5, 2, 1])
```

numpy.**bitwise_right_shift**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'right_shift'>**

Shift the bits of an integer to the right.

Bits are shifted to the right *x2*. Because the internal representation of numbers is in binary format, this operation is equivalent to dividing *x1* by `2**x2`.

Parameters

x1
[array_like, int] Input values.

x2
[array_like, int] Number of bits to remove at the right of *x1*. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray, int] Return *x1* with bits shifted *x2* times to the right. This is a scalar if both *x1* and *x2* are scalars.

See also:

left_shift
: Shift the bits of an integer to the left.

binary_repr
: Return the binary representation of the input number as a string.

Examples

```
>>> import numpy as np
>>> np.binary_repr(10)
'1010'
>>> np.right_shift(10, 1)
5
>>> np.binary_repr(5)
'101'
```

```
>>> np.right_shift(10, [1,2,3])
array([5, 2, 1])
```

The >> operator can be used as a shorthand for `np.right_shift` on ndarrays.

```
>>> x1 = 10
>>> x2 = np.array([1,2,3])
>>> x1 >> x2
array([5, 2, 1])
```

Bit packing

packbits(a, /[, axis, bitorder])	Packs the elements of a binary-valued array into bits in a uint8 array.
unpackbits(a, /[, axis, count, bitorder])	Unpacks elements of a uint8 array into a binary-valued output array.

numpy.**packbits**(*a*, */*, *axis=None*, *bitorder='big'*)

Packs the elements of a binary-valued array into bits in a uint8 array.

The result is padded to full bytes by inserting zero bits at the end.

Parameters

a
: [array_like] An array of integers or booleans whose elements should be packed to bits.

axis
: [int, optional] The dimension over which bit-packing is done. `None` implies packing the flattened array.

bitorder
[{'big', 'little'}, optional] The order of the input bits. 'big' will mimic bin(val), `[0, 0, 0, 0, 0, 0, 1, 1] => 3 = 0b00000011`, 'little' will reverse the order so `[1, 1, 0, 0, 0, 0, 0, 0] => 3`. Defaults to 'big'.

Returns

packed
[ndarray] Array of type uint8 whose elements represent bits corresponding to the logical (0 or nonzero) value of the input elements. The shape of *packed* has the same number of dimensions as the input (unless *axis* is None, in which case the output is 1-D).

See also:

unpackbits
Unpacks elements of a uint8 array into a binary-valued output array.

Examples

```
>>> import numpy as np
>>> a = np.array([[[1,0,1],
...                [0,1,0]],
...               [[1,1,0],
...                [0,0,1]]])
>>> b = np.packbits(a, axis=-1)
>>> b
array([[[160],
        [ 64]],
       [[192],
        [ 32]]], dtype=uint8)
```

Note that in binary 160 = 1010 0000, 64 = 0100 0000, 192 = 1100 0000, and 32 = 0010 0000.

numpy.**unpackbits**(*a*, */*, *axis=None*, *count=None*, *bitorder='big'*)

Unpacks elements of a uint8 array into a binary-valued output array.

Each element of *a* represents a bit-field that should be unpacked into a binary-valued output array. The shape of the output array is either 1-D (if *axis* is `None`) or the same shape as the input array with unpacking done along the axis specified.

Parameters

a
[ndarray, uint8 type] Input array.

axis
[int, optional] The dimension over which bit-unpacking is done. `None` implies unpacking the flattened array.

count
[int or None, optional] The number of elements to unpack along *axis*, provided as a way of undoing the effect of packing a size that is not a multiple of eight. A non-negative number means to only unpack *count* bits. A negative number means to trim off that many bits from the end. `None` means to unpack the entire array (the default). Counts larger than the available number of bits will add zero padding to the output. Negative counts must not exceed the available number of bits.

bitorder
[{'big', 'little'}, optional] The order of the returned bits. 'big' will mimic bin(val), `3 =`

`0b00000011 => [0, 0, 0, 0, 0, 0, 1, 1]`, 'little' will reverse the order to `[1, 1, 0, 0, 0, 0, 0, 0]`. Defaults to 'big'.

Returns

unpacked
[ndarray, uint8 type] The elements are binary-valued (0 or 1).

See also:

packbits
Packs the elements of a binary-valued array into bits in a uint8 array.

Examples

```
>>> import numpy as np
>>> a = np.array([[2], [7], [23]], dtype=np.uint8)
>>> a
array([[ 2],
       [ 7],
       [23]], dtype=uint8)
>>> b = np.unpackbits(a, axis=1)
>>> b
array([[0, 0, 0, 0, 0, 0, 1, 0],
       [0, 0, 0, 0, 0, 1, 1, 1],
       [0, 0, 0, 1, 0, 1, 1, 1]], dtype=uint8)
>>> c = np.unpackbits(a, axis=1, count=-3)
>>> c
array([[0, 0, 0, 0, 0],
       [0, 0, 0, 0, 0],
       [0, 0, 0, 1, 0]], dtype=uint8)
```

```
>>> p = np.packbits(b, axis=0)
>>> np.unpackbits(p, axis=0)
array([[0, 0, 0, 0, 0, 0, 1, 0],
       [0, 0, 0, 0, 0, 1, 1, 1],
       [0, 0, 0, 1, 0, 1, 1, 1],
       [0, 0, 0, 0, 0, 0, 0, 0],
       [0, 0, 0, 0, 0, 0, 0, 0],
       [0, 0, 0, 0, 0, 0, 0, 0],
       [0, 0, 0, 0, 0, 0, 0, 0],
       [0, 0, 0, 0, 0, 0, 0, 0]], dtype=uint8)
>>> np.array_equal(b, np.unpackbits(p, axis=0, count=b.shape[0]))
True
```

Output formatting

binary_repr(num[, width])	Return the binary representation of the input number as a string.

numpy.**binary_repr**(*num*, *width=None*)

Return the binary representation of the input number as a string.

For negative numbers, if width is not given, a minus sign is added to the front. If width is given, the two's complement of the number is returned, with respect to that width.

In a two's-complement system negative numbers are represented by the two's complement of the absolute value. This is the most common method of representing signed integers on computers [1]. A N-bit two's-complement system can represent every integer in the range -2^{N-1} to $+2^{N-1} - 1$.

Parameters

num
[int] Only an integer decimal number can be used.

width
[int, optional] The length of the returned string if *num* is positive, or the length of the two's complement if *num* is negative, provided that *width* is at least a sufficient number of bits for *num* to be represented in the designated form. If the *width* value is insufficient, an error is raised.

Returns

bin
[str] Binary representation of *num* or two's complement of *num*.

See also:

base_repr
Return a string representation of a number in the given base system.

bin
Python's built-in binary representation generator of an integer.

Notes

binary_repr is equivalent to using *base_repr* with base 2, but about 25x faster.

References

[1]

Examples

```
>>> import numpy as np
>>> np.binary_repr(3)
'11'
>>> np.binary_repr(-3)
'-11'
>>> np.binary_repr(3, width=4)
'0011'
```

The two's complement is returned when the input number is negative and width is specified:

```
>>> np.binary_repr(-3, width=3)
'101'
>>> np.binary_repr(-3, width=5)
'11101'
```

1.4.5 Datetime support functions

datetime_as_string(arr[, unit, timezone, ...])	Convert an array of datetimes into an array of strings.
datetime_data(dtype, /)	Get information about the step size of a date or time type.

numpy.**datetime_as_string**(*arr*, *unit=None*, *timezone='naive'*, *casting='same_kind'*)

Convert an array of datetimes into an array of strings.

Parameters

arr
[array_like of datetime64] The array of UTC timestamps to format.

unit
[str] One of None, 'auto', or a *datetime unit*.

timezone
[{'naive', 'UTC', 'local'} or tzinfo] Timezone information to use when displaying the datetime. If 'UTC', end with a Z to indicate UTC time. If 'local', convert to the local timezone first, and suffix with a +-#### timezone offset. If a tzinfo object, then do as with 'local', but use the specified timezone.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}] Casting to allow when changing between datetime units.

Returns

str_arr
[ndarray] An array of strings the same shape as *arr*.

Examples

```
>>> import numpy as np
>>> import pytz
>>> d = np.arange('2002-10-27T04:30', 4*60, 60, dtype='M8[m]')
>>> d
array(['2002-10-27T04:30', '2002-10-27T05:30', '2002-10-27T06:30',
       '2002-10-27T07:30'], dtype='datetime64[m]')
```

Setting the timezone to UTC shows the same information, but with a Z suffix

```
>>> np.datetime_as_string(d, timezone='UTC')
array(['2002-10-27T04:30Z', '2002-10-27T05:30Z', '2002-10-27T06:30Z',
       '2002-10-27T07:30Z'], dtype='<U35')
```

Note that we picked datetimes that cross a DST boundary. Passing in a `pytz` timezone object will print the appropriate offset

```
>>> np.datetime_as_string(d, timezone=pytz.timezone('US/Eastern'))
array(['2002-10-27T00:30-0400', '2002-10-27T01:30-0400',
       '2002-10-27T01:30-0500', '2002-10-27T02:30-0500'], dtype='<U39')
```

Passing in a unit will change the precision

```
>>> np.datetime_as_string(d, unit='h')
array(['2002-10-27T04', '2002-10-27T05', '2002-10-27T06', '2002-10-27T07'],
      dtype='<U32')
>>> np.datetime_as_string(d, unit='s')
array(['2002-10-27T04:30:00', '2002-10-27T05:30:00', '2002-10-27T06:30:00',
       '2002-10-27T07:30:00'], dtype='<U38')
```

'casting' can be used to specify whether precision can be changed

```
>>> np.datetime_as_string(d, unit='h', casting='safe')
Traceback (most recent call last):
    ...
TypeError: Cannot create a datetime string as units 'h' from a NumPy
datetime with units 'm' according to the rule 'safe'
```

numpy.**datetime_data**(*dtype*, */*)

Get information about the step size of a date or time type.

The returned tuple can be passed as the second argument of *numpy.datetime64* and *numpy.timedelta64*.

Parameters

dtype
[dtype] The dtype object, which must be a *datetime64* or *timedelta64* type.

Returns

unit
[str] The *datetime unit* on which this dtype is based.

count
[int] The number of base units in a step.

Examples

```
>>> import numpy as np
>>> dt_25s = np.dtype('timedelta64[25s]')
>>> np.datetime_data(dt_25s)
('s', 25)
>>> np.array(10, dt_25s).astype('timedelta64[s]')
array(250, dtype='timedelta64[s]')
```

The result can be used to construct a datetime that uses the same units as a timedelta

```
>>> np.datetime64('2010', np.datetime_data(dt_25s))
np.datetime64('2010-01-01T00:00:00','25s')
```

Business day functions

busdaycalendar([weekmask, holidays])	A business day calendar object that efficiently stores information defining valid days for the busday family of functions.
is_busday(dates[, weekmask, holidays, ...])	Calculates which of the given dates are valid days, and which are not.
busday_offset(dates, offsets[, roll, ...])	First adjusts the date to fall on a valid day according to the `roll` rule, then applies offsets to the given dates counted in valid days.
busday_count(begindates, enddates[, ...])	Counts the number of valid days between *begindates* and *enddates*, not including the day of *enddates*.

class numpy.**busdaycalendar**(*weekmask='1111100'*, *holidays=None*)

A business day calendar object that efficiently stores information defining valid days for the busday family of functions.

The default valid days are Monday through Friday ("business days"). A busdaycalendar object can be specified with any set of weekly valid days, plus an optional "holiday" dates that always will be invalid.

Once a busdaycalendar object is created, the weekmask and holidays cannot be modified.

Parameters

weekmask
[str or array_like of bool, optional] A seven-element array indicating which of Monday through Sunday are valid days. May be specified as a length-seven list or array, like [1,1,1,1,1,0,0]; a length-seven string, like '1111100'; or a string like "Mon Tue Wed Thu Fri", made up of 3-character abbreviations for weekdays, optionally separated by white space. Valid abbreviations are: Mon Tue Wed Thu Fri Sat Sun

holidays
[array_like of datetime64[D], optional] An array of dates to consider as invalid dates, no matter which weekday they fall upon. Holiday dates may be specified in any order, and NaT (not-a-time) dates are ignored. This list is saved in a normalized form that is suited for fast calculations of valid days.

Returns

out
[busdaycalendar] A business day calendar object containing the specified weekmask and holidays values.

See also:

is_busday
Returns a boolean array indicating valid days.

busday_offset
Applies an offset counted in valid days.

busday_count
Counts how many valid days are in a half-open date range.

Notes

Once a busdaycalendar object is created, you cannot modify the weekmask or holidays. The attributes return copies of internal data.

Examples

```
>>> import numpy as np
>>> # Some important days in July
... bdd = np.busdaycalendar(
...             holidays=['2011-07-01', '2011-07-04', '2011-07-17'])
>>> # Default is Monday to Friday weekdays
... bdd.weekmask
array([ True,  True,  True,  True,  True, False, False])
>>> # Any holidays already on the weekend are removed
... bdd.holidays
array(['2011-07-01', '2011-07-04'], dtype='datetime64[D]')
```

Attributes

weekmask
[(copy) seven-element array of bool] A copy of the seven-element boolean mask indicating valid days.

holidays
[(copy) sorted array of datetime64[D]] A copy of the holiday array indicating additional invalid days.

numpy.**is_busday**(*dates*, *weekmask='1111100'*, *holidays=None*, *busdaycal=None*, *out=None*)

Calculates which of the given dates are valid days, and which are not.

Parameters

dates
[array_like of datetime64[D]] The array of dates to process.

weekmask
[str or array_like of bool, optional] A seven-element array indicating which of Monday through Sunday are valid days. May be specified as a length-seven list or array, like [1,1,1,1,1,0,0]; a length-seven string, like '1111100'; or a string like "Mon Tue Wed Thu Fri", made up of 3-character abbreviations for weekdays, optionally separated by white space. Valid abbreviations are: Mon Tue Wed Thu Fri Sat Sun

holidays
[array_like of datetime64[D], optional] An array of dates to consider as invalid dates. They may be specified in any order, and NaT (not-a-time) dates are ignored. This list is saved in a normalized form that is suited for fast calculations of valid days.

busdaycal
[busdaycalendar, optional] A *busdaycalendar* object which specifies the valid days. If this parameter is provided, neither weekmask nor holidays may be provided.

out
[array of bool, optional] If provided, this array is filled with the result.

Returns

out
[array of bool] An array with the same shape as `dates`, containing True for each valid day, and False for each invalid day.

See also:

busdaycalendar
An object that specifies a custom set of valid days.

busday_offset
Applies an offset counted in valid days.

busday_count
Counts how many valid days are in a half-open date range.

Examples

```
>>> import numpy as np
>>> # The weekdays are Friday, Saturday, and Monday
... np.is_busday(['2011-07-01', '2011-07-02', '2011-07-18'],
...                 holidays=['2011-07-01', '2011-07-04', '2011-07-17'])
array([False, False,  True])
```

numpy.**busday_offset**(*dates*, *offsets*, *roll='raise'*, *weekmask='1111100'*, *holidays=None*, *busdaycal=None*, *out=None*)

First adjusts the date to fall on a valid day according to the `roll` rule, then applies offsets to the given dates counted in valid days.

Parameters

dates
[array_like of datetime64[D]] The array of dates to process.

offsets
[array_like of int] The array of offsets, which is broadcast with `dates`.

roll
[{'raise', 'nat', 'forward', 'following', 'backward', 'preceding', 'modifiedfollowing', 'modifiedpreceding'}, optional] How to treat dates that do not fall on a valid day. The default is 'raise'.

- 'raise' means to raise an exception for an invalid day.
- 'nat' means to return a NaT (not-a-time) for an invalid day.
- 'forward' and 'following' mean to take the first valid day later in time.
- 'backward' and 'preceding' mean to take the first valid day earlier in time.
- 'modifiedfollowing' means to take the first valid day later in time unless it is across a Month boundary, in which case to take the first valid day earlier in time.
- 'modifiedpreceding' means to take the first valid day earlier in time unless it is across a Month boundary, in which case to take the first valid day later in time.

weekmask
[str or array_like of bool, optional] A seven-element array indicating which of Monday through Sunday are valid days. May be specified as a length-seven list or array, like [1,1,1,1,1,0,0]; a length-seven string, like '1111100'; or a string like "Mon Tue Wed Thu Fri", made up of 3-character abbreviations for weekdays, optionally separated by white space. Valid abbreviations are: Mon Tue Wed Thu Fri Sat Sun

holidays
: [array_like of datetime64[D], optional] An array of dates to consider as invalid dates. They may be specified in any order, and NaT (not-a-time) dates are ignored. This list is saved in a normalized form that is suited for fast calculations of valid days.

busdaycal
: [busdaycalendar, optional] A *busdaycalendar* object which specifies the valid days. If this parameter is provided, neither weekmask nor holidays may be provided.

out
: [array of datetime64[D], optional] If provided, this array is filled with the result.

Returns

out
: [array of datetime64[D]] An array with a shape from broadcasting `dates` and `offsets` together, containing the dates with offsets applied.

See also:

busdaycalendar
: An object that specifies a custom set of valid days.

is_busday
: Returns a boolean array indicating valid days.

busday_count
: Counts how many valid days are in a half-open date range.

Examples

```
>>> import numpy as np
>>> # First business day in October 2011 (not accounting for holidays)
... np.busday_offset('2011-10', 0, roll='forward')
np.datetime64('2011-10-03')
>>> # Last business day in February 2012 (not accounting for holidays)
... np.busday_offset('2012-03', -1, roll='forward')
np.datetime64('2012-02-29')
>>> # Third Wednesday in January 2011
... np.busday_offset('2011-01', 2, roll='forward', weekmask='Wed')
np.datetime64('2011-01-19')
>>> # 2012 Mother's Day in Canada and the U.S.
... np.busday_offset('2012-05', 1, roll='forward', weekmask='Sun')
np.datetime64('2012-05-13')
```

```
>>> # First business day on or after a date
... np.busday_offset('2011-03-20', 0, roll='forward')
np.datetime64('2011-03-21')
>>> np.busday_offset('2011-03-22', 0, roll='forward')
np.datetime64('2011-03-22')
>>> # First business day after a date
... np.busday_offset('2011-03-20', 1, roll='backward')
np.datetime64('2011-03-21')
>>> np.busday_offset('2011-03-22', 1, roll='backward')
np.datetime64('2011-03-23')
```

numpy.**busday_count**(*begindates*, *enddates*, *weekmask='1111100'*, *holidays=[]*, *busdaycal=None*, *out=None*)

Counts the number of valid days between *begindates* and *enddates*, not including the day of *enddates*.

If `enddates` specifies a date value that is earlier than the corresponding `begindates` date value, the count will be negative.

Parameters

begindates
[array_like of datetime64[D]] The array of the first dates for counting.

enddates
[array_like of datetime64[D]] The array of the end dates for counting, which are excluded from the count themselves.

weekmask
[str or array_like of bool, optional] A seven-element array indicating which of Monday through Sunday are valid days. May be specified as a length-seven list or array, like [1,1,1,1,1,0,0]; a length-seven string, like '1111100'; or a string like "Mon Tue Wed Thu Fri", made up of 3-character abbreviations for weekdays, optionally separated by white space. Valid abbreviations are: Mon Tue Wed Thu Fri Sat Sun

holidays
[array_like of datetime64[D], optional] An array of dates to consider as invalid dates. They may be specified in any order, and NaT (not-a-time) dates are ignored. This list is saved in a normalized form that is suited for fast calculations of valid days.

busdaycal
[busdaycalendar, optional] A *busdaycalendar* object which specifies the valid days. If this parameter is provided, neither weekmask nor holidays may be provided.

out
[array of int, optional] If provided, this array is filled with the result.

Returns

out
[array of int] An array with a shape from broadcasting `begindates` and `enddates` together, containing the number of valid days between the begin and end dates.

See also:

busdaycalendar
An object that specifies a custom set of valid days.

is_busday
Returns a boolean array indicating valid days.

busday_offset
Applies an offset counted in valid days.

Examples

```
>>> import numpy as np
>>> # Number of weekdays in January 2011
... np.busday_count('2011-01', '2011-02')
21
>>> # Number of weekdays in 2011
>>> np.busday_count('2011', '2012')
260
>>> # Number of Saturdays in 2011
... np.busday_count('2011', '2012', weekmask='Sat')
53
```

1.4.6 Data type routines

can_cast(from_, to[, casting])	Returns True if cast between data types can occur according to the casting rule.
promote_types(type1, type2)	Returns the data type with the smallest size and smallest scalar kind to which both `type1` and `type2` may be safely cast.
min_scalar_type(a, /)	For scalar `a`, returns the data type with the smallest size and smallest scalar kind which can hold its value.
result_type(*arrays_and_dtypes)	Returns the type that results from applying the NumPy type promotion rules to the arguments.
common_type(*arrays)	Return a scalar type which is common to the input arrays.

numpy.**can_cast**(*from_*, *to*, *casting='safe'*)

Returns True if cast between data types can occur according to the casting rule.

Parameters

from_
[dtype, dtype specifier, NumPy scalar, or array] Data type, NumPy scalar, or array to cast from.

to
[dtype or dtype specifier] Data type to cast to.

casting
[{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.
- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

Returns

out
[bool] True if cast can occur according to the casting rule.

See also:

dtype, *result_type*

Notes

Changed in version 2.0: This function does not support Python scalars anymore and does not apply any value-based logic for 0-D arrays and NumPy scalars.

Examples

Basic examples

```
>>> import numpy as np
>>> np.can_cast(np.int32, np.int64)
True
>>> np.can_cast(np.float64, complex)
True
>>> np.can_cast(complex, float)
False
```

```
>>> np.can_cast('i8', 'f8')
True
>>> np.can_cast('i8', 'f4')
False
>>> np.can_cast('i4', 'S4')
False
```

numpy.**promote_types**(*type1*, *type2*)

Returns the data type with the smallest size and smallest scalar kind to which both `type1` and `type2` may be safely cast. The returned data type is always considered "canonical", this mainly means that the promoted dtype will always be in native byte order.

This function is symmetric, but rarely associative.

Parameters

type1
[dtype or dtype specifier] First data type.

type2
[dtype or dtype specifier] Second data type.

Returns

out
[dtype] The promoted data type.

See also:

result_type, *dtype*, *can_cast*

Notes

Please see *numpy.result_type* for additional information about promotion.

Starting in NumPy 1.9, promote_types function now returns a valid string length when given an integer or float dtype as one argument and a string dtype as another argument. Previously it always returned the input string dtype, even if it wasn't long enough to store the max integer/float value converted to a string.

Changed in version 1.23.0.

NumPy now supports promotion for more structured dtypes. It will now remove unnecessary padding from a structure dtype and promote included fields individually.

Examples

```
>>> import numpy as np
>>> np.promote_types('f4', 'f8')
dtype('float64')
```

```
>>> np.promote_types('i8', 'f4')
dtype('float64')
```

```
>>> np.promote_types('>i8', '<c8')
dtype('complex128')
```

```
>>> np.promote_types('i4', 'S8')
dtype('S11')
```

An example of a non-associative case:

```
>>> p = np.promote_types
>>> p('S', p('i1', 'u1'))
dtype('S6')
>>> p(p('S', 'i1'), 'u1')
dtype('S4')
```

numpy.**min_scalar_type**(*a*, */*)

For scalar `a`, returns the data type with the smallest size and smallest scalar kind which can hold its value. For non-scalar array `a`, returns the vector's dtype unmodified.

Floating point values are not demoted to integers, and complex values are not demoted to floats.

Parameters

a
[scalar or array_like] The value whose minimal data type is to be found.

Returns

out
[dtype] The minimal data type.

See also:

result_type, *promote_types*, *dtype*, *can_cast*

Examples

```
>>> import numpy as np
>>> np.min_scalar_type(10)
dtype('uint8')
```

```
>>> np.min_scalar_type(-260)
dtype('int16')
```

```
>>> np.min_scalar_type(3.1)
dtype('float16')
```

```
>>> np.min_scalar_type(1e50)
dtype('float64')
```

```
>>> np.min_scalar_type(np.arange(4,dtype='f8'))
dtype('float64')
```

numpy.**result_type**(**arrays_and_dtypes*)

Returns the type that results from applying the NumPy type promotion rules to the arguments.

Type promotion in NumPy works similarly to the rules in languages like C++, with some slight differences. When both scalars and arrays are used, the array's type takes precedence and the actual value of the scalar is taken into account.

For example, calculating 3*a, where a is an array of 32-bit floats, intuitively should result in a 32-bit float output. If the 3 is a 32-bit integer, the NumPy rules indicate it can't convert losslessly into a 32-bit float, so a 64-bit float should be the result type. By examining the value of the constant, '3', we see that it fits in an 8-bit integer, which can be cast losslessly into the 32-bit float.

Parameters

arrays_and_dtypes
[list of arrays and dtypes] The operands of some operation whose result type is needed.

Returns

out
[dtype] The result type.

See also:

dtype, *promote_types*, *min_scalar_type*, *can_cast*

Notes

The specific algorithm used is as follows.

Categories are determined by first checking which of boolean, integer (int/uint), or floating point (float/complex) the maximum kind of all the arrays and the scalars are.

If there are only scalars or the maximum category of the scalars is higher than the maximum category of the arrays, the data types are combined with *promote_types* to produce the return value.

Otherwise, *min_scalar_type* is called on each scalar, and the resulting data types are all combined with *promote_types* to produce the return value.

The set of int values is not a subset of the uint values for types with the same number of bits, something not reflected in *min_scalar_type*, but handled as a special case in *result_type*.

Examples

```
>>> import numpy as np
>>> np.result_type(3, np.arange(7, dtype='i1'))
dtype('int8')
```

```
>>> np.result_type('i4', 'c8')
dtype('complex128')
```

```
>>> np.result_type(3.0, -2)
dtype('float64')
```

numpy.**common_type**(**arrays*)

Return a scalar type which is common to the input arrays.

The return type will always be an inexact (i.e. floating point) scalar type, even if all the arrays are integer arrays. If one of the inputs is an integer array, the minimum precision type that is returned is a 64-bit floating point dtype.

All input arrays except int64 and uint64 can be safely cast to the returned dtype without loss of information.

Parameters

array1, array2, …
[ndarrays] Input arrays.

Returns

out
[data type code] Data type code.

See also:

dtype*, *mintypecode

Examples

```
>>> np.common_type(np.arange(2, dtype=np.float32))
<class 'numpy.float32'>
>>> np.common_type(np.arange(2, dtype=np.float32), np.arange(2))
<class 'numpy.float64'>
>>> np.common_type(np.arange(4), np.array([45, 6.j]), np.array([45.0]))
<class 'numpy.complex128'>
```

Creating data types

dtype(dtype[, align, copy])	Create a data type object.
rec.format_parser(formats, names, titles[, ...])	Class to convert formats, names, titles description to a dtype.

Data type information

finfo(dtype)	Machine limits for floating point types.
iinfo(type)	Machine limits for integer types.

class numpy.**finfo**(*dtype*)

Machine limits for floating point types.

Parameters

dtype
[float, dtype, or instance] Kind of floating point or complex floating point data-type about which to get information.

See also:

iinfo
The equivalent for integer data types.

spacing
The distance between a value and the nearest adjacent number

nextafter
The next floating point value after x1 towards x2

Notes

For developers of NumPy: do not instantiate this at the module level. The initial calculation of these parameters is expensive and negatively impacts import times. These objects are cached, so calling `finfo()` repeatedly inside your functions is not a problem.

Note that `smallest_normal` is not actually the smallest positive representable value in a NumPy floating point type. As in the IEEE-754 standard [1], NumPy floating point types make use of subnormal numbers to fill the gap between 0 and `smallest_normal`. However, subnormal numbers may have significantly reduced precision [2].

This function can also be used for complex data types as well. If used, the output will be the same as the corresponding real float type (e.g. numpy.finfo(numpy.csingle) is the same as numpy.finfo(numpy.single)). However, the output is true for the real and imaginary components.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.finfo(np.float64).dtype
dtype('float64')
>>> np.finfo(np.complex64).dtype
dtype('float32')
```

Attributes

bits
[int] The number of bits occupied by the type.

dtype
[dtype] Returns the dtype for which *finfo* returns information. For complex input, the returned dtype is the associated `float*` dtype for its real and complex components.

eps
[float] The difference between 1.0 and the next smallest representable float larger than 1.0. For example, for 64-bit binary floats in the IEEE-754 standard, `eps = 2**-52`, approximately 2.22e-16.

epsneg
[float] The difference between 1.0 and the next smallest representable float less than 1.0. For example, for 64-bit binary floats in the IEEE-754 standard, `epsneg = 2**-53`, approximately 1.11e-16.

iexp
[int] The number of bits in the exponent portion of the floating point representation.

machep
[int] The exponent that yields *eps*.

max
[floating point number of the appropriate type] The largest representable number.

maxexp
[int] The smallest positive power of the base (2) that causes overflow.

min
[floating point number of the appropriate type] The smallest representable number, typically `-max`.

minexp
[int] The most negative power of the base (2) consistent with there being no leading 0's in the mantissa.

negep
[int] The exponent that yields *epsneg*.

nexp
[int] The number of bits in the exponent including its sign and bias.

nmant
[int] The number of bits in the mantissa.

precision
[int] The approximate number of decimal digits to which this kind of float is precise.

resolution
[floating point number of the appropriate type] The approximate decimal resolution of this type, i.e., `10**-precision`.

tiny
[float] Return the value for tiny, alias of smallest_normal.

smallest_normal
[float] Return the value for the smallest normal.

smallest_subnormal
[float] The smallest positive floating point number with 0 as leading bit in the mantissa following IEEE-754.

class numpy.**iinfo**(*type*)

Machine limits for integer types.

Parameters

int_type
[integer type, dtype, or instance] The kind of integer data type to get information about.

See also:

finfo
The equivalent for floating point data types.

Examples

With types:

```
>>> import numpy as np
>>> ii16 = np.iinfo(np.int16)
>>> ii16.min
-32768
>>> ii16.max
32767
>>> ii32 = np.iinfo(np.int32)
>>> ii32.min
-2147483648
>>> ii32.max
2147483647
```

With instances:

```
>>> ii32 = np.iinfo(np.int32(10))
>>> ii32.min
-2147483648
>>> ii32.max
2147483647
```

Attributes

bits
[int] The number of bits occupied by the type.

dtype
[dtype] Returns the dtype for which *iinfo* returns information.

min
[int] Minimum value of given dtype.

max
[int] Maximum value of given dtype.

Data type testing

isdtype(dtype, kind)	Determine if a provided dtype is of a specified data type `kind`.
issubdtype(arg1, arg2)	Returns True if first argument is a typecode lower/equal in type hierarchy.

numpy.**isdtype**(*dtype*, *kind*)

Determine if a provided dtype is of a specified data type `kind`.

This function only supports built-in NumPy's data types. Third-party dtypes are not yet supported.

Parameters

dtype
[dtype] The input dtype.

kind
[dtype or str or tuple of dtypes/strs.] dtype or dtype kind. Allowed dtype kinds are: * `'bool'` : boolean kind * `'signed integer'` : signed integer data types * `'unsigned integer'` : unsigned integer data types * `'integral'` : integer data types * `'real floating'` : real-valued floating-point data types * `'complex floating'` : complex floating-point data types * `'numeric'` : numeric data types

Returns

out
[bool]

See also:

issubdtype

Examples

```
>>> import numpy as np
>>> np.isdtype(np.float32, np.float64)
False
>>> np.isdtype(np.float32, "real floating")
True
>>> np.isdtype(np.complex128, ("real floating", "complex floating"))
True
```

numpy.**issubdtype**(*arg1*, *arg2*)

Returns True if first argument is a typecode lower/equal in type hierarchy.

This is like the builtin `issubclass`, but for *dtype*s.

Parameters

arg1, arg2
[dtype_like] *dtype* or object coercible to one

Returns

out
[bool]

See also:

Scalars
Overview of the numpy type hierarchy.

Examples

issubdtype can be used to check the type of arrays:

```
>>> ints = np.array([1, 2, 3], dtype=np.int32)
>>> np.issubdtype(ints.dtype, np.integer)
True
>>> np.issubdtype(ints.dtype, np.floating)
False
```

```
>>> floats = np.array([1, 2, 3], dtype=np.float32)
>>> np.issubdtype(floats.dtype, np.integer)
False
>>> np.issubdtype(floats.dtype, np.floating)
True
```

Similar types of different sizes are not subdtypes of each other:

```
>>> np.issubdtype(np.float64, np.float32)
False
>>> np.issubdtype(np.float32, np.float64)
False
```

but both are subtypes of *floating*:

```
>>> np.issubdtype(np.float64, np.floating)
True
>>> np.issubdtype(np.float32, np.floating)
True
```

For convenience, dtype-like objects are allowed too:

```
>>> np.issubdtype('S1', np.bytes_)
True
>>> np.issubdtype('i4', np.signedinteger)
True
```

Miscellaneous

typename(char)	Return a description for the given data type code.
mintypecode(typechars[, typeset, default])	Return the character for the minimum-size type to which given types can be safely cast.

numpy.**typename**(*char*)

Return a description for the given data type code.

Parameters

char
[str] Data type code.

Returns

out
[str] Description of the input data type code.

See also:

dtype

Examples

```
>>> import numpy as np
>>> typechars = ['S1', '?', 'B', 'D', 'G', 'F', 'I', 'H', 'L', 'O', 'Q',
...              'S', 'U', 'V', 'b', 'd', 'g', 'f', 'i', 'h', 'l', 'q']
>>> for typechar in typechars:
...     print(typechar, ' : ', np.typename(typechar))
...
S1  :  character
?  :  bool
B  :  unsigned char
D  :  complex double precision
G  :  complex long double precision
F  :  complex single precision
I  :  unsigned integer
H  :  unsigned short
L  :  unsigned long integer
O  :  object
Q  :  unsigned long long integer
S  :  string
U  :  unicode
V  :  void
b  :  signed char
d  :  double precision
g  :  long precision
f  :  single precision
i  :  integer
h  :  short
l  :  long integer
q  :  long long integer
```

numpy.**mintypecode**(*typechars*, *typeset='GDFgdf'*, *default='d'*)

Return the character for the minimum-size type to which given types can be safely cast.

The returned type character must represent the smallest size dtype such that an array of the returned type can handle the data from an array of all types in *typechars* (or if *typechars* is an array, then its dtype.char).

Parameters

typechars
[list of str or array_like] If a list of strings, each string should represent a dtype. If array_like, the character representation of the array dtype is used.

typeset
[str or list of str, optional] The set of characters that the returned character is chosen from. The default set is 'GDFgdf'.

default
[str, optional] The default character, this is returned if none of the characters in *typechars* matches a character in *typeset*.

Returns

typechar
[str] The character representing the minimum-size type that was found.

See also:

dtype

Examples

```
>>> import numpy as np
>>> np.mintypecode(['d', 'f', 'S'])
'd'
>>> x = np.array([1.1, 2-3.j])
>>> np.mintypecode(x)
'D'
```

```
>>> np.mintypecode('abceh', default='G')
'G'
```

1.4.7 Floating point error handling

Setting and getting error handling

seterr([all, divide, over, under, invalid])	Set how floating-point errors are handled.
geterr()	Get the current way of handling floating-point errors.
seterrcall(func)	Set the floating-point error callback function or log object.
geterrcall()	Return the current callback function used on floating-point errors.
errstate(**kwargs)	Context manager for floating-point error handling.

numpy.**seterr**(*all=None*, *divide=None*, *over=None*, *under=None*, *invalid=None*)

Set how floating-point errors are handled.

Note that operations on integer scalar types (such as *int16*) are handled like floating point, and are affected by these settings.

Parameters

all
[{'ignore', 'warn', 'raise', 'call', 'print', 'log'}, optional] Set treatment for all types of floating-point errors at once:

- ignore: Take no action when the exception occurs.
- warn: Print a `RuntimeWarning` (via the Python `warnings` module).
- raise: Raise a `FloatingPointError`.
- call: Call a function specified using the *seterrcall* function.
- print: Print a warning directly to `stdout`.
- log: Record error in a Log object specified by *seterrcall*.

The default is not to change the current behavior.

divide
[{'ignore', 'warn', 'raise', 'call', 'print', 'log'}, optional] Treatment for division by zero.

over
[{'ignore', 'warn', 'raise', 'call', 'print', 'log'}, optional] Treatment for floating-point overflow.

under
[{'ignore', 'warn', 'raise', 'call', 'print', 'log'}, optional] Treatment for floating-point underflow.

invalid
[{'ignore', 'warn', 'raise', 'call', 'print', 'log'}, optional] Treatment for invalid floating-point operation.

Returns

old_settings
[dict] Dictionary containing the old settings.

See also:

seterrcall
Set a callback function for the 'call' mode.

geterr*, *geterrcall*, *errstate

Notes

The floating-point exceptions are defined in the IEEE 754 standard [1]:

- Division by zero: infinite result obtained from finite numbers.
- Overflow: result too large to be expressed.
- Underflow: result so close to zero that some precision was lost.
- Invalid operation: result is not an expressible number, typically indicates that a NaN was produced.

Examples

```
>>> import numpy as np
>>> orig_settings = np.seterr(all='ignore')  # seterr to known value
>>> np.int16(32000) * np.int16(3)
np.int16(30464)
>>> np.seterr(over='raise')
{'divide': 'ignore', 'over': 'ignore', 'under': 'ignore', 'invalid': 'ignore'}
>>> old_settings = np.seterr(all='warn', over='raise')
>>> np.int16(32000) * np.int16(3)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
FloatingPointError: overflow encountered in scalar multiply
```

```
>>> old_settings = np.seterr(all='print')
>>> np.geterr()
{'divide': 'print', 'over': 'print', 'under': 'print', 'invalid': 'print'}
>>> np.int16(32000) * np.int16(3)
np.int16(30464)
>>> np.seterr(**orig_settings)  # restore original
{'divide': 'print', 'over': 'print', 'under': 'print', 'invalid': 'print'}
```

numpy.**geterr**()

Get the current way of handling floating-point errors.

Returns

res

[dict] A dictionary with keys “divide”, “over”, “under”, and “invalid”, whose values are from the strings “ignore”, “print”, “log”, “warn”, “raise”, and “call”. The keys represent possible floating-point exceptions, and the values define how these exceptions are handled.

See also:

geterrcall, *seterr*, *seterrcall*

Notes

For complete documentation of the types of floating-point exceptions and treatment options, see *seterr*.

Examples

```
>>> import numpy as np
>>> np.geterr()
{'divide': 'warn', 'over': 'warn', 'under': 'ignore', 'invalid': 'warn'}
>>> np.arange(3.) / np.arange(3.)
array([nan,  1.,  1.])
RuntimeWarning: invalid value encountered in divide
```

```
>>> oldsettings = np.seterr(all='warn', invalid='raise')
>>> np.geterr()
{'divide': 'warn', 'over': 'warn', 'under': 'warn', 'invalid': 'raise'}
>>> np.arange(3.) / np.arange(3.)
Traceback (most recent call last):
```

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```
  ...
FloatingPointError: invalid value encountered in divide
>>> oldsettings = np.seterr(**oldsettings)  # restore original
```

numpy.**seterrcall**(*func*)

Set the floating-point error callback function or log object.

There are two ways to capture floating-point error messages. The first is to set the error-handler to 'call', using *seterr*. Then, set the function to call using this function.

The second is to set the error-handler to 'log', using *seterr*. Floating-point errors then trigger a call to the 'write' method of the provided object.

Parameters

func

[callable f(err, flag) or object with write method] Function to call upon floating-point errors ('call'-mode) or object whose 'write' method is used to log such message ('log'-mode).

The call function takes two arguments. The first is a string describing the type of error (such as "divide by zero", "overflow", "underflow", or "invalid value"), and the second is the status flag. The flag is a byte, whose four least-significant bits indicate the type of error, one of "divide", "over", "under", "invalid":

```
[0 0 0 0 divide over under invalid]
```

In other words, `flags = divide + 2*over + 4*under + 8*invalid`.

If an object is provided, its write method should take one argument, a string.

Returns

h

[callable, log instance or None] The old error handler.

See also:

seterr*, *geterr*, *geterrcall

Examples

Callback upon error:

```
>>> def err_handler(type, flag):
...     print("Floating point error (%s), with flag %s" % (type, flag))
...
```

```
>>> import numpy as np
```

```
>>> orig_handler = np.seterrcall(err_handler)
>>> orig_err = np.seterr(all='call')
```

```
>>> np.array([1, 2, 3]) / 0.0
Floating point error (divide by zero), with flag 1
array([inf, inf, inf])
```

```
>>> np.seterrcall(orig_handler)
<function err_handler at 0x...>
>>> np.seterr(**orig_err)
{'divide': 'call', 'over': 'call', 'under': 'call', 'invalid': 'call'}
```

Log error message:

```
>>> class Log:
...     def write(self, msg):
...         print("LOG: %s" % msg)
...
```

```
>>> log = Log()
>>> saved_handler = np.seterrcall(log)
>>> save_err = np.seterr(all='log')
```

```
>>> np.array([1, 2, 3]) / 0.0
LOG: Warning: divide by zero encountered in divide
array([inf, inf, inf])
```

```
>>> np.seterrcall(orig_handler)
<numpy.Log object at 0x...>
>>> np.seterr(**orig_err)
{'divide': 'log', 'over': 'log', 'under': 'log', 'invalid': 'log'}
```

numpy.**geterrcall**()

Return the current callback function used on floating-point errors.

When the error handling for a floating-point error (one of “divide”, “over”, “under”, or “invalid”) is set to ‘call’ or ‘log’, the function that is called or the log instance that is written to is returned by *geterrcall*. This function or log instance has been set with *seterrcall*.

Returns

errobj
: [callable, log instance or None] The current error handler. If no handler was set through *seterrcall*, None is returned.

See also:

seterrcall*, *seterr*, *geterr

Notes

For complete documentation of the types of floating-point exceptions and treatment options, see *seterr*.

Examples

```
>>> import numpy as np
>>> np.geterrcall()  # we did not yet set a handler, returns None
```

```
>>> orig_settings = np.seterr(all='call')
>>> def err_handler(type, flag):
...     print("Floating point error (%s), with flag %s" % (type, flag))
>>> old_handler = np.seterrcall(err_handler)
>>> np.array([1, 2, 3]) / 0.0
Floating point error (divide by zero), with flag 1
array([inf, inf, inf])
```

```
>>> cur_handler = np.geterrcall()
>>> cur_handler is err_handler
True
>>> old_settings = np.seterr(**orig_settings)  # restore original
>>> old_handler = np.seterrcall(None)  # restore original
```

class numpy.**errstate**(***kwargs*)

Context manager for floating-point error handling.

Using an instance of *errstate* as a context manager allows statements in that context to execute with a known error handling behavior. Upon entering the context the error handling is set with *seterr* and *seterrcall*, and upon exiting it is reset to what it was before.

Changed in version 1.17.0: *errstate* is also usable as a function decorator, saving a level of indentation if an entire function is wrapped.

Changed in version 2.0: *errstate* is now fully thread and asyncio safe, but may not be entered more than once. It is not safe to decorate async functions using `errstate`.

Parameters

kwargs
[{divide, over, under, invalid}] Keyword arguments. The valid keywords are the possible floating-point exceptions. Each keyword should have a string value that defines the treatment for the particular error. Possible values are {'ignore', 'warn', 'raise', 'call', 'print', 'log'}.

See also:

seterr*, *geterr*, *seterrcall*, *geterrcall

Notes

For complete documentation of the types of floating-point exceptions and treatment options, see *seterr*.

Examples

```
>>> import numpy as np
>>> olderr = np.seterr(all='ignore')  # Set error handling to known state.
```

```
>>> np.arange(3) / 0.
array([nan, inf, inf])
>>> with np.errstate(divide='ignore'):
...     np.arange(3) / 0.
array([nan, inf, inf])
```

```
>>> np.sqrt(-1)
np.float64(nan)
>>> with np.errstate(invalid='raise'):
...     np.sqrt(-1)
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
FloatingPointError: invalid value encountered in sqrt
```

Outside the context the error handling behavior has not changed:

```
>>> np.geterr()
{'divide': 'ignore', 'over': 'ignore', 'under': 'ignore', 'invalid': 'ignore'}
>>> olderr = np.seterr(**olderr)  # restore original state
```

Methods

__call__(func)	Call self as a function.

method

errstate.**__call__**(*func*)

Call self as a function.

1.4.8 Functional programming

apply_along_axis(func1d, axis, arr, *args, ...)	Apply a function to 1-D slices along the given axis.
apply_over_axes(func, a, axes)	Apply a function repeatedly over multiple axes.
vectorize([pyfunc, otypes, doc, excluded, ...])	Returns an object that acts like pyfunc, but takes arrays as input.
frompyfunc(func, /, nin, nout, *[, identity])	Takes an arbitrary Python function and returns a NumPy ufunc.
piecewise(x, condlist, funclist, *args, **kw)	Evaluate a piecewise-defined function.

numpy.**apply_along_axis**(*func1d*, *axis*, *arr*, **args*, ***kwargs*)

Apply a function to 1-D slices along the given axis.

Execute *func1d(a, *args, **kwargs)* where *func1d* operates on 1-D arrays and *a* is a 1-D slice of *arr* along *axis*.

This is equivalent to (but faster than) the following use of *ndindex* and *s_*, which sets each of `ii`, `jj`, and `kk` to a tuple of indices:

```
Ni, Nk = a.shape[:axis], a.shape[axis+1:]
for ii in ndindex(Ni):
    for kk in ndindex(Nk):
        f = func1d(arr[ii + s_[:,] + kk])
        Nj = f.shape
        for jj in ndindex(Nj):
            out[ii + jj + kk] = f[jj]
```

Equivalently, eliminating the inner loop, this can be expressed as:

```
Ni, Nk = a.shape[:axis], a.shape[axis+1:]
for ii in ndindex(Ni):
    for kk in ndindex(Nk):
        out[ii + s_[...,] + kk] = func1d(arr[ii + s_[:,] + kk])
```

Parameters

func1d
[function (M,) -> (Nj…)] This function should accept 1-D arrays. It is applied to 1-D slices of *arr* along the specified axis.

axis
[integer] Axis along which *arr* is sliced.

arr
[ndarray (Ni…, M, Nk…)] Input array.

args
[any] Additional arguments to *func1d*.

kwargs
[any] Additional named arguments to *func1d*.

Returns

out
[ndarray (Ni…, Nj…, Nk…)] The output array. The shape of *out* is identical to the shape of *arr*, except along the *axis* dimension. This axis is removed, and replaced with new dimensions equal to the shape of the return value of *func1d*. So if *func1d* returns a scalar *out* will have one fewer dimensions than *arr*.

See also:

apply_over_axes
Apply a function repeatedly over multiple axes.

Examples

```
>>> import numpy as np
>>> def my_func(a):
...     """Average first and last element of a 1-D array"""
...     return (a[0] + a[-1]) * 0.5
>>> b = np.array([[1,2,3], [4,5,6], [7,8,9]])
>>> np.apply_along_axis(my_func, 0, b)
array([4., 5., 6.])
>>> np.apply_along_axis(my_func, 1, b)
array([2.,  5.,  8.])
```

For a function that returns a 1D array, the number of dimensions in *outarr* is the same as *arr*.

```
>>> b = np.array([[8,1,7], [4,3,9], [5,2,6]])
>>> np.apply_along_axis(sorted, 1, b)
array([[1, 7, 8],
       [3, 4, 9],
       [2, 5, 6]])
```

For a function that returns a higher dimensional array, those dimensions are inserted in place of the *axis* dimension.

```
>>> b = np.array([[1,2,3], [4,5,6], [7,8,9]])
>>> np.apply_along_axis(np.diag, -1, b)
array([[[1, 0, 0],
        [0, 2, 0],
        [0, 0, 3]],
       [[4, 0, 0],
        [0, 5, 0],
        [0, 0, 6]],
       [[7, 0, 0],
        [0, 8, 0],
        [0, 0, 9]]])
```

numpy.**apply_over_axes**(*func*, *a*, *axes*)

Apply a function repeatedly over multiple axes.

func is called as *res* = *func(a, axis)*, where *axis* is the first element of *axes*. The result *res* of the function call must have either the same dimensions as *a* or one less dimension. If *res* has one less dimension than *a*, a dimension is inserted before *axis*. The call to *func* is then repeated for each axis in *axes*, with *res* as the first argument.

Parameters

func
: [function] This function must take two arguments, *func(a, axis)*.

a
: [array_like] Input array.

axes
: [array_like] Axes over which *func* is applied; the elements must be integers.

Returns

apply_over_axis
: [ndarray] The output array. The number of dimensions is the same as *a*, but the shape can be different. This depends on whether *func* changes the shape of its output with respect to its input.

See also:

apply_along_axis
: Apply a function to 1-D slices of an array along the given axis.

Notes

This function is equivalent to tuple axis arguments to reorderable ufuncs with keepdims=True. Tuple axis arguments to ufuncs have been available since version 1.7.0.

Examples

```
>>> import numpy as np
>>> a = np.arange(24).reshape(2,3,4)
>>> a
array([[[ 0,  1,  2,  3],
        [ 4,  5,  6,  7],
        [ 8,  9, 10, 11]],
       [[12, 13, 14, 15],
        [16, 17, 18, 19],
        [20, 21, 22, 23]]])
```

Sum over axes 0 and 2. The result has same number of dimensions as the original array:

```
>>> np.apply_over_axes(np.sum, a, [0,2])
array([[[ 60],
        [ 92],
        [124]]])
```

Tuple axis arguments to ufuncs are equivalent:

```
>>> np.sum(a, axis=(0,2), keepdims=True)
array([[[ 60],
        [ 92],
        [124]]])
```

class numpy.**vectorize**(*pyfunc=np._NoValue*, *otypes=None*, *doc=None*, *excluded=None*, *cache=False*, *signature=None*)

Returns an object that acts like pyfunc, but takes arrays as input.

Define a vectorized function which takes a nested sequence of objects or numpy arrays as inputs and returns a single numpy array or a tuple of numpy arrays. The vectorized function evaluates *pyfunc* over successive tuples of the input arrays like the python map function, except it uses the broadcasting rules of numpy.

The data type of the output of *vectorized* is determined by calling the function with the first element of the input. This can be avoided by specifying the *otypes* argument.

Parameters

pyfunc
: [callable, optional] A python function or method. Can be omitted to produce a decorator with keyword arguments.

otypes
: [str or list of dtypes, optional] The output data type. It must be specified as either a string of typecode characters or a list of data type specifiers. There should be one data type specifier for each output.

doc
: [str, optional] The docstring for the function. If None, the docstring will be the `pyfunc.__doc__`.

excluded
: [set, optional] Set of strings or integers representing the positional or keyword arguments for which the function will not be vectorized. These will be passed directly to *pyfunc* unmodified.

cache
: [bool, optional] If *True*, then cache the first function call that determines the number of outputs if *otypes* is not provided.

signature
: [string, optional] Generalized universal function signature, e.g., `(m,n),(n)->(m)` for vectorized matrix-vector multiplication. If provided, `pyfunc` will be called with (and expected to return) arrays with shapes given by the size of corresponding core dimensions. By default, `pyfunc` is assumed to take scalars as input and output.

Returns

out
: [callable] A vectorized function if `pyfunc` was provided, a decorator otherwise.

See also:

frompyfunc
: Takes an arbitrary Python function and returns a ufunc

Notes

The *vectorize* function is provided primarily for convenience, not for performance. The implementation is essentially a for loop.

If *otypes* is not specified, then a call to the function with the first argument will be used to determine the number of outputs. The results of this call will be cached if *cache* is *True* to prevent calling the function twice. However, to implement the cache, the original function must be wrapped which will slow down subsequent calls, so only do this if your function is expensive.

The new keyword argument interface and *excluded* argument support further degrades performance.

References

[1]

Examples

```
>>> import numpy as np
>>> def myfunc(a, b):
...     "Return a-b if a>b, otherwise return a+b"
...     if a > b:
...         return a - b
...     else:
...         return a + b
```

```
>>> vfunc = np.vectorize(myfunc)
>>> vfunc([1, 2, 3, 4], 2)
array([3, 4, 1, 2])
```

The docstring is taken from the input function to *vectorize* unless it is specified:

```
>>> vfunc.__doc__
'Return a-b if a>b, otherwise return a+b'
>>> vfunc = np.vectorize(myfunc, doc='Vectorized `myfunc`')
>>> vfunc.__doc__
'Vectorized `myfunc`'
```

The output type is determined by evaluating the first element of the input, unless it is specified:

```
>>> out = vfunc([1, 2, 3, 4], 2)
>>> type(out[0])
<class 'numpy.int64'>
>>> vfunc = np.vectorize(myfunc, otypes=[float])
>>> out = vfunc([1, 2, 3, 4], 2)
>>> type(out[0])
<class 'numpy.float64'>
```

The *excluded* argument can be used to prevent vectorizing over certain arguments. This can be useful for array-like arguments of a fixed length such as the coefficients for a polynomial as in *polyval*:

```
>>> def mypolyval(p, x):
...     _p = list(p)
...     res = _p.pop(0)
...     while _p:
...         res = res*x + _p.pop(0)
...     return res
```

Here, we exclude the zeroth argument from vectorization whether it is passed by position or keyword.

```
>>> vpolyval = np.vectorize(mypolyval, excluded={0, 'p'})
>>> vpolyval([1, 2, 3], x=[0, 1])
array([3, 6])
>>> vpolyval(p=[1, 2, 3], x=[0, 1])
array([3, 6])
```

The *signature* argument allows for vectorizing functions that act on non-scalar arrays of fixed length. For example, you can use it for a vectorized calculation of Pearson correlation coefficient and its p-value:

```
>>> import scipy.stats
>>> pearsonr = np.vectorize(scipy.stats.pearsonr,
...                 signature='(n),(n)->(),()')
>>> pearsonr([[0, 1, 2, 3]], [[1, 2, 3, 4], [4, 3, 2, 1]])
(array([ 1., -1.]), array([ 0.,  0.]))
```

Or for a vectorized convolution:

```
>>> convolve = np.vectorize(np.convolve, signature='(n),(m)->(k)')
>>> convolve(np.eye(4), [1, 2, 1])
array([[1., 2., 1., 0., 0., 0.],
       [0., 1., 2., 1., 0., 0.],
       [0., 0., 1., 2., 1., 0.],
       [0., 0., 0., 1., 2., 1.]])
```

Decorator syntax is supported. The decorator can be called as a function to provide keyword arguments:

```
>>> @np.vectorize
... def identity(x):
...     return x
```

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```
...
>>> identity([0, 1, 2])
array([0, 1, 2])
>>> @np.vectorize(otypes=[float])
... def as_float(x):
...     return x
...
>>> as_float([0, 1, 2])
array([0., 1., 2.])
```

Methods

__call__(*args, **kwargs)	Call self as a function.

method

vectorize.**__call__**(**args*, ***kwargs*)

Call self as a function.

numpy.**frompyfunc**(*func*, */*, *nin*, *nout*, ***[, *identity*])

Takes an arbitrary Python function and returns a NumPy ufunc.

Can be used, for example, to add broadcasting to a built-in Python function (see Examples section).

Parameters

func
[Python function object] An arbitrary Python function.

nin
[int] The number of input arguments.

nout
[int] The number of objects returned by *func*.

identity
[object, optional] The value to use for the *identity* attribute of the resulting object. If specified, this is equivalent to setting the underlying C `identity` field to `PyUFunc_IdentityValue`. If omitted, the identity is set to `PyUFunc_None`. Note that this is _not_ equivalent to setting the identity to `None`, which implies the operation is reorderable.

Returns

out
[ufunc] Returns a NumPy universal function (`ufunc`) object.

See also:

vectorize
Evaluates pyfunc over input arrays using broadcasting rules of numpy.

Notes

The returned ufunc always returns PyObject arrays.

Examples

Use frompyfunc to add broadcasting to the Python function `oct`:

```
>>> import numpy as np
>>> oct_array = np.frompyfunc(oct, 1, 1)
>>> oct_array(np.array((10, 30, 100)))
array(['0o12', '0o36', '0o144'], dtype=object)
>>> np.array((oct(10), oct(30), oct(100))) # for comparison
array(['0o12', '0o36', '0o144'], dtype='<U5')
```

numpy.**piecewise**(*x*, *condlist*, *funclist*, **args*, ***kw*)

Evaluate a piecewise-defined function.

Given a set of conditions and corresponding functions, evaluate each function on the input data wherever its condition is true.

Parameters

x
: [ndarray or scalar] The input domain.

condlist
: [list of bool arrays or bool scalars] Each boolean array corresponds to a function in *funclist*. Wherever *condlist[i]* is True, *funclist[i](x)* is used as the output value.

  Each boolean array in *condlist* selects a piece of *x*, and should therefore be of the same shape as *x*.

  The length of *condlist* must correspond to that of *funclist*. If one extra function is given, i.e. if `len(funclist) == len(condlist) + 1`, then that extra function is the default value, used wherever all conditions are false.

funclist
: [list of callables, f(x,*args,**kw), or scalars] Each function is evaluated over *x* wherever its corresponding condition is True. It should take a 1d array as input and give an 1d array or a scalar value as output. If, instead of a callable, a scalar is provided then a constant function (`lambda x: scalar`) is assumed.

args
: [tuple, optional] Any further arguments given to *piecewise* are passed to the functions upon execution, i.e., if called `piecewise(..., ..., 1, 'a')`, then each function is called as `f(x, 1, 'a')`.

kw
: [dict, optional] Keyword arguments used in calling *piecewise* are passed to the functions upon execution, i.e., if called `piecewise(..., ..., alpha=1)`, then each function is called as `f(x, alpha=1)`.

Returns

out
: [ndarray] The output is the same shape and type as x and is found by calling the functions in *funclist* on the appropriate portions of *x*, as defined by the boolean arrays in *condlist*. Portions not covered by any condition have a default value of 0.

See also:

choose, *select*, *where*

Notes

This is similar to choose or select, except that functions are evaluated on elements of *x* that satisfy the corresponding condition from *condlist*.

The result is:

```
      |--
      |funclist[0](x[condlist[0]])
out = |funclist[1](x[condlist[1]])
      |...
      |funclist[n2](x[condlist[n2]])
      |--
```

Examples

```
>>> import numpy as np
```

Define the signum function, which is -1 for `x < 0` and +1 for `x >= 0`.

```
>>> x = np.linspace(-2.5, 2.5, 6)
>>> np.piecewise(x, [x < 0, x >= 0], [-1, 1])
array([-1., -1., -1.,  1.,  1.,  1.])
```

Define the absolute value, which is `-x` for `x <0` and `x` for `x >= 0`.

```
>>> np.piecewise(x, [x < 0, x >= 0], [lambda x: -x, lambda x: x])
array([2.5,  1.5,  0.5,  0.5,  1.5,  2.5])
```

Apply the same function to a scalar value.

```
>>> y = -2
>>> np.piecewise(y, [y < 0, y >= 0], [lambda x: -x, lambda x: x])
array(2)
```

1.4.9 Input and output

NumPy binary files (npy, npz)

load(file[, mmap_mode, allow_pickle, ...])	Load arrays or pickled objects from `.npy`, `.npz` or pickled files.
save(file, arr[, allow_pickle, fix_imports])	Save an array to a binary file in NumPy `.npy` format.
savez(file, *args[, allow_pickle])	Save several arrays into a single file in uncompressed `.npz` format.
savez_compressed(file, *args[, allow_pickle])	Save several arrays into a single file in compressed `.npz` format.
lib.npyio.NpzFile(fid)	A dictionary-like object with lazy-loading of files in the zipped archive provided on construction.

numpy.**load**(*file*, *mmap_mode=None*, *allow_pickle=False*, *fix_imports=True*, *encoding='ASCII'*, ***, *max_header_size=10000*)

Load arrays or pickled objects from `.npy`, `.npz` or pickled files.

Warning: Loading files that contain object arrays uses the `pickle` module, which is not secure against erroneous or maliciously constructed data. Consider passing `allow_pickle=False` to load data that is known not to contain object arrays for the safer handling of untrusted sources.

Parameters

file
[file-like object, string, or pathlib.Path] The file to read. File-like objects must support the `seek()` and `read()` methods and must always be opened in binary mode. Pickled files require that the file-like object support the `readline()` method as well.

mmap_mode
[{None, 'r+', 'r', 'w+', 'c'}, optional] If not None, then memory-map the file, using the given mode (see *numpy.memmap* for a detailed description of the modes). A memory-mapped array is kept on disk. However, it can be accessed and sliced like any ndarray. Memory mapping is especially useful for accessing small fragments of large files without reading the entire file into memory.

allow_pickle
[bool, optional] Allow loading pickled object arrays stored in npy files. Reasons for disallowing pickles include security, as loading pickled data can execute arbitrary code. If pickles are disallowed, loading object arrays will fail. Default: False

fix_imports
[bool, optional] Only useful when loading Python 2 generated pickled files on Python 3, which includes npy/npz files containing object arrays. If *fix_imports* is True, pickle will try to map the old Python 2 names to the new names used in Python 3.

encoding
[str, optional] What encoding to use when reading Python 2 strings. Only useful when loading Python 2 generated pickled files in Python 3, which includes npy/npz files containing object arrays. Values other than 'latin1', 'ASCII', and 'bytes' are not allowed, as they can corrupt numerical data. Default: 'ASCII'

max_header_size
[int, optional] Maximum allowed size of the header. Large headers may not be safe to load securely and thus require explicitly passing a larger value. See `ast.literal_eval` for details. This option is ignored when *allow_pickle* is passed. In that case the file is by definition trusted and the limit is unnecessary.

Returns

result
[array, tuple, dict, etc.] Data stored in the file. For `.npz` files, the returned instance of NpzFile class must be closed to avoid leaking file descriptors.

Raises

OSError
If the input file does not exist or cannot be read.

UnpicklingError
If `allow_pickle=True`, but the file cannot be loaded as a pickle.

ValueError
The file contains an object array, but `allow_pickle=False` given.

EOFError
When calling `np.load` multiple times on the same file handle, if all data has already been read

See also:

save*, *savez*, *savez_compressed*, *loadtxt
memmap
Create a memory-map to an array stored in a file on disk.

lib.format.open_memmap
Create or load a memory-mapped `.npy` file.

Notes

- If the file contains pickle data, then whatever object is stored in the pickle is returned.
- If the file is a `.npy` file, then a single array is returned.
- If the file is a `.npz` file, then a dictionary-like object is returned, containing `{filename: array}` key-value pairs, one for each file in the archive.
- If the file is a `.npz` file, the returned value supports the context manager protocol in a similar fashion to the open function:

```
with load('foo.npz') as data:
    a = data['a']
```

The underlying file descriptor is closed when exiting the 'with' block.

Examples

```
>>> import numpy as np
```

Store data to disk, and load it again:

```
>>> np.save('/tmp/123', np.array([[1, 2, 3], [4, 5, 6]]))
>>> np.load('/tmp/123.npy')
array([[1, 2, 3],
       [4, 5, 6]])
```

Store compressed data to disk, and load it again:

```
>>> a=np.array([[1, 2, 3], [4, 5, 6]])
>>> b=np.array([1, 2])
>>> np.savez('/tmp/123.npz', a=a, b=b)
>>> data = np.load('/tmp/123.npz')
>>> data['a']
array([[1, 2, 3],
       [4, 5, 6]])
>>> data['b']
array([1, 2])
>>> data.close()
```

Mem-map the stored array, and then access the second row directly from disk:

```
>>> X = np.load('/tmp/123.npy', mmap_mode='r')
>>> X[1, :]
memmap([4, 5, 6])
```

numpy.**save**(*file*, *arr*, *allow_pickle=True*, *fix_imports=<no value>*)

Save an array to a binary file in NumPy `.npy` format.

Parameters

file
[file, str, or pathlib.Path] File or filename to which the data is saved. If file is a file-object, then the filename is unchanged. If file is a string or Path, a `.npy` extension will be appended to the filename if it does not already have one.

arr
[array_like] Array data to be saved.

allow_pickle
[bool, optional] Allow saving object arrays using Python pickles. Reasons for disallowing pickles include security (loading pickled data can execute arbitrary code) and portability (pickled objects may not be loadable on different Python installations, for example if the stored objects require libraries that are not available, and not all pickled data is compatible between different versions of Python). Default: True

fix_imports
[bool, optional] The *fix_imports* flag is deprecated and has no effect.

Deprecated since version 2.1: This flag is ignored since NumPy 1.17 and was only needed to support loading some files in Python 2 written in Python 3.

See also:

savez
Save several arrays into a `.npz` archive

savetxt, ***load***

Notes

For a description of the `.npy` format, see *numpy.lib.format*.

Any data saved to the file is appended to the end of the file.

Examples

```
>>> import numpy as np
```

```
>>> from tempfile import TemporaryFile
>>> outfile = TemporaryFile()
```

```
>>> x = np.arange(10)
>>> np.save(outfile, x)
```

```
>>> _ = outfile.seek(0) # Only needed to simulate closing & reopening file
>>> np.load(outfile)
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

```
>>> with open('test.npy', 'wb') as f:
...     np.save(f, np.array([1, 2]))
...     np.save(f, np.array([1, 3]))
>>> with open('test.npy', 'rb') as f:
...     a = np.load(f)
...     b = np.load(f)
>>> print(a, b)
# [1 2] [1 3]
```

numpy.**savez**(*file*, **args*, *allow_pickle=True*, ***kwds*)

Save several arrays into a single file in uncompressed `.npz` format.

Provide arrays as keyword arguments to store them under the corresponding name in the output file: `savez(fn, x=x, y=y)`.

If arrays are specified as positional arguments, i.e., `savez(fn, x, y)`, their names will be *arr_0*, *arr_1*, etc.

Parameters

file
[file, str, or pathlib.Path] Either the filename (string) or an open file (file-like object) where the data will be saved. If file is a string or a Path, the `.npz` extension will be appended to the filename if it is not already there.

args
[Arguments, optional] Arrays to save to the file. Please use keyword arguments (see *kwds* below) to assign names to arrays. Arrays specified as args will be named "arr_0", "arr_1", and so on.

allow_pickle
[bool, optional] Allow saving object arrays using Python pickles. Reasons for disallowing pickles include security (loading pickled data can execute arbitrary code) and portability (pickled objects may not be loadable on different Python installations, for example if the stored objects require libraries that are not available, and not all pickled data is compatible between different versions of Python). Default: True

kwds
[Keyword arguments, optional] Arrays to save to the file. Each array will be saved to the output file with its corresponding keyword name.

Returns

None

See also:

save
Save a single array to a binary file in NumPy format.

savetxt
Save an array to a file as plain text.

savez_compressed
Save several arrays into a compressed `.npz` archive

Notes

The `.npz` file format is a zipped archive of files named after the variables they contain. The archive is not compressed and each file in the archive contains one variable in `.npy` format. For a description of the `.npy` format, see *numpy.lib.format*.

When opening the saved `.npz` file with *load* a *NpzFile* object is returned. This is a dictionary-like object which can be queried for its list of arrays (with the `.files` attribute), and for the arrays themselves.

Keys passed in *kwds* are used as filenames inside the ZIP archive. Therefore, keys should be valid filenames; e.g., avoid keys that begin with `/` or contain `..`.

When naming variables with keyword arguments, it is not possible to name a variable `file`, as this would cause the `file` argument to be defined twice in the call to `savez`.

Examples

```
>>> import numpy as np
>>> from tempfile import TemporaryFile
>>> outfile = TemporaryFile()
>>> x = np.arange(10)
>>> y = np.sin(x)
```

Using *savez* with *args, the arrays are saved with default names.

```
>>> np.savez(outfile, x, y)
>>> _ = outfile.seek(0) # Only needed to simulate closing & reopening file
>>> npzfile = np.load(outfile)
>>> npzfile.files
['arr_0', 'arr_1']
>>> npzfile['arr_0']
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

Using *savez* with **kwds, the arrays are saved with the keyword names.

```
>>> outfile = TemporaryFile()
>>> np.savez(outfile, x=x, y=y)
>>> _ = outfile.seek(0)
>>> npzfile = np.load(outfile)
>>> sorted(npzfile.files)
['x', 'y']
>>> npzfile['x']
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
```

numpy.**savez_compressed**(*file*, **args*, *allow_pickle=True*, ***kwds*)

Save several arrays into a single file in compressed `.npz` format.

Provide arrays as keyword arguments to store them under the corresponding name in the output file: `savez_compressed(fn, x=x, y=y)`.

If arrays are specified as positional arguments, i.e., `savez_compressed(fn, x, y)`, their names will be *arr_0*, *arr_1*, etc.

Parameters

file

[file, str, or pathlib.Path] Either the filename (string) or an open file (file-like object) where

the data will be saved. If file is a string or a Path, the `.npz` extension will be appended to the filename if it is not already there.

args
: [Arguments, optional] Arrays to save to the file. Please use keyword arguments (see *kwds* below) to assign names to arrays. Arrays specified as args will be named "arr_0", "arr_1", and so on.

allow_pickle
: [bool, optional] Allow saving object arrays using Python pickles. Reasons for disallowing pickles include security (loading pickled data can execute arbitrary code) and portability (pickled objects may not be loadable on different Python installations, for example if the stored objects require libraries that are not available, and not all pickled data is compatible between different versions of Python). Default: True

kwds
: [Keyword arguments, optional] Arrays to save to the file. Each array will be saved to the output file with its corresponding keyword name.

Returns

None

See also:

numpy.save
: Save a single array to a binary file in NumPy format.

numpy.savetxt
: Save an array to a file as plain text.

numpy.savez
: Save several arrays into an uncompressed `.npz` file format

numpy.load
: Load the files created by savez_compressed.

Notes

The `.npz` file format is a zipped archive of files named after the variables they contain. The archive is compressed with `zipfile.ZIP_DEFLATED` and each file in the archive contains one variable in `.npy` format. For a description of the `.npy` format, see *numpy.lib.format*.

When opening the saved `.npz` file with *load* a *NpzFile* object is returned. This is a dictionary-like object which can be queried for its list of arrays (with the `.files` attribute), and for the arrays themselves.

Examples

```
>>> import numpy as np
>>> test_array = np.random.rand(3, 2)
>>> test_vector = np.random.rand(4)
>>> np.savez_compressed('/tmp/123', a=test_array, b=test_vector)
>>> loaded = np.load('/tmp/123.npz')
>>> print(np.array_equal(test_array, loaded['a']))
True
>>> print(np.array_equal(test_vector, loaded['b']))
True
```

The format of these binary file types is documented in *numpy.lib.format*

Text files

loadtxt(fname[, dtype, comments, delimiter, ...])	Load data from a text file.
savetxt(fname, X[, fmt, delimiter, newline, ...])	Save an array to a text file.
genfromtxt(fname[, dtype, comments, ...])	Load data from a text file, with missing values handled as specified.
fromregex(file, regexp, dtype[, encoding])	Construct an array from a text file, using regular expression parsing.
fromstring(string[, dtype, count, like])	A new 1-D array initialized from text data in a string.
ndarray.tofile(fid[, sep, format])	Write array to a file as text or binary (default).
ndarray.tolist()	Return the array as an `a.ndim`-levels deep nested list of Python scalars.

numpy.**savetxt**(*fname*, *X*, *fmt='%.18e'*, *delimiter=' '*, *newline='\n'*, *header=''*, *footer=''*, *comments='# '*, *encoding=None*)

Save an array to a text file.

Parameters

fname
[filename, file handle or pathlib.Path] If the filename ends in `.gz`, the file is automatically saved in compressed gzip format. *loadtxt* understands gzipped files transparently.

X
[1D or 2D array_like] Data to be saved to a text file.

fmt
[str or sequence of strs, optional] A single format (%10.5f), a sequence of formats, or a multi-format string, e.g. 'Iteration %d – %10.5f', in which case *delimiter* is ignored. For complex *X*, the legal options for *fmt* are:

- a single specifier, `fmt='%.4e'`, resulting in numbers formatted like `' (%s+%sj)' % (fmt, fmt)`
- a full string specifying every real and imaginary part, e.g. `' %.4e %+.4ej %.4e %+.4ej %.4e %+.4ej'` for 3 columns
- a list of specifiers, one per column - in this case, the real and imaginary part must have separate specifiers, e.g. `['%.3e + %.3ej', '(%.15e%+.15ej)']` for 2 columns

delimiter
[str, optional] String or character separating columns.

newline
[str, optional] String or character separating lines.

header
[str, optional] String that will be written at the beginning of the file.

footer
[str, optional] String that will be written at the end of the file.

comments
[str, optional] String that will be prepended to the `header` and `footer` strings, to mark them as comments. Default: '# ', as expected by e.g. `numpy.loadtxt`.

encoding
[{None, str}, optional] Encoding used to encode the outputfile. Does not apply to output streams. If the encoding is something other than 'bytes' or 'latin1' you will not be able to load the file in NumPy versions < 1.14. Default is 'latin1'.

See also:

save
Save an array to a binary file in NumPy `.npy` format

savez
Save several arrays into an uncompressed `.npz` archive

savez_compressed
Save several arrays into a compressed `.npz` archive

Notes

Further explanation of the *fmt* parameter (`%[flag]width[.precision]specifier`):

flags:
`-` : left justify

`+` : Forces to precede result with + or -.

`0` : Left pad the number with zeros instead of space (see width).

width:
Minimum number of characters to be printed. The value is not truncated if it has more characters.

precision:

- For integer specifiers (eg. `d,i,o,x`), the minimum number of digits.
- For `e, E` and `f` specifiers, the number of digits to print after the decimal point.
- For `g` and `G`, the maximum number of significant digits.
- For `s`, the maximum number of characters.

specifiers:
`c` : character

`d` or `i` : signed decimal integer

`e` or `E` : scientific notation with `e` or `E`.

`f` : decimal floating point

`g,G` : use the shorter of `e,E` or `f`

`o` : signed octal

`s` : string of characters

`u` : unsigned decimal integer

`x,X` : unsigned hexadecimal integer

This explanation of `fmt` is not complete, for an exhaustive specification see [1].

References

[1]

Examples

```
>>> import numpy as np
>>> x = y = z = np.arange(0.0,5.0,1.0)
>>> np.savetxt('test.out', x, delimiter=',')   # X is an array
>>> np.savetxt('test.out', (x,y,z))   # x,y,z equal sized 1D arrays
>>> np.savetxt('test.out', x, fmt='%1.4e')   # use exponential notation
```

numpy.**genfromtxt**(*fname*, *dtype=<class 'float'>*, *comments='#'*, *delimiter=None*, *skip_header=0*, *skip_footer=0*, *converters=None*, *missing_values=None*, *filling_values=None*, *usecols=None*, *names=None*, *excludelist=None*, *deletechars=" !#$%&'()*+, -./:;<=>?@[\\]^{|}~"*, *replace_space='_'*, *autostrip=False*, *case_sensitive=True*, *defaultfmt='f%i'*, *unpack=None*, *usemask=False*, *loose=True*, *invalid_raise=True*, *max_rows=None*, *encoding=None*, ***, *ndmin=0*, *like=None*)

Load data from a text file, with missing values handled as specified.

Each line past the first *skip_header* lines is split at the *delimiter* character, and characters following the *comments* character are discarded.

Parameters

fname
: [file, str, pathlib.Path, list of str, generator] File, filename, list, or generator to read. If the filename extension is `.gz` or `.bz2`, the file is first decompressed. Note that generators must return bytes or strings. The strings in a list or produced by a generator are treated as lines.

dtype
: [dtype, optional] Data type of the resulting array. If None, the dtypes will be determined by the contents of each column, individually.

comments
: [str, optional] The character used to indicate the start of a comment. All the characters occurring on a line after a comment are discarded.

delimiter
: [str, int, or sequence, optional] The string used to separate values. By default, any consecutive whitespaces act as delimiter. An integer or sequence of integers can also be provided as width(s) of each field.

skiprows
: [int, optional] *skiprows* was removed in numpy 1.10. Please use *skip_header* instead.

skip_header
: [int, optional] The number of lines to skip at the beginning of the file.

skip_footer
: [int, optional] The number of lines to skip at the end of the file.

converters
: [variable, optional] The set of functions that convert the data of a column to a value. The converters can also be used to provide a default value for missing data: `converters = {3: lambda s: float(s or 0)}`.

missing
: [variable, optional] *missing* was removed in numpy 1.10. Please use *missing_values* instead.

missing_values
[variable, optional] The set of strings corresponding to missing data.

filling_values
[variable, optional] The set of values to be used as default when the data are missing.

usecols
[sequence, optional] Which columns to read, with 0 being the first. For example, `usecols = (1, 4, 5)` will extract the 2nd, 5th and 6th columns.

names
[{None, True, str, sequence}, optional] If *names* is True, the field names are read from the first line after the first *skip_header* lines. This line can optionally be preceded by a comment delimiter. Any content before the comment delimiter is discarded. If *names* is a sequence or a single-string of comma-separated names, the names will be used to define the field names in a structured dtype. If *names* is None, the names of the dtype fields will be used, if any.

excludelist
[sequence, optional] A list of names to exclude. This list is appended to the default list ['return','file','print']. Excluded names are appended with an underscore: for example, *file* would become *file_*.

deletechars
[str, optional] A string combining invalid characters that must be deleted from the names.

defaultfmt
[str, optional] A format used to define default field names, such as "f%i" or "f_%02i".

autostrip
[bool, optional] Whether to automatically strip white spaces from the variables.

replace_space
[char, optional] Character(s) used in replacement of white spaces in the variable names. By default, use a '_'.

case_sensitive
[{True, False, 'upper', 'lower'}, optional] If True, field names are case sensitive. If False or 'upper', field names are converted to upper case. If 'lower', field names are converted to lower case.

unpack
[bool, optional] If True, the returned array is transposed, so that arguments may be unpacked using `x, y, z = genfromtxt(...)`. When used with a structured data-type, arrays are returned for each field. Default is False.

usemask
[bool, optional] If True, return a masked array. If False, return a regular array.

loose
[bool, optional] If True, do not raise errors for invalid values.

invalid_raise
[bool, optional] If True, an exception is raised if an inconsistency is detected in the number of columns. If False, a warning is emitted and the offending lines are skipped.

max_rows
[int, optional] The maximum number of rows to read. Must not be used with skip_footer at the same time. If given, the value must be at least 1. Default is to read the entire file.

encoding
[str, optional] Encoding used to decode the inputfile. Does not apply when *fname* is a file

object. The special value 'bytes' enables backward compatibility workarounds that ensure that you receive byte arrays when possible and passes latin1 encoded strings to converters. Override this value to receive unicode arrays and pass strings as input to converters. If set to None the system default is used. The default value is 'bytes'.

Changed in version 2.0: Before NumPy 2, the default was `'bytes'` for Python 2 compatibility. The default is now `None`.

ndmin
[int, optional] Same parameter as *loadtxt*

New in version 1.23.0.

like
[array_like, optional] Reference object to allow the creation of arrays which are not NumPy arrays. If an array-like passed in as `like` supports the `__array_function__` protocol, the result will be defined by it. In this case, it ensures the creation of an array object compatible with that passed in via this argument.

New in version 1.20.0.

Returns

out
[ndarray] Data read from the text file. If *usemask* is True, this is a masked array.

See also:

numpy.loadtxt
equivalent function when no data is missing.

Notes

- When spaces are used as delimiters, or when no delimiter has been given as input, there should not be any missing data between two fields.
- When variables are named (either by a flexible dtype or with a *names* sequence), there must not be any header in the file (else a ValueError exception is raised).
- Individual values are not stripped of spaces by default. When using a custom converter, make sure the function does remove spaces.
- Custom converters may receive unexpected values due to dtype discovery.

References

[1]

Examples

```
>>> from io import StringIO
>>> import numpy as np
```

Comma delimited file with mixed dtype

```
>>> s = StringIO("1,1.3,abcde")
>>> data = np.genfromtxt(s, dtype=[('myint','i8'),('myfloat','f8'),
... ('mystring','S5')], delimiter=",")
>>> data
array((1, 1.3, b'abcde'),
      dtype=[('myint', '<i8'), ('myfloat', '<f8'), ('mystring', 'S5')])
```

Using dtype = None

```
>>> _ = s.seek(0) # needed for StringIO example only
>>> data = np.genfromtxt(s, dtype=None,
... names = ['myint','myfloat','mystring'], delimiter=",")
>>> data
array((1, 1.3, 'abcde'),
      dtype=[('myint', '<i8'), ('myfloat', '<f8'), ('mystring', '<U5')])
```

Specifying dtype and names

```
>>> _ = s.seek(0)
>>> data = np.genfromtxt(s, dtype="i8,f8,S5",
... names=['myint','myfloat','mystring'], delimiter=",")
>>> data
array((1, 1.3, b'abcde'),
      dtype=[('myint', '<i8'), ('myfloat', '<f8'), ('mystring', 'S5')])
```

An example with fixed-width columns

```
>>> s = StringIO("11.3abcde")
>>> data = np.genfromtxt(s, dtype=None, names=['intvar','fltvar','strvar'],
...     delimiter=[1,3,5])
>>> data
array((1, 1.3, 'abcde'),
      dtype=[('intvar', '<i8'), ('fltvar', '<f8'), ('strvar', '<U5')])
```

An example to show comments

```
>>> f = StringIO('''
... text,# of chars
... hello world,11
... numpy,5''')
>>> np.genfromtxt(f, dtype='S12,S12', delimiter=',')
array([(b'text', b''), (b'hello world', b'11'), (b'numpy', b'5')],
  dtype=[('f0', 'S12'), ('f1', 'S12')])
```

numpy.**fromregex**(*file*, *regexp*, *dtype*, *encoding=None*)

Construct an array from a text file, using regular expression parsing.

The returned array is always a structured array, and is constructed from all matches of the regular expression in the file. Groups in the regular expression are converted to fields of the structured array.

Parameters

file
[file, str, or pathlib.Path] Filename or file object to read.

Changed in version 1.22.0: Now accepts `os.PathLike` implementations.

regexp
[str or regexp] Regular expression used to parse the file. Groups in the regular expression correspond to fields in the dtype.

dtype
[dtype or list of dtypes] Dtype for the structured array; must be a structured datatype.

encoding
[str, optional] Encoding used to decode the inputfile. Does not apply to input streams.

Returns

output
[ndarray] The output array, containing the part of the content of *file* that was matched by *regexp*. *output* is always a structured array.

Raises

TypeError
When *dtype* is not a valid dtype for a structured array.

See also:

fromstring*, *loadtxt

Notes

Dtypes for structured arrays can be specified in several forms, but all forms specify at least the data type and field name. For details see *basics.rec*.

Examples

```
>>> import numpy as np
>>> from io import StringIO
>>> text = StringIO("1312 foo\n1534  bar\n444   qux")
```

```
>>> regexp = r"(\d+)\s+(...)"  # match [digits, whitespace, anything]
>>> output = np.fromregex(text, regexp,
...                       [('num', np.int64), ('key', 'S3')])
>>> output
array([(1312, b'foo'), (1534, b'bar'), ( 444, b'qux')],
      dtype=[('num', '<i8'), ('key', 'S3')])
>>> output['num']
array([1312, 1534,  444])
```

Raw binary files

fromfile(file[, dtype, count, sep, offset, like])	Construct an array from data in a text or binary file.
ndarray.tofile(fid[, sep, format])	Write array to a file as text or binary (default).

String formatting

array2string(a[, max_line_width, precision, ...])	Return a string representation of an array.
array_repr(arr[, max_line_width, precision, ...])	Return the string representation of an array.
array_str(a[, max_line_width, precision, ...])	Return a string representation of the data in an array.
format_float_positional(x[, precision, ...])	Format a floating-point scalar as a decimal string in positional notation.
format_float_scientific(x[, precision, ...])	Format a floating-point scalar as a decimal string in scientific notation.

numpy.**array2string**(*a*, *max_line_width=None*, *precision=None*, *suppress_small=None*, *separator=' '*, *prefix=''*, *style=<no value>*, *formatter=None*, *threshold=None*, *edgeitems=None*, *sign=None*, *floatmode=None*, *suffix=''*, ***, *legacy=None*)

Return a string representation of an array.

Parameters

a
[ndarray] Input array.

max_line_width
[int, optional] Inserts newlines if text is longer than *max_line_width*. Defaults to `numpy.get_printoptions()['linewidth']`.

precision
[int or None, optional] Floating point precision. Defaults to `numpy.get_printoptions()['precision']`.

suppress_small
[bool, optional] Represent numbers "very close" to zero as zero; default is False. Very close is defined by precision: if the precision is 8, e.g., numbers smaller (in absolute value) than 5e-9 are represented as zero. Defaults to `numpy.get_printoptions()['suppress']`.

separator
[str, optional] Inserted between elements.

prefix
[str, optional]

suffix
[str, optional] The length of the prefix and suffix strings are used to respectively align and wrap the output. An array is typically printed as:

```
prefix + array2string(a) + suffix
```

The output is left-padded by the length of the prefix string, and wrapping is forced at the column `max_line_width - len(suffix)`. It should be noted that the content of prefix and suffix strings are not included in the output.

style
[_NoValue, optional] Has no effect, do not use.

Deprecated since version 1.14.0.

formatter
[dict of callables, optional] If not None, the keys should indicate the type(s) that the respective formatting function applies to. Callables should return a string. Types that are not specified (by their corresponding keys) are handled by the default formatters. Individual types for which a formatter can be set are:

- 'bool'
- 'int'
- 'timedelta' : a *numpy.timedelta64*
- 'datetime' : a *numpy.datetime64*
- 'float'
- 'longfloat' : 128-bit floats
- 'complexfloat'
- 'longcomplexfloat' : composed of two 128-bit floats
- 'void' : type *numpy.void*
- 'numpystr' : types *numpy.bytes_* and *numpy.str_*

Other keys that can be used to set a group of types at once are:

- 'all' : sets all types
- 'int_kind' : sets 'int'
- 'float_kind' : sets 'float' and 'longfloat'
- 'complex_kind' : sets 'complexfloat' and 'longcomplexfloat'
- 'str_kind' : sets 'numpystr'

threshold
[int, optional] Total number of array elements which trigger summarization rather than full repr. Defaults to `numpy.get_printoptions()['threshold']`.

edgeitems
[int, optional] Number of array items in summary at beginning and end of each dimension. Defaults to `numpy.get_printoptions()['edgeitems']`.

sign
[string, either '-', '+', or ' ', optional] Controls printing of the sign of floating-point types. If '+', always print the sign of positive values. If ' ', always prints a space (whitespace character) in the sign position of positive values. If '-', omit the sign character of positive values. Defaults to `numpy.get_printoptions()['sign']`.

Changed in version 2.0: The sign parameter can now be an integer type, previously types were floating-point types.

floatmode
[str, optional] Controls the interpretation of the *precision* option for floating-point types. Defaults to `numpy.get_printoptions()['floatmode']`. Can take the following values:

- 'fixed': Always print exactly *precision* fractional digits, even if this would print more or fewer digits than necessary to specify the value uniquely.
- 'unique': Print the minimum number of fractional digits necessary to represent each value uniquely. Different elements may have a different number of digits. The value of the *precision* option is ignored.
- 'maxprec': Print at most *precision* fractional digits, but if an element can be uniquely represented with fewer digits only print it with that many.
- 'maxprec_equal': Print at most *precision* fractional digits, but if every element in the array can be uniquely represented with an equal number of fewer digits, use that many digits for all elements.

legacy
: [string or *False*, optional] If set to the string `'1.13'` enables 1.13 legacy printing mode. This approximates numpy 1.13 print output by including a space in the sign position of floats and different behavior for 0d arrays. If set to *False*, disables legacy mode. Unrecognized strings will be ignored with a warning for forward compatibility.

Returns

array_str
: [str] String representation of the array.

Raises

TypeError
: if a callable in *formatter* does not return a string.

See also:

array_str*, *array_repr*, *set_printoptions*, *get_printoptions

Notes

If a formatter is specified for a certain type, the *precision* keyword is ignored for that type.

This is a very flexible function; *array_repr* and *array_str* are using *array2string* internally so keywords with the same name should work identically in all three functions.

Examples

```
>>> import numpy as np
>>> x = np.array([1e-16,1,2,3])
>>> np.array2string(x, precision=2, separator=',',
...                       suppress_small=True)
'[0.,1.,2.,3.]'
```

```
>>> x  = np.arange(3.)
>>> np.array2string(x, formatter={'float_kind':lambda x: "%.2f" % x})
'[0.00 1.00 2.00]'
```

```
>>> x  = np.arange(3)
>>> np.array2string(x, formatter={'int':lambda x: hex(x)})
'[0x0 0x1 0x2]'
```

numpy.**array_repr**(*arr*, *max_line_width=None*, *precision=None*, *suppress_small=None*)

Return the string representation of an array.

Parameters

arr
[ndarray] Input array.

max_line_width
[int, optional] Inserts newlines if text is longer than *max_line_width*. Defaults to `numpy.get_printoptions()['linewidth']`.

precision
[int, optional] Floating point precision. Defaults to `numpy.get_printoptions()['precision']`.

suppress_small
[bool, optional] Represent numbers "very close" to zero as zero; default is False. Very close is defined by precision: if the precision is 8, e.g., numbers smaller (in absolute value) than 5e-9 are represented as zero. Defaults to `numpy.get_printoptions()['suppress']`.

Returns

string
[str] The string representation of an array.

See also:

array_str, *array2string*, *set_printoptions*

Examples

```
>>> import numpy as np
>>> np.array_repr(np.array([1,2]))
'array([1, 2])'
>>> np.array_repr(np.ma.array([0.]))
'MaskedArray([0.])'
>>> np.array_repr(np.array([], np.int32))
'array([], dtype=int32)'
```

```
>>> x = np.array([1e-6, 4e-7, 2, 3])
>>> np.array_repr(x, precision=6, suppress_small=True)
'array([0.000001,  0.      ,  2.      ,  3.      ])'
```

numpy.**array_str**(*a*, *max_line_width=None*, *precision=None*, *suppress_small=None*)

Return a string representation of the data in an array.

The data in the array is returned as a single string. This function is similar to *array_repr*, the difference being that *array_repr* also returns information on the kind of array and its data type.

Parameters

a
[ndarray] Input array.

max_line_width
[int, optional] Inserts newlines if text is longer than *max_line_width*. Defaults to `numpy.get_printoptions()['linewidth']`.

precision
: [int, optional] Floating point precision. Defaults to `numpy.get_printoptions()['precision']`.

suppress_small
: [bool, optional] Represent numbers "very close" to zero as zero; default is False. Very close is defined by precision: if the precision is 8, e.g., numbers smaller (in absolute value) than 5e-9 are represented as zero. Defaults to `numpy.get_printoptions()['suppress']`.

See also:

array2string*, *array_repr*, *set_printoptions

Examples

```
>>> import numpy as np
>>> np.array_str(np.arange(3))
'[0 1 2]'
```

numpy.**format_float_positional**(*x*, *precision=None*, *unique=True*, *fractional=True*, *trim='k'*, *sign=False*, *pad_left=None*, *pad_right=None*, *min_digits=None*)

Format a floating-point scalar as a decimal string in positional notation.

Provides control over rounding, trimming and padding. Uses and assumes IEEE unbiased rounding. Uses the "Dragon4" algorithm.

Parameters

x
: [python float or numpy floating scalar] Value to format.

precision
: [non-negative integer or None, optional] Maximum number of digits to print. May be None if *unique* is *True*, but must be an integer if unique is *False*.

unique
: [boolean, optional] If *True*, use a digit-generation strategy which gives the shortest representation which uniquely identifies the floating-point number from other values of the same type, by judicious rounding. If *precision* is given fewer digits than necessary can be printed, or if *min_digits* is given more can be printed, in which cases the last digit is rounded with unbiased rounding. If *False*, digits are generated as if printing an infinite-precision value and stopping after *precision* digits, rounding the remaining value with unbiased rounding

fractional
: [boolean, optional] If *True*, the cutoffs of *precision* and *min_digits* refer to the total number of digits after the decimal point, including leading zeros. If *False*, *precision* and *min_digits* refer to the total number of significant digits, before or after the decimal point, ignoring leading zeros.

trim
: [one of 'k', '.', '0', '-', optional] Controls post-processing trimming of trailing digits, as follows:

- 'k' : keep trailing zeros, keep decimal point (no trimming)
- '.' : trim all trailing zeros, leave decimal point
- '0' : trim all but the zero before the decimal point. Insert the zero if it is missing.
- '-' : trim trailing zeros and any trailing decimal point

sign
[boolean, optional] Whether to show the sign for positive values.

pad_left
[non-negative integer, optional] Pad the left side of the string with whitespace until at least that many characters are to the left of the decimal point.

pad_right
[non-negative integer, optional] Pad the right side of the string with whitespace until at least that many characters are to the right of the decimal point.

min_digits
[non-negative integer or None, optional] Minimum number of digits to print. Only has an effect if *unique=True* in which case additional digits past those necessary to uniquely identify the value may be printed, rounding the last additional digit.

New in version 1.21.0.

Returns

rep
[string] The string representation of the floating point value

See also:

format_float_scientific

Examples

```
>>> import numpy as np
>>> np.format_float_positional(np.float32(np.pi))
'3.1415927'
>>> np.format_float_positional(np.float16(np.pi))
'3.14'
>>> np.format_float_positional(np.float16(0.3))
'0.3'
>>> np.format_float_positional(np.float16(0.3), unique=False, precision=10)
'0.3000488281'
```

numpy.**format_float_scientific**(*x*, *precision=None*, *unique=True*, *trim='k'*, *sign=False*, *pad_left=None*, *exp_digits=None*, *min_digits=None*)

Format a floating-point scalar as a decimal string in scientific notation.

Provides control over rounding, trimming and padding. Uses and assumes IEEE unbiased rounding. Uses the "Dragon4" algorithm.

Parameters

x
[python float or numpy floating scalar] Value to format.

precision
[non-negative integer or None, optional] Maximum number of digits to print. May be None if `unique` is *True*, but must be an integer if unique is *False*.

unique
[boolean, optional] If *True*, use a digit-generation strategy which gives the shortest representation which uniquely identifies the floating-point number from other values of the same type, by judicious rounding. If *precision* is given fewer digits than necessary can be printed. If

min_digits is given more can be printed, in which cases the last digit is rounded with unbiased rounding. If *False*, digits are generated as if printing an infinite-precision value and stopping after *precision* digits, rounding the remaining value with unbiased rounding

trim
[one of 'k', '.', '0', '-', optional] Controls post-processing trimming of trailing digits, as follows:

- 'k' : keep trailing zeros, keep decimal point (no trimming)
- '.' : trim all trailing zeros, leave decimal point
- '0' : trim all but the zero before the decimal point. Insert the zero if it is missing.
- '-' : trim trailing zeros and any trailing decimal point

sign
[boolean, optional] Whether to show the sign for positive values.

pad_left
[non-negative integer, optional] Pad the left side of the string with whitespace until at least that many characters are to the left of the decimal point.

exp_digits
[non-negative integer, optional] Pad the exponent with zeros until it contains at least this many digits. If omitted, the exponent will be at least 2 digits.

min_digits
[non-negative integer or None, optional] Minimum number of digits to print. This only has an effect for *unique=True*. In that case more digits than necessary to uniquely identify the value may be printed and rounded unbiased.

New in version 1.21.0.

Returns

rep
[string] The string representation of the floating point value

See also:

format_float_positional

Examples

```
>>> import numpy as np
>>> np.format_float_scientific(np.float32(np.pi))
'3.1415927e+00'
>>> s = np.float32(1.23e24)
>>> np.format_float_scientific(s, unique=False, precision=15)
'1.230000071797338e+24'
>>> np.format_float_scientific(s, exp_digits=4)
'1.23e+0024'
```

Memory mapping files

memmap(filename[, dtype, mode, offset, ...])	Create a memory-map to an array stored in a *binary* file on disk.
lib.format.open_memmap(filename[, mode, ...])	Open a .npy file as a memory-mapped array.

Text formatting options

set_printoptions([precision, threshold, ...])	Set printing options.
get_printoptions()	Return the current print options.
printoptions(*args, **kwargs)	Context manager for setting print options.

numpy.**set_printoptions**(*precision=None*, *threshold=None*, *edgeitems=None*, *linewidth=None*, *suppress=None*, *nanstr=None*, *infstr=None*, *formatter=None*, *sign=None*, *floatmode=None*, ***, *legacy=None*, *override_repr=None*)

Set printing options.

These options determine the way floating point numbers, arrays and other NumPy objects are displayed.

Parameters

precision
[int or None, optional] Number of digits of precision for floating point output (default 8). May be None if *floatmode* is not *fixed*, to print as many digits as necessary to uniquely specify the value.

threshold
[int, optional] Total number of array elements which trigger summarization rather than full repr (default 1000). To always use the full repr without summarization, pass sys.maxsize.

edgeitems
[int, optional] Number of array items in summary at beginning and end of each dimension (default 3).

linewidth
[int, optional] The number of characters per line for the purpose of inserting line breaks (default 75).

suppress
[bool, optional] If True, always print floating point numbers using fixed point notation, in which case numbers equal to zero in the current precision will print as zero. If False, then scientific notation is used when absolute value of the smallest number is < 1e-4 or the ratio of the maximum absolute value to the minimum is > 1e3. The default is False.

nanstr
[str, optional] String representation of floating point not-a-number (default nan).

infstr
[str, optional] String representation of floating point infinity (default inf).

sign
[string, either '-', '+', or ' ', optional] Controls printing of the sign of floating-point types. If '+', always print the sign of positive values. If ' ', always prints a space (whitespace character) in the sign position of positive values. If '-', omit the sign character of positive values. (default '-')

Changed in version 2.0: The sign parameter can now be an integer type, previously types were floating-point types.

formatter
[dict of callables, optional] If not None, the keys should indicate the type(s) that the respective formatting function applies to. Callables should return a string. Types that are not specified (by their corresponding keys) are handled by the default formatters. Individual types for which a formatter can be set are:

- 'bool'
- 'int'
- 'timedelta' : a *numpy.timedelta64*
- 'datetime' : a *numpy.datetime64*
- 'float'
- 'longfloat' : 128-bit floats
- 'complexfloat'
- 'longcomplexfloat' : composed of two 128-bit floats
- 'numpystr' : types *numpy.bytes_* and *numpy.str_*
- 'object' : *np.object_* arrays

Other keys that can be used to set a group of types at once are:

- 'all' : sets all types
- 'int_kind' : sets 'int'
- 'float_kind' : sets 'float' and 'longfloat'
- 'complex_kind' : sets 'complexfloat' and 'longcomplexfloat'
- 'str_kind' : sets 'numpystr'

floatmode
[str, optional] Controls the interpretation of the *precision* option for floating-point types. Can take the following values (default maxprec_equal):

- **'fixed': Always print exactly *precision* fractional digits,**
  even if this would print more or fewer digits than necessary to specify the value uniquely.
- **'unique': Print the minimum number of fractional digits necessary**
  to represent each value uniquely. Different elements may have a different number of digits. The value of the *precision* option is ignored.
- **'maxprec': Print at most *precision* fractional digits, but if**
  an element can be uniquely represented with fewer digits only print it with that many.
- **'maxprec_equal': Print at most *precision* fractional digits,**
  but if every element in the array can be uniquely represented with an equal number of fewer digits, use that many digits for all elements.

legacy
[string or *False*, optional] If set to the string `'1.13'` enables 1.13 legacy printing mode. This approximates numpy 1.13 print output by including a space in the sign position of floats and different behavior for 0d arrays. This also enables 1.21 legacy printing mode (described below).

If set to the string `'1.21'` enables 1.21 legacy printing mode. This approximates numpy 1.21 print output of complex structured dtypes by not inserting spaces after commas that separate fields and after colons.

If set to `'1.25'` approximates printing of 1.25 which mainly means that numeric scalars are printed without their type information, e.g. as `3.0` rather than `np.float64(3.0)`.

If set to `'2.1'`, shape information is not given when arrays are summarized (i.e., multiple elements replaced with `...`).

If set to *False*, disables legacy mode.

Unrecognized strings will be ignored with a warning for forward compatibility.

Changed in version 1.22.0.

Changed in version 2.2.

override_repr: callable, optional
If set a passed function will be used for generating arrays' repr. Other options will be ignored.

See also:

get_printoptions, *printoptions*, *array2string*

Notes

formatter is always reset with a call to *set_printoptions*.

Use *printoptions* as a context manager to set the values temporarily.

Examples

Floating point precision can be set:

```
>>> import numpy as np
>>> np.set_printoptions(precision=4)
>>> np.array([1.123456789])
[1.1235]
```

Long arrays can be summarised:

```
>>> np.set_printoptions(threshold=5)
>>> np.arange(10)
array([0, 1, 2, ..., 7, 8, 9], shape=(10,))
```

Small results can be suppressed:

```
>>> eps = np.finfo(float).eps
>>> x = np.arange(4.)
>>> x**2 - (x + eps)**2
array([-4.9304e-32, -4.4409e-16,  0.0000e+00,  0.0000e+00])
>>> np.set_printoptions(suppress=True)
>>> x**2 - (x + eps)**2
array([-0., -0.,  0.,  0.])
```

A custom formatter can be used to display array elements as desired:

```
>>> np.set_printoptions(formatter={'all':lambda x: 'int: '+str(-x)})
>>> x = np.arange(3)
>>> x
array([int: 0, int: -1, int: -2])
>>> np.set_printoptions()  # formatter gets reset
>>> x
array([0, 1, 2])
```

To put back the default options, you can use:

```
>>> np.set_printoptions(edgeitems=3, infstr='inf',
... linewidth=75, nanstr='nan', precision=8,
... suppress=False, threshold=1000, formatter=None)
```

Also to temporarily override options, use *printoptions* as a context manager:

```
>>> with np.printoptions(precision=2, suppress=True, threshold=5):
...     np.linspace(0, 10, 10)
array([ 0.  ,  1.11,  2.22, ...,  7.78,  8.89, 10.  ], shape=(10,))
```

numpy.**get_printoptions**()

Return the current print options.

Returns

print_opts

[dict] Dictionary of current print options with keys

- precision : int
- threshold : int
- edgeitems : int
- linewidth : int
- suppress : bool
- nanstr : str
- infstr : str
- sign : str
- formatter : dict of callables
- floatmode : str
- legacy : str or False

For a full description of these options, see *set_printoptions*.

See also:

set_printoptions, ***printoptions***

Examples

```
>>> import numpy as np
```

```
>>> np.get_printoptions()
{'edgeitems': 3, 'threshold': 1000, ..., 'override_repr': None}
```

```
>>> np.get_printoptions()['linewidth']
75
>>> np.set_printoptions(linewidth=100)
>>> np.get_printoptions()['linewidth']
100
```

numpy.**printoptions**(**args*, ***kwargs*)

Context manager for setting print options.

Set print options for the scope of the *with* block, and restore the old options at the end. See *set_printoptions* for the full description of available options.

See also:

set_printoptions, ***get_printoptions***

Examples

```
>>> import numpy as np
```

```
>>> from numpy.testing import assert_equal
>>> with np.printoptions(precision=2):
...     np.array([2.0]) / 3
array([0.67])
```

The *as*-clause of the *with*-statement gives the current print options:

```
>>> with np.printoptions(precision=2) as opts:
...      assert_equal(opts, np.get_printoptions())
```

Base-n representations

binary_repr(num[, width])	Return the binary representation of the input number as a string.
base_repr(number[, base, padding])	Return a string representation of a number in the given base system.

numpy.**base_repr**(*number*, *base=2*, *padding=0*)

Return a string representation of a number in the given base system.

Parameters

number
[int] The value to convert. Positive and negative values are handled.

base
: [int, optional] Convert *number* to the *base* number system. The valid range is 2-36, the default value is 2.

padding
: [int, optional] Number of zeros padded on the left. Default is 0 (no padding).

Returns

out
: [str] String representation of *number* in *base* system.

See also:

binary_repr
: Faster version of *base_repr* for base 2.

Examples

```
>>> import numpy as np
>>> np.base_repr(5)
'101'
>>> np.base_repr(6, 5)
'11'
>>> np.base_repr(7, base=5, padding=3)
'00012'
```

```
>>> np.base_repr(10, base=16)
'A'
>>> np.base_repr(32, base=16)
'20'
```

Data sources

lib.npyio.DataSource([destpath])	A generic data source file (file, http, ftp, ...).

Binary format description

lib.format	Binary serialization

1.4.10 Indexing routines

See also:

basics.indexing

Generating index arrays

*c_*	Translates slice objects to concatenation along the second axis.
*r_*	Translates slice objects to concatenation along the first axis.
*s_*	A nicer way to build up index tuples for arrays.
nonzero(a)	Return the indices of the elements that are non-zero.
where(condition, [x, y], /)	Return elements chosen from *x* or *y* depending on *condition*.
indices(dimensions[, dtype, sparse])	Return an array representing the indices of a grid.
*ix_*(*args)	Construct an open mesh from multiple sequences.
ogrid	An instance which returns an open multi-dimensional "meshgrid".
ravel_multi_index(multi_index, dims[, mode, ...])	Converts a tuple of index arrays into an array of flat indices, applying boundary modes to the multi-index.
unravel_index(indices, shape[, order])	Converts a flat index or array of flat indices into a tuple of coordinate arrays.
diag_indices(n[, ndim])	Return the indices to access the main diagonal of an array.
diag_indices_from(arr)	Return the indices to access the main diagonal of an n-dimensional array.
mask_indices(n, mask_func[, k])	Return the indices to access (n, n) arrays, given a masking function.
tril_indices(n[, k, m])	Return the indices for the lower-triangle of an (n, m) array.
tril_indices_from(arr[, k])	Return the indices for the lower-triangle of arr.
triu_indices(n[, k, m])	Return the indices for the upper-triangle of an (n, m) array.
triu_indices_from(arr[, k])	Return the indices for the upper-triangle of arr.

numpy.**c_ = <numpy.lib._index_tricks_impl.CClass object>**

Translates slice objects to concatenation along the second axis.

This is short-hand for `np.r_['-1,2,0', index expression]`, which is useful because of its common occurrence. In particular, arrays will be stacked along their last axis after being upgraded to at least 2-D with 1's post-pended to the shape (column vectors made out of 1-D arrays).

See also:

column_stack
Stack 1-D arrays as columns into a 2-D array.

r_
For more detailed documentation.

Examples

```
>>> import numpy as np
>>> np.c_[np.array([1,2,3]), np.array([4,5,6])]
array([[1, 4],
       [2, 5],
       [3, 6]])
>>> np.c_[np.array([[1,2,3]]), 0, 0, np.array([[4,5,6]])]
array([[1, 2, 3, ..., 4, 5, 6]])
```

numpy.**r_ = <numpy.lib._index_tricks_impl.RClass object>**

Translates slice objects to concatenation along the first axis.

This is a simple way to build up arrays quickly. There are two use cases.

1. If the index expression contains comma separated arrays, then stack them along their first axis.
2. If the index expression contains slice notation or scalars then create a 1-D array with a range indicated by the slice notation.

If slice notation is used, the syntax `start:stop:step` is equivalent to `np.arange(start, stop, step)` inside of the brackets. However, if `step` is an imaginary number (i.e. 100j) then its integer portion is interpreted as a number-of-points desired and the start and stop are inclusive. In other words `start:stop:stepj` is interpreted as `np.linspace(start, stop, step, endpoint=1)` inside of the brackets. After expansion of slice notation, all comma separated sequences are concatenated together.

Optional character strings placed as the first element of the index expression can be used to change the output. The strings 'r' or 'c' result in matrix output. If the result is 1-D and 'r' is specified a 1 x N (row) matrix is produced. If the result is 1-D and 'c' is specified, then a N x 1 (column) matrix is produced. If the result is 2-D then both provide the same matrix result.

A string integer specifies which axis to stack multiple comma separated arrays along. A string of two comma-separated integers allows indication of the minimum number of dimensions to force each entry into as the second integer (the axis to concatenate along is still the first integer).

A string with three comma-separated integers allows specification of the axis to concatenate along, the minimum number of dimensions to force the entries to, and which axis should contain the start of the arrays which are less than the specified number of dimensions. In other words the third integer allows you to specify where the 1's should be placed in the shape of the arrays that have their shapes upgraded. By default, they are placed in the front of the shape tuple. The third argument allows you to specify where the start of the array should be instead. Thus, a third argument of '0' would place the 1's at the end of the array shape. Negative integers specify where in the new shape tuple the last dimension of upgraded arrays should be placed, so the default is '-1'.

Parameters

Not a function, so takes no parameters

Returns

A concatenated ndarray or matrix.

See also:

concatenate
Join a sequence of arrays along an existing axis.

*c_*
Translates slice objects to concatenation along the second axis.

Examples

```
>>> import numpy as np
>>> np.r_[np.array([1,2,3]), 0, 0, np.array([4,5,6])]
array([1, 2, 3, ..., 4, 5, 6])
>>> np.r_[-1:1:6j, [0]*3, 5, 6]
array([-1. , -0.6, -0.2,  0.2,  0.6,  1. ,  0. ,  0. ,  0. ,  5. ,  6. ])
```

String integers specify the axis to concatenate along or the minimum number of dimensions to force entries into.

```
>>> a = np.array([[0, 1, 2], [3, 4, 5]])
>>> np.r_['-1', a, a] # concatenate along last axis
array([[0, 1, 2, 0, 1, 2],
       [3, 4, 5, 3, 4, 5]])
>>> np.r_['0,2', [1,2,3], [4,5,6]] # concatenate along first axis, dim>=2
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> np.r_['0,2,0', [1,2,3], [4,5,6]]
array([[1],
       [2],
       [3],
       [4],
       [5],
       [6]])
>>> np.r_['1,2,0', [1,2,3], [4,5,6]]
array([[1, 4],
       [2, 5],
       [3, 6]])
```

Using ‘r’ or ‘c’ as a first string argument creates a matrix.

```
>>> np.r_['r',[1,2,3], [4,5,6]]
matrix([[1, 2, 3, 4, 5, 6]])
```

numpy.**s_ = <numpy.lib._index_tricks_impl.IndexExpression object>**

A nicer way to build up index tuples for arrays.

Note: Use one of the two predefined instances `index_exp` or *s_* rather than directly using *IndexExpression*.

For any index combination, including slicing and axis insertion, `a[indices]` is the same as `a[np.index_exp[indices]]` for any array *a*. However, `np.index_exp[indices]` can be used anywhere in Python code and returns a tuple of slice objects that can be used in the construction of complex index expressions.

Parameters

maketuple
[bool] If True, always returns a tuple.

See also:

s_
Predefined instance without tuple conversion: *s_ = IndexExpression(maketuple=False)*. The `index_exp` is another predefined instance that always returns a tuple: *index_exp = IndexExpression(maketuple=True)*.

Notes

You can do all this with `slice` plus a few special objects, but there's a lot to remember and this version is simpler because it uses the standard array indexing syntax.

Examples

```
>>> import numpy as np
>>> np.s_[2::2]
slice(2, None, 2)
>>> np.index_exp[2::2]
(slice(2, None, 2),)
```

```
>>> np.array([0, 1, 2, 3, 4])[np.s_[2::2]]
array([2, 4])
```

numpy.**nonzero**(*a*)

Return the indices of the elements that are non-zero.

Returns a tuple of arrays, one for each dimension of *a*, containing the indices of the non-zero elements in that dimension. The values in *a* are always tested and returned in row-major, C-style order.

To group the indices by element, rather than dimension, use *argwhere*, which returns a row for each non-zero element.

Note: When called on a zero-d array or scalar, `nonzero(a)` is treated as `nonzero(atleast_1d(a))`.

Deprecated since version 1.17.0: Use *atleast_1d* explicitly if this behavior is deliberate.

Parameters

a
[array_like] Input array.

Returns

tuple_of_arrays
[tuple] Indices of elements that are non-zero.

See also:

flatnonzero
Return indices that are non-zero in the flattened version of the input array.

ndarray.nonzero
Equivalent ndarray method.

count_nonzero
Counts the number of non-zero elements in the input array.

Notes

While the nonzero values can be obtained with `a[nonzero(a)]`, it is recommended to use `x[x.astype(bool)]` or `x[x != 0]` instead, which will correctly handle 0-d arrays.

Examples

```
>>> import numpy as np
>>> x = np.array([[3, 0, 0], [0, 4, 0], [5, 6, 0]])
>>> x
array([[3, 0, 0],
       [0, 4, 0],
       [5, 6, 0]])
>>> np.nonzero(x)
(array([0, 1, 2, 2]), array([0, 1, 0, 1]))
```

```
>>> x[np.nonzero(x)]
array([3, 4, 5, 6])
>>> np.transpose(np.nonzero(x))
array([[0, 0],
       [1, 1],
       [2, 0],
       [2, 1]])
```

A common use for `nonzero` is to find the indices of an array, where a condition is True. Given an array *a*, the condition *a* > 3 is a boolean array and since False is interpreted as 0, np.nonzero(a > 3) yields the indices of the *a* where the condition is true.

```
>>> a = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
>>> a > 3
array([[False, False, False],
       [ True,  True,  True],
       [ True,  True,  True]])
>>> np.nonzero(a > 3)
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

Using this result to index *a* is equivalent to using the mask directly:

```
>>> a[np.nonzero(a > 3)]
array([4, 5, 6, 7, 8, 9])
>>> a[a > 3]  # prefer this spelling
array([4, 5, 6, 7, 8, 9])
```

`nonzero` can also be called as a method of the array.

```
>>> (a > 3).nonzero()
(array([1, 1, 1, 2, 2, 2]), array([0, 1, 2, 0, 1, 2]))
```

`numpy.`**`where`**(*condition*, [*x*, *y*,]/)

Return elements chosen from *x* or *y* depending on *condition*.

Note: When only *condition* is provided, this function is a shorthand for `np.asarray(condition).nonzero()`. Using *nonzero* directly should be preferred, as it behaves correctly for subclasses. The rest of this documentation covers only the case where all three arguments are provided.

Parameters

condition
[array_like, bool] Where True, yield *x*, otherwise yield *y*.

x, y
[array_like] Values from which to choose. *x*, *y* and *condition* need to be broadcastable to some shape.

Returns

out
[ndarray] An array with elements from *x* where *condition* is True, and elements from *y* elsewhere.

See also:

choose
nonzero
The function that is called when x and y are omitted

Notes

If all the arrays are 1-D, *where* is equivalent to:

```
[xv if c else yv
 for c, xv, yv in zip(condition, x, y)]
```

Examples

```
>>> import numpy as np
>>> a = np.arange(10)
>>> a
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> np.where(a < 5, a, 10*a)
array([ 0,  1,  2,  3,  4, 50, 60, 70, 80, 90])
```

This can be used on multidimensional arrays too:

```
>>> np.where([[True, False], [True, True]],
...          [[1, 2], [3, 4]],
...          [[9, 8], [7, 6]])
array([[1, 8],
       [3, 4]])
```

The shapes of x, y, and the condition are broadcast together:

```
>>> x, y = np.ogrid[:3, :4]
>>> np.where(x < y, x, 10 + y)  # both x and 10+y are broadcast
array([[10,  0,  0,  0],
       [10, 11,  1,  1],
       [10, 11, 12,  2]])
```

```
>>> a = np.array([[0, 1, 2],
...               [0, 2, 4],
...               [0, 3, 6]])
>>> np.where(a < 4, a, -1)  # -1 is broadcast
array([[ 0,  1,  2],
       [ 0,  2, -1],
       [ 0,  3, -1]])
```

numpy.**indices**(*dimensions*, *dtype=<class 'int'>*, *sparse=False*)

Return an array representing the indices of a grid.

Compute an array where the subarrays contain index values 0, 1, … varying only along the corresponding axis.

Parameters

dimensions
[sequence of ints] The shape of the grid.

dtype
[dtype, optional] Data type of the result.

sparse
[boolean, optional] Return a sparse representation of the grid instead of a dense representation. Default is False.

Returns

grid
[one ndarray or tuple of ndarrays]

If sparse is False:
Returns one array of grid indices, `grid.shape = (len(dimensions),) + tuple(dimensions)`.

If sparse is True:
Returns a tuple of arrays, with `grid[i].shape = (1, ..., 1, dimensions[i], 1, ..., 1)` with dimensions[i] in the ith place

See also:

mgrid*, *ogrid*, *meshgrid

Notes

The output shape in the dense case is obtained by prepending the number of dimensions in front of the tuple of dimensions, i.e. if *dimensions* is a tuple `(r0, ..., rN-1)` of length `N`, the output shape is `(N, r0, ..., rN-1)`.

The subarrays `grid[k]` contains the N-D array of indices along the `k-th` axis. Explicitly:

```
grid[k, i0, i1, ..., iN-1] = ik
```

Examples

```
>>> import numpy as np
>>> grid = np.indices((2, 3))
>>> grid.shape
(2, 2, 3)
>>> grid[0]        # row indices
array([[0, 0, 0],
       [1, 1, 1]])
>>> grid[1]        # column indices
array([[0, 1, 2],
       [0, 1, 2]])
```

The indices can be used as an index into an array.

```
>>> x = np.arange(20).reshape(5, 4)
>>> row, col = np.indices((2, 3))
>>> x[row, col]
array([[0, 1, 2],
       [4, 5, 6]])
```

Note that it would be more straightforward in the above example to extract the required elements directly with `x[:2, :3]`.

If sparse is set to true, the grid will be returned in a sparse representation.

```
>>> i, j = np.indices((2, 3), sparse=True)
>>> i.shape
(2, 1)
>>> j.shape
(1, 3)
>>> i        # row indices
array([[0],
       [1]])
>>> j        # column indices
array([[0, 1, 2]])
```

numpy.**ix_**(**args*)

Construct an open mesh from multiple sequences.

This function takes N 1-D sequences and returns N outputs with N dimensions each, such that the shape is 1 in all but one dimension and the dimension with the non-unit shape value cycles through all N dimensions.

Using *ix_* one can quickly construct index arrays that will index the cross product. `a[np.ix_([1,3],[2,5])]` returns the array `[[a[1,2] a[1,5]], [a[3,2] a[3,5]]]`.

Parameters

args
: [1-D sequences] Each sequence should be of integer or boolean type. Boolean sequences will be interpreted as boolean masks for the corresponding dimension (equivalent to passing in `np.nonzero(boolean_sequence)`).

Returns

out
: [tuple of ndarrays] N arrays with N dimensions each, with N the number of input sequences. Together these arrays form an open mesh.

See also:

ogrid, *mgrid*, *meshgrid*

Examples

```
>>> import numpy as np
>>> a = np.arange(10).reshape(2, 5)
>>> a
array([[0, 1, 2, 3, 4],
       [5, 6, 7, 8, 9]])
>>> ixgrid = np.ix_([0, 1], [2, 4])
>>> ixgrid
(array([[0],
       [1]]), array([[2, 4]]))
>>> ixgrid[0].shape, ixgrid[1].shape
((2, 1), (1, 2))
>>> a[ixgrid]
array([[2, 4],
       [7, 9]])
```

```
>>> ixgrid = np.ix_([True, True], [2, 4])
>>> a[ixgrid]
array([[2, 4],
       [7, 9]])
>>> ixgrid = np.ix_([True, True], [False, False, True, False, True])
>>> a[ixgrid]
array([[2, 4],
       [7, 9]])
```

numpy.**ravel_multi_index**(*multi_index*, *dims*, *mode='raise'*, *order='C'*)

Converts a tuple of index arrays into an array of flat indices, applying boundary modes to the multi-index.

Parameters

multi_index
[tuple of array_like] A tuple of integer arrays, one array for each dimension.

dims
[tuple of ints] The shape of array into which the indices from `multi_index` apply.

mode
[{'raise', 'wrap', 'clip'}, optional] Specifies how out-of-bounds indices are handled. Can specify either one mode or a tuple of modes, one mode per index.

- 'raise' – raise an error (default)
- 'wrap' – wrap around
- 'clip' – clip to the range

In 'clip' mode, a negative index which would normally wrap will clip to 0 instead.

order
[{'C', 'F'}, optional] Determines whether the multi-index should be viewed as indexing in row-major (C-style) or column-major (Fortran-style) order.

Returns

raveled_indices
[ndarray] An array of indices into the flattened version of an array of dimensions `dims`.

See also:

unravel_index

Examples

```
>>> import numpy as np
>>> arr = np.array([[3,6,6],[4,5,1]])
>>> np.ravel_multi_index(arr, (7,6))
array([22, 41, 37])
>>> np.ravel_multi_index(arr, (7,6), order='F')
array([31, 41, 13])
>>> np.ravel_multi_index(arr, (4,6), mode='clip')
array([22, 23, 19])
>>> np.ravel_multi_index(arr, (4,4), mode=('clip','wrap'))
array([12, 13, 13])
```

```
>>> np.ravel_multi_index((3,1,4,1), (6,7,8,9))
1621
```

numpy.**unravel_index**(*indices*, *shape*, *order='C'*)

Converts a flat index or array of flat indices into a tuple of coordinate arrays.

Parameters

indices
[array_like] An integer array whose elements are indices into the flattened version of an array of dimensions `shape`. Before version 1.6.0, this function accepted just one index value.

shape
[tuple of ints] The shape of the array to use for unraveling `indices`.

order
[{'C', 'F'}, optional] Determines whether the indices should be viewed as indexing in row-major (C-style) or column-major (Fortran-style) order.

Returns

unraveled_coords
[tuple of ndarray] Each array in the tuple has the same shape as the `indices` array.

See also:

ravel_multi_index

Examples

```
>>> import numpy as np
>>> np.unravel_index([22, 41, 37], (7,6))
(array([3, 6, 6]), array([4, 5, 1]))
>>> np.unravel_index([31, 41, 13], (7,6), order='F')
(array([3, 6, 6]), array([4, 5, 1]))
```

```
>>> np.unravel_index(1621, (6,7,8,9))
(3, 1, 4, 1)
```

numpy.**diag_indices**(*n*, *ndim=2*)

Return the indices to access the main diagonal of an array.

This returns a tuple of indices that can be used to access the main diagonal of an array *a* with `a.ndim >= 2` dimensions and shape (n, n, …, n). For `a.ndim = 2` this is the usual diagonal, for `a.ndim > 2` this is the set of indices to access `a[i, i, ..., i]` for `i = [0..n-1]`.

Parameters

n
[int] The size, along each dimension, of the arrays for which the returned indices can be used.

ndim
[int, optional] The number of dimensions.

See also:

diag_indices_from

Examples

```
>>> import numpy as np
```

Create a set of indices to access the diagonal of a (4, 4) array:

```
>>> di = np.diag_indices(4)
>>> di
(array([0, 1, 2, 3]), array([0, 1, 2, 3]))
>>> a = np.arange(16).reshape(4, 4)
>>> a
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
>>> a[di] = 100
>>> a
array([[100,   1,   2,   3],
       [  4, 100,   6,   7],
       [  8,   9, 100,  11],
       [ 12,  13,  14, 100]])
```

Now, we create indices to manipulate a 3-D array:

```
>>> d3 = np.diag_indices(2, 3)
>>> d3
(array([0, 1]), array([0, 1]), array([0, 1]))
```

And use it to set the diagonal of an array of zeros to 1:

```
>>> a = np.zeros((2, 2, 2), dtype=int)
>>> a[d3] = 1
>>> a
array([[[1, 0],
        [0, 0]],
       [[0, 0],
        [0, 1]]])
```

numpy.**diag_indices_from**(*arr*)

Return the indices to access the main diagonal of an n-dimensional array.

See *diag_indices* for full details.

Parameters

arr
[array, at least 2-D]

See also:

diag_indices

Examples

```
>>> import numpy as np
```

Create a 4 by 4 array.

```
>>> a = np.arange(16).reshape(4, 4)
>>> a
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
```

Get the indices of the diagonal elements.

```
>>> di = np.diag_indices_from(a)
>>> di
(array([0, 1, 2, 3]), array([0, 1, 2, 3]))
```

```
>>> a[di]
array([ 0,  5, 10, 15])
```

This is simply syntactic sugar for diag_indices.

```
>>> np.diag_indices(a.shape[0])
(array([0, 1, 2, 3]), array([0, 1, 2, 3]))
```

numpy.**mask_indices**(*n*, *mask_func*, *k=0*)

Return the indices to access (n, n) arrays, given a masking function.

Assume *mask_func* is a function that, for a square array a of size `(n, n)` with a possible offset argument *k*, when called as `mask_func(a, k)` returns a new array with zeros in certain locations (functions like *triu* or *tril* do precisely this). Then this function returns the indices where the non-zero values would be located.

Parameters

n
[int] The returned indices will be valid to access arrays of shape (n, n).

mask_func
[callable] A function whose call signature is similar to that of *triu*, *tril*. That is, `mask_func(x, k)` returns a boolean array, shaped like *x*. *k* is an optional argument to the function.

k

[scalar] An optional argument which is passed through to *mask_func*. Functions like `triu`, `tril` take a second argument that is interpreted as an offset.

Returns

indices

[tuple of arrays.] The *n* arrays of indices corresponding to the locations where `mask_func(np.ones((n, n)), k)` is True.

See also:

triu*, *tril*, *triu_indices*, *tril_indices

Examples

```
>>> import numpy as np
```

These are the indices that would allow you to access the upper triangular part of any 3x3 array:

```
>>> iu = np.mask_indices(3, np.triu)
```

For example, if *a* is a 3x3 array:

```
>>> a = np.arange(9).reshape(3, 3)
>>> a
array([[0, 1, 2],
       [3, 4, 5],
       [6, 7, 8]])
>>> a[iu]
array([0, 1, 2, 4, 5, 8])
```

An offset can be passed also to the masking function. This gets us the indices starting on the first diagonal right of the main one:

```
>>> iu1 = np.mask_indices(3, np.triu, 1)
```

with which we now extract only three elements:

```
>>> a[iu1]
array([1, 2, 5])
```

numpy.**tril_indices**(*n*, *k=0*, *m=None*)

Return the indices for the lower-triangle of an (n, m) array.

Parameters

n

[int] The row dimension of the arrays for which the returned indices will be valid.

k

[int, optional] Diagonal offset (see `tril` for details).

m

[int, optional] The column dimension of the arrays for which the returned arrays will be valid. By default *m* is taken equal to *n*.

Returns

inds
: [tuple of arrays] The row and column indices, respectively. The row indices are sorted in non-decreasing order, and the correspdonding column indices are strictly increasing for each row.

See also:

triu_indices
: similar function, for upper-triangular.

mask_indices
: generic function accepting an arbitrary mask function.

tril, ***triu***

Examples

```
>>> import numpy as np
```

Compute two different sets of indices to access 4x4 arrays, one for the lower triangular part starting at the main diagonal, and one starting two diagonals further right:

```
>>> il1 = np.tril_indices(4)
>>> il1
(array([0, 1, 1, 2, 2, 2, 3, 3, 3, 3]), array([0, 0, 1, 0, 1, 2, 0, 1, 2, 3]))
```

Note that row indices (first array) are non-decreasing, and the corresponding column indices (second array) are strictly increasing for each row. Here is how they can be used with a sample array:

```
>>> a = np.arange(16).reshape(4, 4)
>>> a
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
```

Both for indexing:

```
>>> a[il1]
array([ 0,  4,  5, ..., 13, 14, 15])
```

And for assigning values:

```
>>> a[il1] = -1
>>> a
array([[-1,  1,  2,  3],
       [-1, -1,  6,  7],
       [-1, -1, -1, 11],
       [-1, -1, -1, -1]])
```

These cover almost the whole array (two diagonals right of the main one):

```
>>> il2 = np.tril_indices(4, 2)
>>> a[il2] = -10
>>> a
array([[-10, -10, -10,   3],
```

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```
       [-10, -10, -10, -10],
       [-10, -10, -10, -10],
       [-10, -10, -10, -10]])
```

numpy.**tril_indices_from**(*arr*, *k=0*)

Return the indices for the lower-triangle of arr.

See *tril_indices* for full details.

Parameters

arr
[array_like] The indices will be valid for square arrays whose dimensions are the same as arr.

k
[int, optional] Diagonal offset (see *tril* for details).

See also:

tril_indices, ***tril***, ***triu_indices_from***

Examples

```
>>> import numpy as np
```

Create a 4 by 4 array

```
>>> a = np.arange(16).reshape(4, 4)
>>> a
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
```

Pass the array to get the indices of the lower triangular elements.

```
>>> trili = np.tril_indices_from(a)
>>> trili
(array([0, 1, 1, 2, 2, 2, 3, 3, 3, 3]), array([0, 0, 1, 0, 1, 2, 0, 1, 2, 3]))
```

```
>>> a[trili]
array([ 0,  4,  5,  8,  9, 10, 12, 13, 14, 15])
```

This is syntactic sugar for tril_indices().

```
>>> np.tril_indices(a.shape[0])
(array([0, 1, 1, 2, 2, 2, 3, 3, 3, 3]), array([0, 0, 1, 0, 1, 2, 0, 1, 2, 3]))
```

Use the *k* parameter to return the indices for the lower triangular array up to the k-th diagonal.

```
>>> trili1 = np.tril_indices_from(a, k=1)
>>> a[trili1]
array([ 0,  1,  4,  5,  6,  8,  9, 10, 11, 12, 13, 14, 15])
```

numpy.**triu_indices**(*n*, *k=0*, *m=None*)

Return the indices for the upper-triangle of an (n, m) array.

Parameters

n
[int] The size of the arrays for which the returned indices will be valid.

k
[int, optional] Diagonal offset (see *triu* for details).

m
[int, optional] The column dimension of the arrays for which the returned arrays will be valid. By default *m* is taken equal to *n*.

Returns

inds
[tuple, shape(2) of ndarrays, shape(*n*)] The row and column indices, respectively. The row indices are sorted in non-decreasing order, and the correspdonding column indices are strictly increasing for each row.

See also:

tril_indices
similar function, for lower-triangular.

mask_indices
generic function accepting an arbitrary mask function.

triu, ***tril***

Examples

```
>>> import numpy as np
```

Compute two different sets of indices to access 4x4 arrays, one for the upper triangular part starting at the main diagonal, and one starting two diagonals further right:

```
>>> iu1 = np.triu_indices(4)
>>> iu1
(array([0, 0, 0, 0, 1, 1, 1, 2, 2, 3]), array([0, 1, 2, 3, 1, 2, 3, 2, 3, 3]))
```

Note that row indices (first array) are non-decreasing, and the corresponding column indices (second array) are strictly increasing for each row.

Here is how they can be used with a sample array:

```
>>> a = np.arange(16).reshape(4, 4)
>>> a
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
```

Both for indexing:

```
>>> a[iu1]
array([ 0,  1,  2, ..., 10, 11, 15])
```

And for assigning values:

```
>>> a[iu1] = -1
>>> a
array([[-1, -1, -1, -1],
       [ 4, -1, -1, -1],
       [ 8,  9, -1, -1],
       [12, 13, 14, -1]])
```

These cover only a small part of the whole array (two diagonals right of the main one):

```
>>> iu2 = np.triu_indices(4, 2)
>>> a[iu2] = -10
>>> a
array([[ -1,  -1, -10, -10],
       [  4,  -1,  -1, -10],
       [  8,   9,  -1,  -1],
       [ 12,  13,  14,  -1]])
```

numpy.**triu_indices_from**(*arr*, *k=0*)

Return the indices for the upper-triangle of arr.

See *triu_indices* for full details.

Parameters

arr
: [ndarray, shape(N, N)] The indices will be valid for square arrays.

k
: [int, optional] Diagonal offset (see *triu* for details).

Returns

triu_indices_from
: [tuple, shape(2) of ndarray, shape(N)] Indices for the upper-triangle of *arr*.

See also:

triu_indices*, *triu*, *tril_indices_from

Examples

```
>>> import numpy as np
```

Create a 4 by 4 array

```
>>> a = np.arange(16).reshape(4, 4)
>>> a
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11],
       [12, 13, 14, 15]])
```

Pass the array to get the indices of the upper triangular elements.

```
>>> triui = np.triu_indices_from(a)
>>> triui
(array([0, 0, 0, 0, 1, 1, 1, 2, 2, 3]), array([0, 1, 2, 3, 1, 2, 3, 2, 3, 3]))
```

```
>>> a[triui]
array([ 0,  1,  2,  3,  5,  6,  7, 10, 11, 15])
```

This is syntactic sugar for triu_indices().

```
>>> np.triu_indices(a.shape[0])
(array([0, 0, 0, 0, 1, 1, 1, 2, 2, 3]), array([0, 1, 2, 3, 1, 2, 3, 2, 3, 3]))
```

Use the *k* parameter to return the indices for the upper triangular array from the k-th diagonal.

```
>>> triuim1 = np.triu_indices_from(a, k=1)
>>> a[triuim1]
array([ 1,  2,  3,  6,  7, 11])
```

Indexing-like operations

take(a, indices[, axis, out, mode])	Take elements from an array along an axis.
take_along_axis(arr, indices, axis)	Take values from the input array by matching 1d index and data slices.
choose(a, choices[, out, mode])	Construct an array from an index array and a list of arrays to choose from.
compress(condition, a[, axis, out])	Return selected slices of an array along given axis.
diag(v[, k])	Extract a diagonal or construct a diagonal array.
diagonal(a[, offset, axis1, axis2])	Return specified diagonals.
select(condlist, choicelist[, default])	Return an array drawn from elements in choicelist, depending on conditions.

numpy.**take**(*a*, *indices*, *axis=None*, *out=None*, *mode='raise'*)

Take elements from an array along an axis.

When axis is not None, this function does the same thing as "fancy" indexing (indexing arrays using arrays); however, it can be easier to use if you need elements along a given axis. A call such as `np.take(arr, indices, axis=3)` is equivalent to `arr[:,:,:,indices,...]`.

Explained without fancy indexing, this is equivalent to the following use of *ndindex*, which sets each of `ii`, `jj`, and `kk` to a tuple of indices:

```
Ni, Nk = a.shape[:axis], a.shape[axis+1:]
Nj = indices.shape
for ii in ndindex(Ni):
    for jj in ndindex(Nj):
        for kk in ndindex(Nk):
            out[ii + jj + kk] = a[ii + (indices[jj],) + kk]
```

Parameters

a
[array_like (Ni…, M, Nk…)] The source array.

indices
[array_like (Nj…)] The indices of the values to extract. Also allow scalars for indices.

axis
[int, optional] The axis over which to select values. By default, the flattened input array is used.

out
: [ndarray, optional (Ni…, Nj…, Nk…)] If provided, the result will be placed in this array. It should be of the appropriate shape and dtype. Note that *out* is always buffered if *mode='raise'*; use other modes for better performance.

mode
: [{'raise', 'wrap', 'clip'}, optional] Specifies how out-of-bounds indices will behave.

- 'raise' – raise an error (default)
- 'wrap' – wrap around
- 'clip' – clip to the range

'clip' mode means that all indices that are too large are replaced by the index that addresses the last element along that axis. Note that this disables indexing with negative numbers.

Returns

out
: [ndarray (Ni…, Nj…, Nk…)] The returned array has the same type as *a*.

See also:

compress
: Take elements using a boolean mask

ndarray.take
: equivalent method

take_along_axis
: Take elements by matching the array and the index arrays

Notes

By eliminating the inner loop in the description above, and using *s_* to build simple slice objects, *take* can be expressed in terms of applying fancy indexing to each 1-d slice:

```
Ni, Nk = a.shape[:axis], a.shape[axis+1:]
for ii in ndindex(Ni):
    for kk in ndindex(Nj):
        out[ii + s_[...,] + kk] = a[ii + s_[:,] + kk][indices]
```

For this reason, it is equivalent to (but faster than) the following use of *apply_along_axis*:

```
out = np.apply_along_axis(lambda a_1d: a_1d[indices], axis, a)
```

Examples

```
>>> import numpy as np
>>> a = [4, 3, 5, 7, 6, 8]
>>> indices = [0, 1, 4]
>>> np.take(a, indices)
array([4, 3, 6])
```

In this example if *a* is an ndarray, "fancy" indexing can be used.

```
>>> a = np.array(a)
>>> a[indices]
array([4, 3, 6])
```

If *indices* is not one dimensional, the output also has these dimensions.

```
>>> np.take(a, [[0, 1], [2, 3]])
array([[4, 3],
       [5, 7]])
```

numpy.**take_along_axis**(*arr*, *indices*, *axis*)

Take values from the input array by matching 1d index and data slices.

This iterates over matching 1d slices oriented along the specified axis in the index and data arrays, and uses the former to look up values in the latter. These slices can be different lengths.

Functions returning an index along an axis, like *argsort* and *argpartition*, produce suitable indices for this function.

Parameters

arr
[ndarray (Ni…, M, Nk…)] Source array

indices
[ndarray (Ni…, J, Nk…)] Indices to take along each 1d slice of *arr*. This must match the dimension of arr, but dimensions Ni and Nj only need to broadcast against *arr*.

axis
[int] The axis to take 1d slices along. If axis is None, the input array is treated as if it had first been flattened to 1d, for consistency with *sort* and *argsort*.

Returns

out: ndarray (Ni…, J, Nk…)
The indexed result.

See also:

take
Take along an axis, using the same indices for every 1d slice

put_along_axis
Put values into the destination array by matching 1d index and data slices

Notes

This is equivalent to (but faster than) the following use of *ndindex* and *s_*, which sets each of `ii` and `kk` to a tuple of indices:

```
Ni, M, Nk = a.shape[:axis], a.shape[axis], a.shape[axis+1:]
J = indices.shape[axis]  # Need not equal M
out = np.empty(Ni + (J,) + Nk)

for ii in ndindex(Ni):
    for kk in ndindex(Nk):
        a_1d       = a      [ii + s_[:,] + kk]
        indices_1d = indices[ii + s_[:,] + kk]
```

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```
        out_1d     = out    [ii + s_[:,] + kk]
        for j in range(J):
            out_1d[j] = a_1d[indices_1d[j]]
```

Equivalently, eliminating the inner loop, the last two lines would be:

```
out_1d[:] = a_1d[indices_1d]
```

Examples

```
>>> import numpy as np
```

For this sample array

```
>>> a = np.array([[10, 30, 20], [60, 40, 50]])
```

We can sort either by using sort directly, or argsort and this function

```
>>> np.sort(a, axis=1)
array([[10, 20, 30],
       [40, 50, 60]])
>>> ai = np.argsort(a, axis=1)
>>> ai
array([[0, 2, 1],
       [1, 2, 0]])
>>> np.take_along_axis(a, ai, axis=1)
array([[10, 20, 30],
       [40, 50, 60]])
```

The same works for max and min, if you maintain the trivial dimension with `keepdims`:

```
>>> np.max(a, axis=1, keepdims=True)
array([[30],
       [60]])
>>> ai = np.argmax(a, axis=1, keepdims=True)
>>> ai
array([[1],
       [0]])
>>> np.take_along_axis(a, ai, axis=1)
array([[30],
       [60]])
```

If we want to get the max and min at the same time, we can stack the indices first

```
>>> ai_min = np.argmin(a, axis=1, keepdims=True)
>>> ai_max = np.argmax(a, axis=1, keepdims=True)
>>> ai = np.concatenate([ai_min, ai_max], axis=1)
>>> ai
array([[0, 1],
       [1, 0]])
>>> np.take_along_axis(a, ai, axis=1)
array([[10, 30],
       [40, 60]])
```

numpy.**choose**(*a*, *choices*, *out=None*, *mode='raise'*)

Construct an array from an index array and a list of arrays to choose from.

First of all, if confused or uncertain, definitely look at the Examples - in its full generality, this function is less simple than it might seem from the following code description:

```
np.choose(a,c) == np.array([c[a[I]][I] for I in np.ndindex(a.shape)])
```

But this omits some subtleties. Here is a fully general summary:

Given an "index" array (*a*) of integers and a sequence of `n` arrays (*choices*), *a* and each choice array are first broadcast, as necessary, to arrays of a common shape; calling these *Ba* and *Bchoices[i], i = 0,...,n-1* we have that, necessarily, `Ba.shape == Bchoices[i].shape` for each `i`. Then, a new array with shape `Ba.shape` is created as follows:

- if `mode='raise'` (the default), then, first of all, each element of `a` (and thus `Ba`) must be in the range `[0, n-1]`; now, suppose that `i` (in that range) is the value at the `(j0, j1, ..., jm)` position in `Ba` - then the value at the same position in the new array is the value in `Bchoices[i]` at that same position;
- if `mode='wrap'`, values in *a* (and thus *Ba*) may be any (signed) integer; modular arithmetic is used to map integers outside the range *[0, n-1]* back into that range; and then the new array is constructed as above;
- if `mode='clip'`, values in *a* (and thus `Ba`) may be any (signed) integer; negative integers are mapped to 0; values greater than `n-1` are mapped to `n-1`; and then the new array is constructed as above.

Parameters

a
: [int array] This array must contain integers in `[0, n-1]`, where `n` is the number of choices, unless `mode=wrap` or `mode=clip`, in which cases any integers are permissible.

choices
: [sequence of arrays] Choice arrays. *a* and all of the choices must be broadcastable to the same shape. If *choices* is itself an array (not recommended), then its outermost dimension (i.e., the one corresponding to `choices.shape[0]`) is taken as defining the "sequence".

out
: [array, optional] If provided, the result will be inserted into this array. It should be of the appropriate shape and dtype. Note that *out* is always buffered if `mode='raise'`; use other modes for better performance.

mode
: [{'raise' (default), 'wrap', 'clip'}, optional] Specifies how indices outside `[0, n-1]` will be treated:

  - 'raise' : an exception is raised
  - 'wrap' : value becomes value mod `n`
  - 'clip' : values < 0 are mapped to 0, values > n-1 are mapped to n-1

Returns

merged_array
: [array] The merged result.

Raises

ValueError: shape mismatch
: If *a* and each choice array are not all broadcastable to the same shape.

See also:

ndarray.choose
: equivalent method

numpy.take_along_axis
: Preferable if *choices* is an array

Notes

To reduce the chance of misinterpretation, even though the following "abuse" is nominally supported, *choices* should neither be, nor be thought of as, a single array, i.e., the outermost sequence-like container should be either a list or a tuple.

Examples

```
>>> import numpy as np
>>> choices = [[0, 1, 2, 3], [10, 11, 12, 13],
...   [20, 21, 22, 23], [30, 31, 32, 33]]
>>> np.choose([2, 3, 1, 0], choices
... # the first element of the result will be the first element of the
... # third (2+1) "array" in choices, namely, 20; the second element
... # will be the second element of the fourth (3+1) choice array, i.e.,
... # 31, etc.
... )
array([20, 31, 12,  3])
>>> np.choose([2, 4, 1, 0], choices, mode='clip') # 4 goes to 3 (4-1)
array([20, 31, 12,  3])
>>> # because there are 4 choice arrays
>>> np.choose([2, 4, 1, 0], choices, mode='wrap') # 4 goes to (4 mod 4)
array([20,  1, 12,  3])
>>> # i.e., 0
```

A couple examples illustrating how choose broadcasts:

```
>>> a = [[1, 0, 1], [0, 1, 0], [1, 0, 1]]
>>> choices = [-10, 10]
>>> np.choose(a, choices)
array([[ 10, -10,  10],
       [-10,  10, -10],
       [ 10, -10,  10]])
```

```
>>> # With thanks to Anne Archibald
>>> a = np.array([0, 1]).reshape((2,1,1))
>>> c1 = np.array([1, 2, 3]).reshape((1,3,1))
>>> c2 = np.array([-1, -2, -3, -4, -5]).reshape((1,1,5))
>>> np.choose(a, (c1, c2)) # result is 2x3x5, res[0,:,:]=c1, res[1,:,:]=c2
array([[[ 1,  1,  1,  1,  1],
        [ 2,  2,  2,  2,  2],
        [ 3,  3,  3,  3,  3]],
       [[-1, -2, -3, -4, -5],
        [-1, -2, -3, -4, -5],
        [-1, -2, -3, -4, -5]]])
```

numpy.**compress**(*condition*, *a*, *axis=None*, *out=None*)

Return selected slices of an array along given axis.

When working along a given axis, a slice along that axis is returned in *output* for each index where *condition* evaluates to True. When working on a 1-D array, `compress` is equivalent to `extract`.

Parameters

condition
[1-D array of bools] Array that selects which entries to return. If len(condition) is less than the size of *a* along the given axis, then output is truncated to the length of the condition array.

a
[array_like] Array from which to extract a part.

axis
[int, optional] Axis along which to take slices. If None (default), work on the flattened array.

out
[ndarray, optional] Output array. Its type is preserved and it must be of the right shape to hold the output.

Returns

compressed_array
[ndarray] A copy of *a* without the slices along axis for which *condition* is false.

See also:

take*, *choose*, *diag*, *diagonal*, *select
ndarray.compress
Equivalent method in ndarray

extract
Equivalent method when working on 1-D arrays

ufuncs-output-type

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4], [5, 6]])
>>> a
array([[1, 2],
       [3, 4],
       [5, 6]])
>>> np.compress([0, 1], a, axis=0)
array([[3, 4]])
>>> np.compress([False, True, True], a, axis=0)
array([[3, 4],
       [5, 6]])
>>> np.compress([False, True], a, axis=1)
array([[2],
       [4],
       [6]])
```

Working on the flattened array does not return slices along an axis but selects elements.

```
>>> np.compress([False, True], a)
array([2])
```

numpy.**select**(*condlist*, *choicelist*, *default=0*)

Return an array drawn from elements in choicelist, depending on conditions.

Parameters

condlist
[list of bool ndarrays] The list of conditions which determine from which array in *choicelist* the output elements are taken. When multiple conditions are satisfied, the first one encountered in *condlist* is used.

choicelist
[list of ndarrays] The list of arrays from which the output elements are taken. It has to be of the same length as *condlist*.

default
[scalar, optional] The element inserted in *output* when all conditions evaluate to False.

Returns

output
[ndarray] The output at position m is the m-th element of the array in *choicelist* where the m-th element of the corresponding array in *condlist* is True.

See also:

where
Return elements from one of two arrays depending on condition.

take, ***choose***, ***compress***, ***diag***, ***diagonal***

Examples

```
>>> import numpy as np
```

Beginning with an array of integers from 0 to 5 (inclusive), elements less than `3` are negated, elements greater than `3` are squared, and elements not meeting either of these conditions (exactly `3`) are replaced with a *default* value of `42`.

```
>>> x = np.arange(6)
>>> condlist = [x<3, x>3]
>>> choicelist = [x, x**2]
>>> np.select(condlist, choicelist, 42)
array([ 0,  1,  2, 42, 16, 25])
```

When multiple conditions are satisfied, the first one encountered in *condlist* is used.

```
>>> condlist = [x<=4, x>3]
>>> choicelist = [x, x**2]
>>> np.select(condlist, choicelist, 55)
array([ 0,  1,  2,  3,  4, 25])
```

Inserting data into arrays

place(arr, mask, vals)	Change elements of an array based on conditional and input values.
put(a, ind, v[, mode])	Replaces specified elements of an array with given values.
put_along_axis(arr, indices, values, axis)	Put values into the destination array by matching 1d index and data slices.
putmask(a, mask, values)	Changes elements of an array based on conditional and input values.
fill_diagonal(a, val[, wrap])	Fill the main diagonal of the given array of any dimensionality.

numpy.**place**(*arr*, *mask*, *vals*)

Change elements of an array based on conditional and input values.

Similar to `np.copyto(arr, vals, where=mask)`, the difference is that *place* uses the first N elements of *vals*, where N is the number of True values in *mask*, while *copyto* uses the elements where *mask* is True.

Note that *extract* does the exact opposite of *place*.

Parameters

arr
[ndarray] Array to put data into.

mask
[array_like] Boolean mask array. Must have the same size as *a*.

vals
[1-D sequence] Values to put into *a*. Only the first N elements are used, where N is the number of True values in *mask*. If *vals* is smaller than N, it will be repeated, and if elements of *a* are to be masked, this sequence must be non-empty.

See also:

copyto*, *put*, *take*, *extract

Examples

```
>>> import numpy as np
>>> arr = np.arange(6).reshape(2, 3)
>>> np.place(arr, arr>2, [44, 55])
>>> arr
array([[ 0,  1,  2],
       [44, 55, 44]])
```

numpy.**put**(*a*, *ind*, *v*, *mode='raise'*)

Replaces specified elements of an array with given values.

The indexing works on the flattened target array. *put* is roughly equivalent to:

```
a.flat[ind] = v
```

Parameters

a
: [ndarray] Target array.

ind
: [array_like] Target indices, interpreted as integers.

v
: [array_like] Values to place in *a* at target indices. If *v* is shorter than *ind* it will be repeated as necessary.

mode
: [{'raise', 'wrap', 'clip'}, optional] Specifies how out-of-bounds indices will behave.

- 'raise' – raise an error (default)
- 'wrap' – wrap around
- 'clip' – clip to the range

'clip' mode means that all indices that are too large are replaced by the index that addresses the last element along that axis. Note that this disables indexing with negative numbers. In 'raise' mode, if an exception occurs the target array may still be modified.

See also:

putmask, ***place***
put_along_axis
: Put elements by matching the array and the index arrays

Examples

```
>>> import numpy as np
>>> a = np.arange(5)
>>> np.put(a, [0, 2], [-44, -55])
>>> a
array([-44,   1, -55,   3,   4])
```

```
>>> a = np.arange(5)
>>> np.put(a, 22, -5, mode='clip')
>>> a
array([ 0,  1,  2,  3, -5])
```

numpy.**put_along_axis**(*arr*, *indices*, *values*, *axis*)
: Put values into the destination array by matching 1d index and data slices.

This iterates over matching 1d slices oriented along the specified axis in the index and data arrays, and uses the former to place values into the latter. These slices can be different lengths.

Functions returning an index along an axis, like *argsort* and *argpartition*, produce suitable indices for this function.

Parameters

arr
: [ndarray (Ni…, M, Nk…)] Destination array.

indices
: [ndarray (Ni…, J, Nk…)] Indices to change along each 1d slice of *arr*. This must match the dimension of arr, but dimensions in Ni and Nj may be 1 to broadcast against *arr*.

values
: [array_like (Ni…, J, Nk…)] values to insert at those indices. Its shape and dimension are broadcast to match that of *indices*.

axis
: [int] The axis to take 1d slices along. If axis is None, the destination array is treated as if a flattened 1d view had been created of it.

See also:

take_along_axis
: Take values from the input array by matching 1d index and data slices

Notes

This is equivalent to (but faster than) the following use of *ndindex* and *s_*, which sets each of `ii` and `kk` to a tuple of indices:

```
Ni, M, Nk = a.shape[:axis], a.shape[axis], a.shape[axis+1:]
J = indices.shape[axis]  # Need not equal M

for ii in ndindex(Ni):
    for kk in ndindex(Nk):
        a_1d       = a      [ii + s_[:,] + kk]
        indices_1d = indices[ii + s_[:,] + kk]
        values_1d  = values [ii + s_[:,] + kk]
        for j in range(J):
            a_1d[indices_1d[j]] = values_1d[j]
```

Equivalently, eliminating the inner loop, the last two lines would be:

```
a_1d[indices_1d] = values_1d
```

Examples

```
>>> import numpy as np
```

For this sample array

```
>>> a = np.array([[10, 30, 20], [60, 40, 50]])
```

We can replace the maximum values with:

```
>>> ai = np.argmax(a, axis=1, keepdims=True)
>>> ai
array([[1],
       [0]])
>>> np.put_along_axis(a, ai, 99, axis=1)
>>> a
array([[10, 99, 20],
       [99, 40, 50]])
```

numpy.**putmask**(*a*, *mask*, *values*)

Changes elements of an array based on conditional and input values.

Sets `a.flat[n] = values[n]` for each n where `mask.flat[n]==True`.

If *values* is not the same size as *a* and *mask* then it will repeat. This gives behavior different from `a[mask] = values`.

Parameters

a
[ndarray] Target array.

mask
[array_like] Boolean mask array. It has to be the same shape as *a*.

values
[array_like] Values to put into *a* where *mask* is True. If *values* is smaller than *a* it will be repeated.

See also:

place, ***put***, ***take***, ***copyto***

Examples

```
>>> import numpy as np
>>> x = np.arange(6).reshape(2, 3)
>>> np.putmask(x, x>2, x**2)
>>> x
array([[ 0,  1,  2],
       [ 9, 16, 25]])
```

If *values* is smaller than *a* it is repeated:

```
>>> x = np.arange(5)
>>> np.putmask(x, x>1, [-33, -44])
>>> x
array([  0,   1, -33, -44, -33])
```

numpy.**fill_diagonal**(*a*, *val*, *wrap=False*)

Fill the main diagonal of the given array of any dimensionality.

For an array *a* with `a.ndim >= 2`, the diagonal is the list of values `a[i, ..., i]` with indices `i` all identical. This function modifies the input array in-place without returning a value.

Parameters

a
[array, at least 2-D.] Array whose diagonal is to be filled in-place.

val
[scalar or array_like] Value(s) to write on the diagonal. If *val* is scalar, the value is written along the diagonal. If array-like, the flattened *val* is written along the diagonal, repeating if necessary to fill all diagonal entries.

wrap
[bool] For tall matrices in NumPy version up to 1.6.2, the diagonal "wrapped" after N columns. You can have this behavior with this option. This affects only tall matrices.

See also:

diag_indices, ***diag_indices_from***

Notes

This functionality can be obtained via *diag_indices*, but internally this version uses a much faster implementation that never constructs the indices and uses simple slicing.

Examples

```
>>> import numpy as np
>>> a = np.zeros((3, 3), int)
>>> np.fill_diagonal(a, 5)
>>> a
array([[5, 0, 0],
       [0, 5, 0],
       [0, 0, 5]])
```

The same function can operate on a 4-D array:

```
>>> a = np.zeros((3, 3, 3, 3), int)
>>> np.fill_diagonal(a, 4)
```

We only show a few blocks for clarity:

```
>>> a[0, 0]
array([[4, 0, 0],
       [0, 0, 0],
       [0, 0, 0]])
>>> a[1, 1]
array([[0, 0, 0],
       [0, 4, 0],
       [0, 0, 0]])
>>> a[2, 2]
array([[0, 0, 0],
       [0, 0, 0],
       [0, 0, 4]])
```

The wrap option affects only tall matrices:

```
>>> # tall matrices no wrap
>>> a = np.zeros((5, 3), int)
>>> np.fill_diagonal(a, 4)
>>> a
array([[4, 0, 0],
       [0, 4, 0],
       [0, 0, 4],
       [0, 0, 0],
       [0, 0, 0]])
```

```
>>> # tall matrices wrap
>>> a = np.zeros((5, 3), int)
>>> np.fill_diagonal(a, 4, wrap=True)
>>> a
array([[4, 0, 0],
       [0, 4, 0],
       [0, 0, 4],
       [0, 0, 0],
       [4, 0, 0]])
```

```
>>> # wide matrices
>>> a = np.zeros((3, 5), int)
>>> np.fill_diagonal(a, 4, wrap=True)
>>> a
array([[4, 0, 0, 0, 0],
       [0, 4, 0, 0, 0],
       [0, 0, 4, 0, 0]])
```

The anti-diagonal can be filled by reversing the order of elements using either *numpy.flipud* or *numpy.fliplr*.

```
>>> a = np.zeros((3, 3), int);
>>> np.fill_diagonal(np.fliplr(a), [1,2,3])  # Horizontal flip
>>> a
array([[0, 0, 1],
       [0, 2, 0],
       [3, 0, 0]])
>>> np.fill_diagonal(np.flipud(a), [1,2,3])  # Vertical flip
>>> a
array([[0, 0, 3],
       [0, 2, 0],
       [1, 0, 0]])
```

Note that the order in which the diagonal is filled varies depending on the flip function.

Iterating over arrays

nditer(op[, flags, op_flags, op_dtypes, ...])	Efficient multi-dimensional iterator object to iterate over arrays.
ndenumerate(arr)	Multidimensional index iterator.
ndindex(*shape)	An N-dimensional iterator object to index arrays.
nested_iters(op, axes[, flags, op_flags, ...])	Create nditers for use in nested loops
flatiter()	Flat iterator object to iterate over arrays.
iterable(y)	Check whether or not an object can be iterated over.

class numpy.**nditer**(*op*, *flags=None*, *op_flags=None*, *op_dtypes=None*, *order='K'*, *casting='safe'*, *op_axes=None*, *itershape=None*, *buffersize=0*)

Efficient multi-dimensional iterator object to iterate over arrays. To get started using this object, see the *introductory guide to array iteration*.

Parameters

op
[ndarray or sequence of array_like] The array(s) to iterate over.

flags
[sequence of str, optional] Flags to control the behavior of the iterator.

- `buffered` enables buffering when required.
- `c_index` causes a C-order index to be tracked.
- `f_index` causes a Fortran-order index to be tracked.
- `multi_index` causes a multi-index, or a tuple of indices with one per iteration dimension, to be tracked.

- `common_dtype` causes all the operands to be converted to a common data type, with copying or buffering as necessary.
- `copy_if_overlap` causes the iterator to determine if read operands have overlap with write operands, and make temporary copies as necessary to avoid overlap. False positives (needless copying) are possible in some cases.
- `delay_bufalloc` delays allocation of the buffers until a reset() call is made. Allows `allocate` operands to be initialized before their values are copied into the buffers.
- `external_loop` causes the `values` given to be one-dimensional arrays with multiple values instead of zero-dimensional arrays.
- `grow_inner` allows the `value` array sizes to be made larger than the buffer size when both `buffered` and `external_loop` is used.
- `ranged` allows the iterator to be restricted to a sub-range of the iterindex values.
- `refs_ok` enables iteration of reference types, such as object arrays.
- `reduce_ok` enables iteration of `readwrite` operands which are broadcasted, also known as reduction operands.
- `zerosize_ok` allows `itersize` to be zero.

op_flags
[list of list of str, optional] This is a list of flags for each operand. At minimum, one of `readonly`, `readwrite`, or `writeonly` must be specified.

- `readonly` indicates the operand will only be read from.
- `readwrite` indicates the operand will be read from and written to.
- `writeonly` indicates the operand will only be written to.
- `no_broadcast` prevents the operand from being broadcasted.
- `contig` forces the operand data to be contiguous.
- `aligned` forces the operand data to be aligned.
- `nbo` forces the operand data to be in native byte order.
- `copy` allows a temporary read-only copy if required.
- `updateifcopy` allows a temporary read-write copy if required.
- `allocate` causes the array to be allocated if it is None in the `op` parameter.
- `no_subtype` prevents an `allocate` operand from using a subtype.
- `arraymask` indicates that this operand is the mask to use for selecting elements when writing to operands with the 'writemasked' flag set. The iterator does not enforce this, but when writing from a buffer back to the array, it only copies those elements indicated by this mask.
- `writemasked` indicates that only elements where the chosen `arraymask` operand is True will be written to.
- `overlap_assume_elementwise` can be used to mark operands that are accessed only in the iterator order, to allow less conservative copying when `copy_if_overlap` is present.

op_dtypes
[dtype or tuple of dtype(s), optional] The required data type(s) of the operands. If copying or buffering is enabled, the data will be converted to/from their original types.

order
: [{'C', 'F', 'A', 'K'}, optional] Controls the iteration order. 'C' means C order, 'F' means Fortran order, 'A' means 'F' order if all the arrays are Fortran contiguous, 'C' order otherwise, and 'K' means as close to the order the array elements appear in memory as possible. This also affects the element memory order of `allocate` operands, as they are allocated to be compatible with iteration order. Default is 'K'.

casting
: [{'no', 'equiv', 'safe', 'same_kind', 'unsafe'}, optional] Controls what kind of data casting may occur when making a copy or buffering. Setting this to 'unsafe' is not recommended, as it can adversely affect accumulations.

- 'no' means the data types should not be cast at all.
- 'equiv' means only byte-order changes are allowed.
- 'safe' means only casts which can preserve values are allowed.
- 'same_kind' means only safe casts or casts within a kind, like float64 to float32, are allowed.
- 'unsafe' means any data conversions may be done.

op_axes
: [list of list of ints, optional] If provided, is a list of ints or None for each operands. The list of axes for an operand is a mapping from the dimensions of the iterator to the dimensions of the operand. A value of -1 can be placed for entries, causing that dimension to be treated as *newaxis*.

itershape
: [tuple of ints, optional] The desired shape of the iterator. This allows `allocate` operands with a dimension mapped by op_axes not corresponding to a dimension of a different operand to get a value not equal to 1 for that dimension.

buffersize
: [int, optional] When buffering is enabled, controls the size of the temporary buffers. Set to 0 for the default value.

Notes

nditer supersedes *flatiter*. The iterator implementation behind *nditer* is also exposed by the NumPy C API.

The Python exposure supplies two iteration interfaces, one which follows the Python iterator protocol, and another which mirrors the C-style do-while pattern. The native Python approach is better in most cases, but if you need the coordinates or index of an iterator, use the C-style pattern.

Examples

Here is how we might write an `iter_add` function, using the Python iterator protocol:

```
>>> import numpy as np
```

```
>>> def iter_add_py(x, y, out=None):
...     addop = np.add
...     it = np.nditer([x, y, out], [],
...                 [['readonly'], ['readonly'], ['writeonly','allocate']])
...     with it:
```

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```
...         for (a, b, c) in it:
...             addop(a, b, out=c)
...         return it.operands[2]
```

Here is the same function, but following the C-style pattern:

```
>>> def iter_add(x, y, out=None):
...     addop = np.add
...     it = np.nditer([x, y, out], [],
...                 [['readonly'], ['readonly'], ['writeonly','allocate']])
...     with it:
...         while not it.finished:
...             addop(it[0], it[1], out=it[2])
...             it.iternext()
...         return it.operands[2]
```

Here is an example outer product function:

```
>>> def outer_it(x, y, out=None):
...     mulop = np.multiply
...     it = np.nditer([x, y, out], ['external_loop'],
...             [['readonly'], ['readonly'], ['writeonly', 'allocate']],
...             op_axes=[list(range(x.ndim)) + [-1] * y.ndim,
...                      [-1] * x.ndim + list(range(y.ndim)),
...                      None])
...     with it:
...         for (a, b, c) in it:
...             mulop(a, b, out=c)
...         return it.operands[2]
```

```
>>> a = np.arange(2)+1
>>> b = np.arange(3)+1
>>> outer_it(a,b)
array([[1, 2, 3],
       [2, 4, 6]])
```

Here is an example function which operates like a "lambda" ufunc:

```
>>> def luf(lamdaexpr, *args, **kwargs):
...     '''luf(lambdaexpr, op1, ..., opn, out=None, order='K', casting='safe',␣
↪buffersize=0)'''
...     nargs = len(args)
...     op = (kwargs.get('out',None),) + args
...     it = np.nditer(op, ['buffered','external_loop'],
...             [['writeonly','allocate','no_broadcast']] +
...                             [['readonly','nbo','aligned']]*nargs,
...             order=kwargs.get('order','K'),
...             casting=kwargs.get('casting','safe'),
...             buffersize=kwargs.get('buffersize',0))
...     while not it.finished:
...         it[0] = lamdaexpr(*it[1:])
...         it.iternext()
...     return it.operands[0]
```

```
>>> a = np.arange(5)
>>> b = np.ones(5)
```

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```
>>> luf(lambda i,j:i*i + j/2, a, b)
array([  0.5,   1.5,   4.5,   9.5,  16.5])
```

If operand flags `"writeonly"` or `"readwrite"` are used the operands may be views into the original data with the *WRITEBACKIFCOPY* flag. In this case *nditer* must be used as a context manager or the *nditer.close* method must be called before using the result. The temporary data will be written back to the original data when the `__exit__` function is called but not before:

```
>>> a = np.arange(6, dtype='i4')[::-2]
>>> with np.nditer(a, [],
...         [['writeonly', 'updateifcopy']],
...         casting='unsafe',
...         op_dtypes=[np.dtype('f4')]) as i:
...     x = i.operands[0]
...     x[:] = [-1, -2, -3]
...     # a still unchanged here
>>> a, x
(array([-1, -2, -3], dtype=int32), array([-1., -2., -3.], dtype=float32))
```

It is important to note that once the iterator is exited, dangling references (like *x* in the example) may or may not share data with the original data *a*. If writeback semantics were active, i.e. if *x.base.flags.writebackifcopy* is *True*, then exiting the iterator will sever the connection between *x* and *a*, writing to *x* will no longer write to *a*. If writeback semantics are not active, then *x.data* will still point at some part of *a.data*, and writing to one will affect the other.

Context management and the *close* method appeared in version 1.15.0.

Attributes

dtypes
: [tuple of dtype(s)] The data types of the values provided in `value`. This may be different from the operand data types if buffering is enabled. Valid only before the iterator is closed.

finished
: [bool] Whether the iteration over the operands is finished or not.

has_delayed_bufalloc
: [bool] If True, the iterator was created with the `delay_bufalloc` flag, and no reset() function was called on it yet.

has_index
: [bool] If True, the iterator was created with either the `c_index` or the `f_index` flag, and the property `index` can be used to retrieve it.

has_multi_index
: [bool] If True, the iterator was created with the `multi_index` flag, and the property `multi_index` can be used to retrieve it.

index
: When the `c_index` or `f_index` flag was used, this property provides access to the index. Raises a ValueError if accessed and `has_index` is False.

iterationneedsapi
: [bool] Whether iteration requires access to the Python API, for example if one of the operands is an object array.

iterindex
: [int] An index which matches the order of iteration.

itersize
[int] Size of the iterator.

itviews
Structured view(s) of `operands` in memory, matching the reordered and optimized iterator access pattern. Valid only before the iterator is closed.

multi_index
When the `multi_index` flag was used, this property provides access to the index. Raises a ValueError if accessed accessed and `has_multi_index` is False.

ndim
[int] The dimensions of the iterator.

nop
[int] The number of iterator operands.

operands
[tuple of operand(s)] operands[*Slice*]

shape
[tuple of ints] Shape tuple, the shape of the iterator.

value
Value of `operands` at current iteration. Normally, this is a tuple of array scalars, but if the flag `external_loop` is used, it is a tuple of one dimensional arrays.

Methods

close()	Resolve all writeback semantics in writeable operands.
copy()	Get a copy of the iterator in its current state.
debug_print()	Print the current state of the *nditer* instance and debug info to stdout.
enable_external_loop()	When the "external_loop" was not used during construction, but is desired, this modifies the iterator to behave as if the flag was specified.
iternext()	Check whether iterations are left, and perform a single internal iteration without returning the result.
remove_axis(i, /)	Removes axis *i* from the iterator.
remove_multi_index()	When the "multi_index" flag was specified, this removes it, allowing the internal iteration structure to be optimized further.
reset()	Reset the iterator to its initial state.

method

nditer.**close**()

Resolve all writeback semantics in writeable operands.

See also:

Modifying array values

method

nditer.**copy**()

Get a copy of the iterator in its current state.

Examples

```
>>> import numpy as np
>>> x = np.arange(10)
>>> y = x + 1
>>> it = np.nditer([x, y])
>>> next(it)
(array(0), array(1))
>>> it2 = it.copy()
>>> next(it2)
(array(1), array(2))
```

method

nditer.**debug_print**()

Print the current state of the *nditer* instance and debug info to stdout.

method

nditer.**enable_external_loop**()

When the "external_loop" was not used during construction, but is desired, this modifies the iterator to behave as if the flag was specified.

method

nditer.**iternext**()

Check whether iterations are left, and perform a single internal iteration without returning the result. Used in the C-style pattern do-while pattern. For an example, see *nditer*.

Returns

iternext
[bool] Whether or not there are iterations left.

method

nditer.**remove_axis**(*i*, /)

Removes axis *i* from the iterator. Requires that the flag "multi_index" be enabled.

method

nditer.**remove_multi_index**()

When the "multi_index" flag was specified, this removes it, allowing the internal iteration structure to be optimized further.

method

nditer.**reset**()

Reset the iterator to its initial state.

class numpy.**ndindex**(**shape*)

An N-dimensional iterator object to index arrays.

Given the shape of an array, an *ndindex* instance iterates over the N-dimensional index of the array. At each iteration a tuple of indices is returned, the last dimension is iterated over first.

Parameters

shape
[ints, or a single tuple of ints] The size of each dimension of the array can be passed as individual parameters or as the elements of a tuple.

See also:

ndenumerate, *flatiter*

Examples

```
>>> import numpy as np
```

Dimensions as individual arguments

```
>>> for index in np.ndindex(3, 2, 1):
...     print(index)
(0, 0, 0)
(0, 1, 0)
(1, 0, 0)
(1, 1, 0)
(2, 0, 0)
(2, 1, 0)
```

Same dimensions - but in a tuple `(3, 2, 1)`

```
>>> for index in np.ndindex((3, 2, 1)):
...     print(index)
(0, 0, 0)
(0, 1, 0)
(1, 0, 0)
(1, 1, 0)
(2, 0, 0)
(2, 1, 0)
```

Methods

ndincr()	Increment the multi-dimensional index by one.

method

ndindex.**ndincr**()

Increment the multi-dimensional index by one.

This method is for backward compatibility only: do not use.

Deprecated since version 1.20.0: This method has been advised against since numpy 1.8.0, but only started emitting DeprecationWarning as of this version.

numpy.**nested_iters**(*op*, *axes*, *flags=None*, *op_flags=None*, *op_dtypes=None*, *order='K'*, *casting='safe'*, *buffersize=0*)

Create nditers for use in nested loops

Create a tuple of *nditer* objects which iterate in nested loops over different axes of the op argument. The first iterator is used in the outermost loop, the last in the innermost loop. Advancing one will change the subsequent iterators to point at its new element.

Parameters

op
[ndarray or sequence of array_like] The array(s) to iterate over.

axes
[list of list of int] Each item is used as an "op_axes" argument to an nditer

flags, op_flags, op_dtypes, order, casting, buffersize (optional)
See *nditer* parameters of the same name

Returns

iters
[tuple of nditer] An nditer for each item in *axes*, outermost first

See also:

nditer

Examples

Basic usage. Note how y is the "flattened" version of [a[:, 0, :], a[:, 1, 0], a[:, 2, :]] since we specified the first iter's axes as [1]

```
>>> import numpy as np
>>> a = np.arange(12).reshape(2, 3, 2)
>>> i, j = np.nested_iters(a, [[1], [0, 2]], flags=["multi_index"])
>>> for x in i:
...      print(i.multi_index)
...      for y in j:
...          print('', j.multi_index, y)
(0,)
 (0, 0) 0
 (0, 1) 1
 (1, 0) 6
 (1, 1) 7
(1,)
 (0, 0) 2
 (0, 1) 3
 (1, 0) 8
 (1, 1) 9
(2,)
 (0, 0) 4
 (0, 1) 5
 (1, 0) 10
 (1, 1) 11
```

class numpy.**flatiter**

Flat iterator object to iterate over arrays.

A *flatiter* iterator is returned by `x.flat` for any array *x*. It allows iterating over the array as if it were a 1-D array, either in a for-loop or by calling its *next* method.

Iteration is done in row-major, C-style order (the last index varying the fastest). The iterator can also be indexed using basic slicing or advanced indexing.

See also:

ndarray.flat
Return a flat iterator over an array.

ndarray.flatten
Returns a flattened copy of an array.

Notes

A *flatiter* iterator can not be constructed directly from Python code by calling the *flatiter* constructor.

Examples

```
>>> import numpy as np
>>> x = np.arange(6).reshape(2, 3)
>>> fl = x.flat
>>> type(fl)
<class 'numpy.flatiter'>
>>> for item in fl:
...     print(item)
...
0
1
2
3
4
5
```

```
>>> fl[2:4]
array([2, 3])
```

Attributes

base
A reference to the array that is iterated over.

coords
An N-dimensional tuple of current coordinates.

index
Current flat index into the array.

Methods

copy()	Get a copy of the iterator as a 1-D array.

method

flatiter.**copy**()
Get a copy of the iterator as a 1-D array.

Examples

```
>>> import numpy as np
>>> x = np.arange(6).reshape(2, 3)
>>> x
array([[0, 1, 2],
       [3, 4, 5]])
>>> fl = x.flat
>>> fl.copy()
array([0, 1, 2, 3, 4, 5])
```

numpy.**iterable**(*y*)

Check whether or not an object can be iterated over.

Parameters

y
: [object] Input object.

Returns

b
: [bool] Return `True` if the object has an iterator method or is a sequence and `False` otherwise.

Notes

In most cases, the results of `np.iterable(obj)` are consistent with `isinstance(obj, collections.abc.Iterable)`. One notable exception is the treatment of 0-dimensional arrays:

```
>>> from collections.abc import Iterable
>>> a = np.array(1.0)  # 0-dimensional numpy array
>>> isinstance(a, Iterable)
True
>>> np.iterable(a)
False
```

Examples

```
>>> import numpy as np
>>> np.iterable([1, 2, 3])
True
>>> np.iterable(2)
False
```

1.4.11 Logic functions

Truth value testing

all(a[, axis, out, keepdims, where])	Test whether all array elements along a given axis evaluate to True.
any(a[, axis, out, keepdims, where])	Test whether any array element along a given axis evaluates to True.

numpy.**all**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, *, *where=<no value>*)

Test whether all array elements along a given axis evaluate to True.

Parameters

a
[array_like] Input array or object that can be converted to an array.

axis
[None or int or tuple of ints, optional] Axis or axes along which a logical AND reduction is performed. The default (`axis=None`) is to perform a logical AND over all the dimensions of the input array. *axis* may be negative, in which case it counts from the last to the first axis. If this is a tuple of ints, a reduction is performed on multiple axes, instead of a single axis or all the axes as before.

out
[ndarray, optional] Alternate output array in which to place the result. It must have the same shape as the expected output and its type is preserved (e.g., if `dtype(out)` is float, the result will consist of 0.0's and 1.0's). See ufuncs-output-type for more details.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

If the default value is passed, then *keepdims* will not be passed through to the *all* method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

where
[array_like of bool, optional] Elements to include in checking for all *True* values. See *reduce* for details.

New in version 1.20.0.

Returns

all
[ndarray, bool] A new boolean or array is returned unless *out* is specified, in which case a reference to *out* is returned.

See also:

ndarray.all
equivalent method

any
Test whether any element along a given axis evaluates to True.

Notes

Not a Number (NaN), positive infinity and negative infinity evaluate to *True* because these are not equal to zero.

Changed in version 2.0: Before NumPy 2.0, `all` did not return booleans for object dtype input arrays. This behavior is still available via `np.logical_and.reduce`.

Examples

```
>>> import numpy as np
>>> np.all([[True,False],[True,True]])
False
```

```
>>> np.all([[True,False],[True,True]], axis=0)
array([ True, False])
```

```
>>> np.all([-1, 4, 5])
True
```

```
>>> np.all([1.0, np.nan])
True
```

```
>>> np.all([[True, True], [False, True]], where=[[True], [False]])
True
```

```
>>> o=np.array(False)
>>> z=np.all([-1, 4, 5], out=o)
>>> id(z), id(o), z
(28293632, 28293632, array(True)) # may vary
```

numpy.**any**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, ***, *where=<no value>*)

Test whether any array element along a given axis evaluates to True.

Returns single boolean if *axis* is `None`

Parameters

a
: [array_like] Input array or object that can be converted to an array.

axis
: [None or int or tuple of ints, optional] Axis or axes along which a logical OR reduction is performed. The default (`axis=None`) is to perform a logical OR over all the dimensions of the input array. *axis* may be negative, in which case it counts from the last to the first axis. If this is a tuple of ints, a reduction is performed on multiple axes, instead of a single axis or all the axes as before.

out
: [ndarray, optional] Alternate output array in which to place the result. It must have the same shape as the expected output and its type is preserved (e.g., if it is of type float, then it will remain so, returning 1.0 for True and 0.0 for False, regardless of the type of *a*). See ufuncs-output-type for more details.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

  If the default value is passed, then *keepdims* will not be passed through to the *any* method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

where

[array_like of bool, optional] Elements to include in checking for any *True* values. See *reduce* for details.

New in version 1.20.0.

Returns

any
[bool or ndarray] A new boolean or *ndarray* is returned unless *out* is specified, in which case a reference to *out* is returned.

See also:

ndarray.any
equivalent method

all
Test whether all elements along a given axis evaluate to True.

Notes

Not a Number (NaN), positive infinity and negative infinity evaluate to *True* because these are not equal to zero.

Changed in version 2.0: Before NumPy 2.0, `any` did not return booleans for object dtype input arrays. This behavior is still available via `np.logical_or.reduce`.

Examples

```
>>> import numpy as np
>>> np.any([[True, False], [True, True]])
True
```

```
>>> np.any([[True,  False, True ],
...         [False, False, False]], axis=0)
array([ True, False, True])
```

```
>>> np.any([-1, 0, 5])
True
```

```
>>> np.any([[np.nan], [np.inf]], axis=1, keepdims=True)
array([[ True],
       [ True]])
```

```
>>> np.any([[True, False], [False, False]], where=[[False], [True]])
False
```

```
>>> a = np.array([[1, 0, 0],
...               [0, 0, 1],
...               [0, 0, 0]])
>>> np.any(a, axis=0)
array([ True, False,  True])
>>> np.any(a, axis=1)
array([ True,  True, False])
```

```
>>> o=np.array(False)
>>> z=np.any([-1, 4, 5], out=o)
>>> z, o
(array(True), array(True))
>>> # Check now that z is a reference to o
>>> z is o
True
>>> id(z), id(o) # identity of z and o
(191614240, 191614240)
```

Array contents

isfinite(x, /[, out, where, casting, order, ...])	Test element-wise for finiteness (not infinity and not Not a Number).
isinf(x, /[, out, where, casting, order, ...])	Test element-wise for positive or negative infinity.
isnan(x, /[, out, where, casting, order, ...])	Test element-wise for NaN and return result as a boolean array.
isnat(x, /[, out, where, casting, order, ...])	Test element-wise for NaT (not a time) and return result as a boolean array.
isneginf(x[, out])	Test element-wise for negative infinity, return result as bool array.
isposinf(x[, out])	Test element-wise for positive infinity, return result as bool array.

numpy.**isfinite**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isfinite'>**

Test element-wise for finiteness (not infinity and not Not a Number).

The result is returned as a boolean array.

Parameters

x
: [array_like] Input values.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray, bool] True where `x` is not positive infinity, negative infinity, or NaN; false otherwise. This is a scalar if *x* is a scalar.

See also:

isinf, *isneginf*, *isposinf*, *isnan*

Notes

Not a Number, positive infinity and negative infinity are considered to be non-finite.

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity. Also that positive infinity is not equivalent to negative infinity. But infinity is equivalent to positive infinity. Errors result if the second argument is also supplied when *x* is a scalar input, or if first and second arguments have different shapes.

Examples

```
>>> import numpy as np
>>> np.isfinite(1)
True
>>> np.isfinite(0)
True
>>> np.isfinite(np.nan)
False
>>> np.isfinite(np.inf)
False
>>> np.isfinite(-np.inf)
False
>>> np.isfinite([np.log(-1.),1.,np.log(0)])
array([False,  True, False])
```

```
>>> x = np.array([-np.inf, 0., np.inf])
>>> y = np.array([2, 2, 2])
>>> np.isfinite(x, y)
array([0, 1, 0])
>>> y
array([0, 1, 0])
```

numpy.**isinf** (*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isinf'>**

Test element-wise for positive or negative infinity.

Returns a boolean array of the same shape as *x*, True where `x == +/-inf`, otherwise False.

Parameters

x
: [array_like] Input values

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain

its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[bool (scalar) or boolean ndarray] True where `x` is positive or negative infinity, false otherwise. This is a scalar if *x* is a scalar.

See also:

isneginf*, *isposinf*, *isnan*, *isfinite

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754).

Errors result if the second argument is supplied when the first argument is a scalar, or if the first and second arguments have different shapes.

Examples

```
>>> import numpy as np
>>> np.isinf(np.inf)
True
>>> np.isinf(np.nan)
False
>>> np.isinf(-np.inf)
True
>>> np.isinf([np.inf, -np.inf, 1.0, np.nan])
array([ True,  True, False, False])
```

```
>>> x = np.array([-np.inf, 0., np.inf])
>>> y = np.array([2, 2, 2])
>>> np.isinf(x, y)
array([1, 0, 1])
>>> y
array([1, 0, 1])
```

numpy.**isnan**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'isnan'>**

Test element-wise for NaN and return result as a boolean array.

Parameters

x
[array_like] Input array.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or bool] True where `x` is NaN, false otherwise. This is a scalar if *x* is a scalar.

See also:

isinf*, *isneginf*, *isposinf*, *isfinite*, *isnat

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity.

Examples

```
>>> import numpy as np
>>> np.isnan(np.nan)
True
>>> np.isnan(np.inf)
False
>>> np.isnan([np.log(-1.),1.,np.log(0)])
array([ True, False, False])
```

numpy.**isnat** (*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*])
= <ufunc 'isnat'>

Test element-wise for NaT (not a time) and return result as a boolean array.

Parameters

x
[array_like] Input array with datetime or timedelta data type.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or bool] True where `x` is NaT, false otherwise. This is a scalar if *x* is a scalar.

See also:

isnan*, *isinf*, *isneginf*, *isposinf*, *isfinite

Examples

```
>>> import numpy as np
>>> np.isnat(np.datetime64("NaT"))
True
>>> np.isnat(np.datetime64("2016-01-01"))
False
>>> np.isnat(np.array(["NaT", "2016-01-01"], dtype="datetime64[ns]"))
array([ True, False])
```

`numpy.`**`isneginf`**(*x*, *out=None*)

Test element-wise for negative infinity, return result as bool array.

Parameters

x
[array_like] The input array.

out
[array_like, optional] A location into which the result is stored. If provided, it must have a shape that the input broadcasts to. If not provided or None, a freshly-allocated boolean array is returned.

Returns

out
[ndarray] A boolean array with the same dimensions as the input. If second argument is not supplied then a numpy boolean array is returned with values True where the corresponding element of the input is negative infinity and values False where the element of the input is not negative infinity.

If a second argument is supplied the result is stored there. If the type of that array is a numeric type the result is represented as zeros and ones, if the type is boolean then as False and True. The return value *out* is then a reference to that array.

See also:

isinf*, *isposinf*, *isnan*, *isfinite

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754).

Errors result if the second argument is also supplied when x is a scalar input, if first and second arguments have different shapes, or if the first argument has complex values.

Examples

```
>>> import numpy as np
>>> np.isneginf(-np.inf)
True
>>> np.isneginf(np.inf)
False
>>> np.isneginf([-np.inf, 0., np.inf])
array([ True, False, False])
```

```
>>> x = np.array([-np.inf, 0., np.inf])
>>> y = np.array([2, 2, 2])
>>> np.isneginf(x, y)
array([1, 0, 0])
>>> y
array([1, 0, 0])
```

numpy.**isposinf**(*x*, *out=None*)

Test element-wise for positive infinity, return result as bool array.

Parameters

x
: [array_like] The input array.

out
: [array_like, optional] A location into which the result is stored. If provided, it must have a shape that the input broadcasts to. If not provided or None, a freshly-allocated boolean array is returned.

Returns

out
: [ndarray] A boolean array with the same dimensions as the input. If second argument is not supplied then a boolean array is returned with values True where the corresponding element of the input is positive infinity and values False where the element of the input is not positive infinity.

  If a second argument is supplied the result is stored there. If the type of that array is a numeric type the result is represented as zeros and ones, if the type is boolean then as False and True. The return value *out* is then a reference to that array.

See also:

isinf, ***isneginf***, ***isfinite***, ***isnan***

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754).

Errors result if the second argument is also supplied when x is a scalar input, if first and second arguments have different shapes, or if the first argument has complex values

Examples

```
>>> import numpy as np
>>> np.isposinf(np.inf)
True
>>> np.isposinf(-np.inf)
False
>>> np.isposinf([-np.inf, 0., np.inf])
array([False, False,  True])
```

```
>>> x = np.array([-np.inf, 0., np.inf])
>>> y = np.array([2, 2, 2])
>>> np.isposinf(x, y)
array([0, 0, 1])
>>> y
array([0, 0, 1])
```

Array type testing

iscomplex(x)	Returns a bool array, where True if input element is complex.
iscomplexobj(x)	Check for a complex type or an array of complex numbers.
isfortran(a)	Check if the array is Fortran contiguous but *not* C contiguous.
isreal(x)	Returns a bool array, where True if input element is real.
isrealobj(x)	Return True if x is a not complex type or an array of complex numbers.
isscalar(element)	Returns True if the type of *element* is a scalar type.

numpy.**iscomplex**(*x*)

Returns a bool array, where True if input element is complex.

What is tested is whether the input has a non-zero imaginary part, not if the input type is complex.

Parameters

x
[array_like] Input array.

Returns

out
[ndarray of bools] Output array.

See also:

isreal
iscomplexobj
Return True if x is a complex type or an array of complex numbers.

Examples

```
>>> import numpy as np
>>> np.iscomplex([1+1j, 1+0j, 4.5, 3, 2, 2j])
array([ True, False, False, False, False,  True])
```

numpy.**iscomplexobj**(*x*)

Check for a complex type or an array of complex numbers.

The type of the input is checked, not the value. Even if the input has an imaginary part equal to zero, *iscomplexobj* evaluates to True.

Parameters

x
[any] The input can be of any type and shape.

Returns

iscomplexobj
[bool] The return value, True if *x* is of a complex type or has at least one complex element.

See also:

isrealobj, *iscomplex*

Examples

```
>>> import numpy as np
>>> np.iscomplexobj(1)
False
>>> np.iscomplexobj(1+0j)
True
>>> np.iscomplexobj([3, 1+0j, True])
True
```

numpy.**isfortran**(*a*)

Check if the array is Fortran contiguous but *not* C contiguous.

This function is obsolete. If you only want to check if an array is Fortran contiguous use `a.flags.f_contiguous` instead.

Parameters

a
[ndarray] Input array.

Returns

isfortran
[bool] Returns True if the array is Fortran contiguous but *not* C contiguous.

Examples

np.array allows to specify whether the array is written in C-contiguous order (last index varies the fastest), or FORTRAN-contiguous order in memory (first index varies the fastest).

```
>>> import numpy as np
>>> a = np.array([[1, 2, 3], [4, 5, 6]], order='C')
>>> a
array([[1, 2, 3],
       [4, 5, 6]])
>>> np.isfortran(a)
False
```

```
>>> b = np.array([[1, 2, 3], [4, 5, 6]], order='F')
>>> b
array([[1, 2, 3],
       [4, 5, 6]])
>>> np.isfortran(b)
True
```

The transpose of a C-ordered array is a FORTRAN-ordered array.

```
>>> a = np.array([[1, 2, 3], [4, 5, 6]], order='C')
>>> a
array([[1, 2, 3],
       [4, 5, 6]])
>>> np.isfortran(a)
False
>>> b = a.T
>>> b
array([[1, 4],
       [2, 5],
       [3, 6]])
>>> np.isfortran(b)
True
```

C-ordered arrays evaluate as False even if they are also FORTRAN-ordered.

```
>>> np.isfortran(np.array([1, 2], order='F'))
False
```

numpy.**isreal**(*x*)

Returns a bool array, where True if input element is real.

If element has complex type with zero imaginary part, the return value for that element is True.

Parameters

x
[array_like] Input array.

Returns

out
[ndarray, bool] Boolean array of same shape as *x*.

See also:

iscomplex
isrealobj
Return True if x is not a complex type.

Notes

isreal may behave unexpectedly for string or object arrays (see examples)

Examples

```
>>> import numpy as np
>>> a = np.array([1+1j, 1+0j, 4.5, 3, 2, 2j], dtype=complex)
>>> np.isreal(a)
array([False,  True,  True,  True,  True, False])
```

The function does not work on string arrays.

```
>>> a = np.array([2j, "a"], dtype="U")
>>> np.isreal(a)  # Warns about non-elementwise comparison
False
```

Returns True for all elements in input array of `dtype=object` even if any of the elements is complex.

```
>>> a = np.array([1, "2", 3+4j], dtype=object)
>>> np.isreal(a)
array([ True,  True,  True])
```

isreal should not be used with object arrays

```
>>> a = np.array([1+2j, 2+1j], dtype=object)
>>> np.isreal(a)
array([ True,  True])
```

numpy.**isrealobj**(*x*)
Return True if x is a not complex type or an array of complex numbers.

The type of the input is checked, not the value. So even if the input has an imaginary part equal to zero, *isrealobj* evaluates to False if the data type is complex.

Parameters

x
[any] The input can be of any type and shape.

Returns

y
[bool] The return value, False if *x* is of a complex type.

See also:

iscomplexobj, *isreal*

Notes

The function is only meant for arrays with numerical values but it accepts all other objects. Since it assumes array input, the return value of other objects may be True.

```
>>> np.isrealobj('A string')
True
>>> np.isrealobj(False)
True
>>> np.isrealobj(None)
True
```

Examples

```
>>> import numpy as np
>>> np.isrealobj(1)
True
>>> np.isrealobj(1+0j)
False
>>> np.isrealobj([3, 1+0j, True])
False
```

numpy.**isscalar**(*element*)

Returns True if the type of *element* is a scalar type.

Parameters

element
[any] Input argument, can be of any type and shape.

Returns

val
[bool] True if *element* is a scalar type, False if it is not.

See also:

ndim
Get the number of dimensions of an array

Notes

If you need a stricter way to identify a *numerical* scalar, use `isinstance(x, numbers.Number)`, as that returns `False` for most non-numerical elements such as strings.

In most cases `np.ndim(x) == 0` should be used instead of this function, as that will also return true for 0d arrays. This is how numpy overloads functions in the style of the `dx` arguments to *gradient* and the `bins` argument to *histogram*. Some key differences:

x	iss-calar(x)	np.ndim(x) == 0
PEP 3141 numeric objects (including builtins)	True	True
builtin string and buffer objects	True	True
other builtin objects, like pathlib.Path, *Exception*, the result of re.compile	False	True
third-party objects like matplotlib.figure.Figure	False	True
zero-dimensional numpy arrays	False	True
other numpy arrays	False	False
list, *tuple*, and other sequence objects	False	False

Examples

```
>>> import numpy as np
```

```
>>> np.isscalar(3.1)
True
```

```
>>> np.isscalar(np.array(3.1))
False
```

```
>>> np.isscalar([3.1])
False
```

```
>>> np.isscalar(False)
True
```

```
>>> np.isscalar('numpy')
True
```

NumPy supports PEP 3141 numbers:

```
>>> from fractions import Fraction
>>> np.isscalar(Fraction(5, 17))
True
>>> from numbers import Number
>>> np.isscalar(Number())
True
```

Logical operations

logical_and(x1, x2, /[, out, where, ...])	Compute the truth value of x1 AND x2 element-wise.
logical_or(x1, x2, /[, out, where, casting, ...])	Compute the truth value of x1 OR x2 element-wise.
logical_not(x, /[, out, where, casting, ...])	Compute the truth value of NOT x element-wise.
logical_xor(x1, x2, /[, out, where, ...])	Compute the truth value of x1 XOR x2, element-wise.

numpy.**logical_and**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'logical_and'>**

Compute the truth value of x1 AND x2 element-wise.

Parameters

x1, x2
[array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or bool] Boolean result of the logical AND operation applied to the elements of *x1* and *x2*; the shape is determined by broadcasting. This is a scalar if both *x1* and *x2* are scalars.

See also:

logical_or*, *logical_not*, *logical_xor
bitwise_and

Examples

```
>>> import numpy as np
>>> np.logical_and(True, False)
False
>>> np.logical_and([True, False], [False, False])
array([False, False])
```

```
>>> x = np.arange(5)
>>> np.logical_and(x>1, x<4)
array([False, False,  True,  True, False])
```

The `&` operator can be used as a shorthand for `np.logical_and` on boolean ndarrays.

```
>>> a = np.array([True, False])
>>> b = np.array([False, False])
>>> a & b
array([False, False])
```

numpy.**logical_or**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'logical_or'>**

Compute the truth value of x1 OR x2 element-wise.

Parameters

x1, x2
[array_like] Logical OR is applied to the elements of *x1* and *x2*. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or bool] Boolean result of the logical OR operation applied to the elements of *x1* and *x2*; the shape is determined by broadcasting. This is a scalar if both *x1* and *x2* are scalars.

See also:

logical_and*, *logical_not*, *logical_xor
bitwise_or

Examples

```
>>> import numpy as np
>>> np.logical_or(True, False)
True
>>> np.logical_or([True, False], [False, False])
array([ True, False])
```

```
>>> x = np.arange(5)
>>> np.logical_or(x < 1, x > 3)
array([ True, False, False, False,  True])
```

The `|` operator can be used as a shorthand for `np.logical_or` on boolean ndarrays.

```
>>> a = np.array([True, False])
>>> b = np.array([False, False])
>>> a | b
array([ True, False])
```

numpy.**logical_not**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'logical_not'>**

Compute the truth value of NOT x element-wise.

Parameters

x
: [array_like] Logical NOT is applied to the elements of *x*.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [bool or ndarray of bool] Boolean result with the same shape as *x* of the NOT operation on elements of *x*. This is a scalar if *x* is a scalar.

See also:

logical_and*, *logical_or*, *logical_xor

Examples

```
>>> import numpy as np
>>> np.logical_not(3)
False
>>> np.logical_not([True, False, 0, 1])
array([False,  True,  True, False])
```

```
>>> x = np.arange(5)
>>> np.logical_not(x<3)
array([False, False, False,  True,  True])
```

numpy.**logical_xor**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'logical_xor'>**

Compute the truth value of x1 XOR x2, element-wise.

Parameters

x1, x2
: [array_like] Logical XOR is applied to the elements of *x1* and *x2*. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[bool or ndarray of bool] Boolean result of the logical XOR operation applied to the elements of *x1* and *x2*; the shape is determined by broadcasting. This is a scalar if both *x1* and *x2* are scalars.

See also:

logical_and, ***logical_or***, ***logical_not***, ***bitwise_xor***

Examples

```
>>> import numpy as np
>>> np.logical_xor(True, False)
True
>>> np.logical_xor([True, True, False, False], [True, False, True, False])
array([False,  True,  True, False])
```

```
>>> x = np.arange(5)
>>> np.logical_xor(x < 1, x > 3)
array([ True, False, False, False,  True])
```

Simple example showing support of broadcasting

```
>>> np.logical_xor(0, np.eye(2))
array([[ True, False],
       [False,  True]])
```

Comparison

allclose(a, b[, rtol, atol, equal_nan])	Returns True if two arrays are element-wise equal within a tolerance.
isclose(a, b[, rtol, atol, equal_nan])	Returns a boolean array where two arrays are element-wise equal within a tolerance.
array_equal(a1, a2[, equal_nan])	True if two arrays have the same shape and elements, False otherwise.
array_equiv(a1, a2)	Returns True if input arrays are shape consistent and all elements equal.

numpy.**allclose**(*a*, *b*, *rtol=1e-05*, *atol=1e-08*, *equal_nan=False*)

Returns True if two arrays are element-wise equal within a tolerance.

The tolerance values are positive, typically very small numbers. The relative difference (*rtol* * abs(*b*)) and the absolute difference *atol* are added together to compare against the absolute difference between *a* and *b*.

Warning: The default *atol* is not appropriate for comparing numbers with magnitudes much smaller than one (see Notes).

NaNs are treated as equal if they are in the same place and if `equal_nan=True`. Infs are treated as equal if they are in the same place and of the same sign in both arrays.

Parameters

a, b
[array_like] Input arrays to compare.

rtol
[array_like] The relative tolerance parameter (see Notes).

atol
[array_like] The absolute tolerance parameter (see Notes).

equal_nan
[bool] Whether to compare NaN's as equal. If True, NaN's in *a* will be considered equal to NaN's in *b* in the output array.

Returns

allclose
[bool] Returns True if the two arrays are equal within the given tolerance; False otherwise.

See also:

isclose, *all*, *any*, *equal*

Notes

If the following equation is element-wise True, then allclose returns True.:

```
absolute(a - b) <= (atol + rtol * absolute(b))
```

The above equation is not symmetric in *a* and *b*, so that `allclose(a, b)` might be different from `allclose(b, a)` in some rare cases.

The default value of *atol* is not appropriate when the reference value *b* has magnitude smaller than one. For example, it is unlikely that `a = 1e-9` and `b = 2e-9` should be considered "close", yet `allclose(1e-9, 2e-9)` is `True` with default settings. Be sure to select *atol* for the use case at hand, especially for defining the threshold below which a non-zero value in *a* will be considered "close" to a very small or zero value in *b*.

The comparison of *a* and *b* uses standard broadcasting, which means that *a* and *b* need not have the same shape in order for `allclose(a, b)` to evaluate to True. The same is true for *equal* but not *array_equal*.

allclose is not defined for non-numeric data types. *bool* is considered a numeric data-type for this purpose.

Examples

```
>>> import numpy as np
>>> np.allclose([1e10,1e-7], [1.00001e10,1e-8])
False
```

```
>>> np.allclose([1e10,1e-8], [1.00001e10,1e-9])
True
```

```
>>> np.allclose([1e10,1e-8], [1.0001e10,1e-9])
False
```

```
>>> np.allclose([1.0, np.nan], [1.0, np.nan])
False
```

```
>>> np.allclose([1.0, np.nan], [1.0, np.nan], equal_nan=True)
True
```

numpy.**isclose**(*a*, *b*, *rtol=1e-05*, *atol=1e-08*, *equal_nan=False*)

Returns a boolean array where two arrays are element-wise equal within a tolerance.

The tolerance values are positive, typically very small numbers. The relative difference (*rtol* * abs(*b*)) and the absolute difference *atol* are added together to compare against the absolute difference between *a* and *b*.

Warning: The default *atol* is not appropriate for comparing numbers with magnitudes much smaller than one (see Notes).

Parameters

a, b
: [array_like] Input arrays to compare.

rtol
: [array_like] The relative tolerance parameter (see Notes).

atol
: [array_like] The absolute tolerance parameter (see Notes).

equal_nan
: [bool] Whether to compare NaN's as equal. If True, NaN's in *a* will be considered equal to NaN's in *b* in the output array.

Returns

y
: [array_like] Returns a boolean array of where *a* and *b* are equal within the given tolerance. If both *a* and *b* are scalars, returns a single boolean value.

See also:

allclose
math.isclose

Notes

For finite values, isclose uses the following equation to test whether two floating point values are equivalent.:

```
absolute(a - b) <= (atol + rtol * absolute(b))
```

Unlike the built-in `math.isclose`, the above equation is not symmetric in *a* and *b* – it assumes *b* is the reference value – so that *isclose(a, b)* might be different from *isclose(b, a)*.

The default value of *atol* is not appropriate when the reference value *b* has magnitude smaller than one. For example, it is unlikely that `a = 1e-9` and `b = 2e-9` should be considered "close", yet `isclose(1e-9, 2e-9)` is `True` with default settings. Be sure to select *atol* for the use case at hand, especially for defining the threshold below which a non-zero value in *a* will be considered "close" to a very small or zero value in *b*.

`isclose` is not defined for non-numeric data types. *`bool`* is considered a numeric data-type for this purpose.

Examples

```
>>> import numpy as np
>>> np.isclose([1e10,1e-7], [1.00001e10,1e-8])
array([ True, False])
```

```
>>> np.isclose([1e10,1e-8], [1.00001e10,1e-9])
array([ True, True])
```

```
>>> np.isclose([1e10,1e-8], [1.0001e10,1e-9])
array([False,  True])
```

```
>>> np.isclose([1.0, np.nan], [1.0, np.nan])
array([ True, False])
```

```
>>> np.isclose([1.0, np.nan], [1.0, np.nan], equal_nan=True)
array([ True, True])
```

```
>>> np.isclose([1e-8, 1e-7], [0.0, 0.0])
array([ True, False])
```

```
>>> np.isclose([1e-100, 1e-7], [0.0, 0.0], atol=0.0)
array([False, False])
```

```
>>> np.isclose([1e-10, 1e-10], [1e-20, 0.0])
array([ True,  True])
```

```
>>> np.isclose([1e-10, 1e-10], [1e-20, 0.999999e-10], atol=0.0)
array([False,  True])
```

numpy.**array_equal**(*a1*, *a2*, *equal_nan=False*)

True if two arrays have the same shape and elements, False otherwise.

Parameters

a1, a2
[array_like] Input arrays.

equal_nan
[bool] Whether to compare NaN's as equal. If the dtype of a1 and a2 is complex, values will be considered equal if either the real or the imaginary component of a given value is `nan`.

Returns

b
[bool] Returns True if the arrays are equal.

See also:

allclose
Returns True if two arrays are element-wise equal within a tolerance.

array_equiv
Returns True if input arrays are shape consistent and all elements equal.

Examples

```
>>> import numpy as np
```

```
>>> np.array_equal([1, 2], [1, 2])
True
```

```
>>> np.array_equal(np.array([1, 2]), np.array([1, 2]))
True
```

```
>>> np.array_equal([1, 2], [1, 2, 3])
False
```

```
>>> np.array_equal([1, 2], [1, 4])
False
```

```
>>> a = np.array([1, np.nan])
>>> np.array_equal(a, a)
False
```

```
>>> np.array_equal(a, a, equal_nan=True)
True
```

When `equal_nan` is True, complex values with nan components are considered equal if either the real *or* the imaginary components are nan.

```
>>> a = np.array([1 + 1j])
>>> b = a.copy()
>>> a.real = np.nan
>>> b.imag = np.nan
>>> np.array_equal(a, b, equal_nan=True)
True
```

numpy.**array_equiv**(*a1*, *a2*)

Returns True if input arrays are shape consistent and all elements equal.

Shape consistent means they are either the same shape, or one input array can be broadcasted to create the same shape as the other one.

Parameters

a1, a2
[array_like] Input arrays.

Returns

out
[bool] True if equivalent, False otherwise.

Examples

```
>>> import numpy as np
>>> np.array_equiv([1, 2], [1, 2])
True
>>> np.array_equiv([1, 2], [1, 3])
False
```

Showing the shape equivalence:

```
>>> np.array_equiv([1, 2], [[1, 2], [1, 2]])
True
>>> np.array_equiv([1, 2], [[1, 2, 1, 2], [1, 2, 1, 2]])
False
```

```
>>> np.array_equiv([1, 2], [[1, 2], [1, 3]])
False
```

greater(x1, x2, /[, out, where, casting, ...])	Return the truth value of (x1 > x2) element-wise.
greater_equal(x1, x2, /[, out, where, ...])	Return the truth value of (x1 >= x2) element-wise.
less(x1, x2, /[, out, where, casting, ...])	Return the truth value of (x1 < x2) element-wise.
less_equal(x1, x2, /[, out, where, casting, ...])	Return the truth value of (x1 <= x2) element-wise.
equal(x1, x2, /[, out, where, casting, ...])	Return (x1 == x2) element-wise.
not_equal(x1, x2, /[, out, where, casting, ...])	Return (x1 != x2) element-wise.

numpy.**greater**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'greater'>**

Return the truth value of (x1 > x2) element-wise.

Parameters

x1, x2
[array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

greater_equal*, *less*, *less_equal*, *equal*, *not_equal

Examples

```
>>> import numpy as np
>>> np.greater([4,2],[2,2])
array([ True, False])
```

The > operator can be used as a shorthand for `np.greater` on ndarrays.

```
>>> a = np.array([4, 2])
>>> b = np.array([2, 2])
>>> a > b
array([ True, False])
```

numpy.**greater_equal**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'greater_equal'>**

Return the truth value of (x1 >= x2) element-wise.

Parameters

x1, x2
[array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[bool or ndarray of bool] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

greater*, *less*, *less_equal*, *equal*, *not_equal

Examples

```
>>> import numpy as np
>>> np.greater_equal([4, 2, 1], [2, 2, 2])
array([ True, True, False])
```

The >= operator can be used as a shorthand for `np.greater_equal` on ndarrays.

```
>>> a = np.array([4, 2, 1])
>>> b = np.array([2, 2, 2])
>>> a >= b
array([ True,  True, False])
```

`numpy.`**`less`**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'less'>**

Return the truth value of (x1 < x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

greater*, *less_equal*, *greater_equal*, *equal*, *not_equal

Examples

```
>>> import numpy as np
>>> np.less([1, 2], [2, 2])
array([ True, False])
```

The < operator can be used as a shorthand for `np.less` on ndarrays.

```
>>> a = np.array([1, 2])
>>> b = np.array([2, 2])
>>> a < b
array([ True, False])
```

numpy.**less_equal**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'less_equal'>**

Return the truth value of (x1 <= x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

greater, ***less***, ***greater_equal***, ***equal***, ***not_equal***

Examples

```
>>> import numpy as np
>>> np.less_equal([4, 2, 1], [2, 2, 2])
array([False,  True,  True])
```

The <= operator can be used as a shorthand for `np.less_equal` on ndarrays.

```
>>> a = np.array([4, 2, 1])
>>> b = np.array([2, 2, 2])
>>> a <= b
array([False,  True,  True])
```

`numpy.`**`equal`**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'equal'>**

Return (x1 == x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

not_equal, ***greater_equal***, ***less_equal***, ***greater***, ***less***

Examples

```
>>> import numpy as np
>>> np.equal([0, 1, 3], np.arange(3))
array([ True,  True, False])
```

What is compared are values, not types. So an int (1) and an array of length one can evaluate as True:

```
>>> np.equal(1, np.ones(1))
array([ True])
```

The == operator can be used as a shorthand for `np.equal` on ndarrays.

```
>>> a = np.array([2, 4, 6])
>>> b = np.array([2, 4, 2])
>>> a == b
array([ True,  True, False])
```

numpy.**not_equal**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'not_equal'>**

Return (x1 != x2) element-wise.

Parameters

x1, x2
: [array_like] Input arrays. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Output array, element-wise comparison of *x1* and *x2*. Typically of type bool, unless `dtype=object` is passed. This is a scalar if both *x1* and *x2* are scalars.

See also:

equal, ***greater***, ***greater_equal***, ***less***, ***less_equal***

Examples

```
>>> import numpy as np
>>> np.not_equal([1.,2.], [1., 3.])
array([False,  True])
>>> np.not_equal([1, 2], [[1, 3],[1, 4]])
array([[False,  True],
       [False,  True]])
```

The != operator can be used as a shorthand for `np.not_equal` on ndarrays.

```
>>> a = np.array([1., 2.])
>>> b = np.array([1., 3.])
>>> a != b
array([False,  True])
```

1.4.12 Mathematical functions

Trigonometric functions

sin(x, /[, out, where, casting, order, ...])	Trigonometric sine, element-wise.
cos(x, /[, out, where, casting, order, ...])	Cosine element-wise.
tan(x, /[, out, where, casting, order, ...])	Compute tangent element-wise.
arcsin(x, /[, out, where, casting, order, ...])	Inverse sine, element-wise.
asin(x, /[, out, where, casting, order, ...])	Inverse sine, element-wise.
arccos(x, /[, out, where, casting, order, ...])	Trigonometric inverse cosine, element-wise.
acos(x, /[, out, where, casting, order, ...])	Trigonometric inverse cosine, element-wise.
arctan(x, /[, out, where, casting, order, ...])	Trigonometric inverse tangent, element-wise.
atan(x, /[, out, where, casting, order, ...])	Trigonometric inverse tangent, element-wise.
hypot(x1, x2, /[, out, where, casting, ...])	Given the "legs" of a right triangle, return its hypotenuse.
arctan2(x1, x2, /[, out, where, casting, ...])	Element-wise arc tangent of `x1/x2` choosing the quadrant correctly.
atan2(x1, x2, /[, out, where, casting, ...])	Element-wise arc tangent of `x1/x2` choosing the quadrant correctly.
degrees(x, /[, out, where, casting, order, ...])	Convert angles from radians to degrees.
radians(x, /[, out, where, casting, order, ...])	Convert angles from degrees to radians.
unwrap(p[, discont, axis, period])	Unwrap by taking the complement of large deltas with respect to the period.
deg2rad(x, /[, out, where, casting, order, ...])	Convert angles from degrees to radians.
rad2deg(x, /[, out, where, casting, order, ...])	Convert angles from radians to degrees.

numpy.**sin**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'sin'>**

Trigonometric sine, element-wise.

Parameters

x
: [array_like] Angle, in radians (2π rad equals 360 degrees).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None,

a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[array_like] The sine of each element of x. This is a scalar if x is a scalar.

See also:

arcsin*, *sinh*, *cos

Notes

The sine is one of the fundamental functions of trigonometry (the mathematical study of triangles). Consider a circle of radius 1 centered on the origin. A ray comes in from the $+x$ axis, makes an angle at the origin (measured counter-clockwise from that axis), and departs from the origin. The y coordinate of the outgoing ray's intersection with the unit circle is the sine of that angle. It ranges from -1 for $x = 3\pi/2$ to +1 for $\pi/2$. The function has zeroes where the angle is a multiple of π. Sines of angles between π and 2π are negative. The numerous properties of the sine and related functions are included in any standard trigonometry text.

Examples

```
>>> import numpy as np
```

Print sine of one angle:

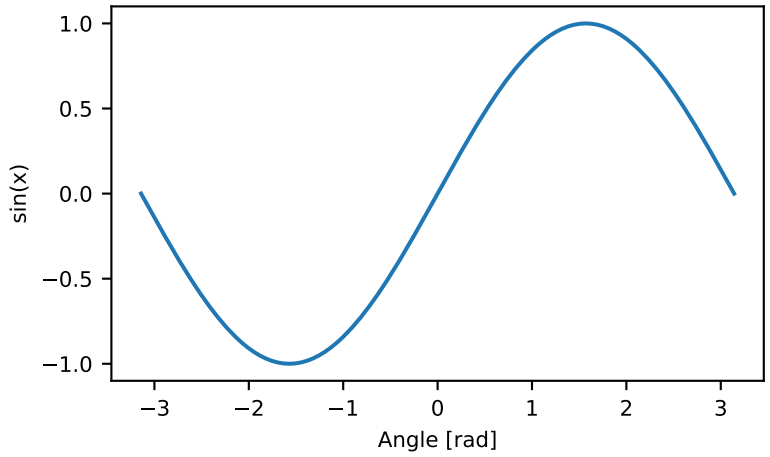
```
>>> np.sin(np.pi/2.)
1.0
```

Print sines of an array of angles given in degrees:

```
>>> np.sin(np.array((0., 30., 45., 60., 90.)) * np.pi / 180. )
array([ 0.        ,  0.5       ,  0.70710678,  0.8660254 ,  1.        ])
```

Plot the sine function:

```
>>> import matplotlib.pylab as plt
>>> x = np.linspace(-np.pi, np.pi, 201)
>>> plt.plot(x, np.sin(x))
>>> plt.xlabel('Angle [rad]')
>>> plt.ylabel('sin(x)')
>>> plt.axis('tight')
>>> plt.show()
```



numpy.**cos**(*x*, /, *out=None*, *, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'cos'>**

Cosine element-wise.

Parameters

x
[array_like] Input array in radians.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The corresponding cosine values. This is a scalar if *x* is a scalar.

Notes

If *out* is provided, the function writes the result into it, and returns a reference to *out*. (See Examples)

References

M. Abramowitz and I. A. Stegun, Handbook of Mathematical Functions. New York, NY: Dover, 1972.

Examples

```
>>> import numpy as np
>>> np.cos(np.array([0, np.pi/2, np.pi]))
array([  1.00000000e+00,   6.12303177e-17,  -1.00000000e+00])
>>>
>>> # Example of providing the optional output parameter
>>> out1 = np.array([0], dtype='d')
>>> out2 = np.cos([0.1], out1)
>>> out2 is out1
True
>>>
>>> # Example of ValueError due to provision of shape mis-matched `out`
>>> np.cos(np.zeros((3,3)),np.zeros((2,2)))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operands could not be broadcast together with shapes (3,3) (2,2)
```

numpy.**tan**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'tan'>**

Compute tangent element-wise.

Equivalent to `np.sin(x)/np.cos(x)` element-wise.

Parameters

x
: [array_like] Input array.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] The corresponding tangent values. This is a scalar if *x* is a scalar.

Notes

If *out* is provided, the function writes the result into it, and returns a reference to *out*. (See Examples)

References

M. Abramowitz and I. A. Stegun, Handbook of Mathematical Functions. New York, NY: Dover, 1972.

Examples

```
>>> import numpy as np
>>> from math import pi
>>> np.tan(np.array([-pi,pi/2,pi]))
array([  1.22460635e-16,   1.63317787e+16,  -1.22460635e-16])
>>>
>>> # Example of providing the optional output parameter illustrating
>>> # that what is returned is a reference to said parameter
>>> out1 = np.array([0], dtype='d')
>>> out2 = np.cos([0.1], out1)
>>> out2 is out1
True
>>>
>>> # Example of ValueError due to provision of shape mis-matched `out`
>>> np.cos(np.zeros((3,3)),np.zeros((2,2)))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operands could not be broadcast together with shapes (3,3) (2,2)
```

numpy.**arcsin**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arcsin'>**

Inverse sine, element-wise.

Parameters

x
[array_like] *y*-coordinate on the unit circle.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

angle
[ndarray] The inverse sine of each element in *x*, in radians and in the closed interval `[-pi/2, pi/2]`. This is a scalar if *x* is a scalar.

See also:

sin, *cos*, *arccos*, *tan*, *arctan*, *arctan2*, *emath.arcsin*

Notes

arcsin is a multivalued function: for each x there are infinitely many numbers z such that $sin(z) = x$. The convention is to return the angle z whose real part lies in [-pi/2, pi/2].

For real-valued input data types, *arcsin* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arcsin* is a complex analytic function that has, by convention, the branch cuts [-inf, -1] and [1, inf] and is continuous from above on the former and from below on the latter.

The inverse sine is also known as *asin* or sin^{-1}.

References

Abramowitz, M. and Stegun, I. A., *Handbook of Mathematical Functions*, 10th printing, New York: Dover, 1964, pp. 79ff. https://personal.math.ubc.ca/~cbm/aands/page_79.htm

Examples

```
>>> import numpy as np
>>> np.arcsin(1)     # pi/2
1.5707963267948966
>>> np.arcsin(-1)    # -pi/2
-1.5707963267948966
>>> np.arcsin(0)
0.0
```

numpy.**asin**(*x*, /, *out=None*, *, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arcsin'>**

Inverse sine, element-wise.

Parameters

x
: [array_like] *y*-coordinate on the unit circle.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

angle
[ndarray] The inverse sine of each element in *x*, in radians and in the closed interval `[-pi/2, pi/2]`. This is a scalar if *x* is a scalar.

See also:

sin*, *cos*, *arccos*, *tan*, *arctan*, *arctan2*, *emath.arcsin

Notes

arcsin is a multivalued function: for each *x* there are infinitely many numbers *z* such that $sin(z) = x$. The convention is to return the angle *z* whose real part lies in [-pi/2, pi/2].

For real-valued input data types, *arcsin* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arcsin* is a complex analytic function that has, by convention, the branch cuts [-inf, -1] and [1, inf] and is continuous from above on the former and from below on the latter.

The inverse sine is also known as *asin* or sin^{-1}.

References

Abramowitz, M. and Stegun, I. A., *Handbook of Mathematical Functions*, 10th printing, New York: Dover, 1964, pp. 79ff. https://personal.math.ubc.ca/~cbm/aands/page_79.htm

Examples

```
>>> import numpy as np
>>> np.arcsin(1)     # pi/2
1.5707963267948966
>>> np.arcsin(-1)    # -pi/2
-1.5707963267948966
>>> np.arcsin(0)
0.0
```

numpy.**arccos**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arccos'>**

Trigonometric inverse cosine, element-wise.

The inverse of *cos* so that, if `y = cos(x)`, then `x = arccos(y)`.

Parameters

x
[array_like] *x*-coordinate on the unit circle. For real arguments, the domain is [-1, 1].

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

angle
[ndarray] The angle of the ray intersecting the unit circle at the given *x*-coordinate in radians [0, pi]. This is a scalar if *x* is a scalar.

See also:

cos*, *arctan*, *arcsin*, *emath.arccos

Notes

arccos is a multivalued function: for each *x* there are infinitely many numbers *z* such that `cos(z) = x`. The convention is to return the angle *z* whose real part lies in *[0, pi]*.

For real-valued input data types, *arccos* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arccos* is a complex analytic function that has branch cuts `[-inf, -1]` and *[1, inf]* and is continuous from above on the former and from below on the latter.

The inverse *cos* is also known as *acos* or cos^-1.

References

M. Abramowitz and I.A. Stegun, "Handbook of Mathematical Functions", 10th printing, 1964, pp. 79. https://personal.math.ubc.ca/~cbm/aands/page_79.htm

Examples

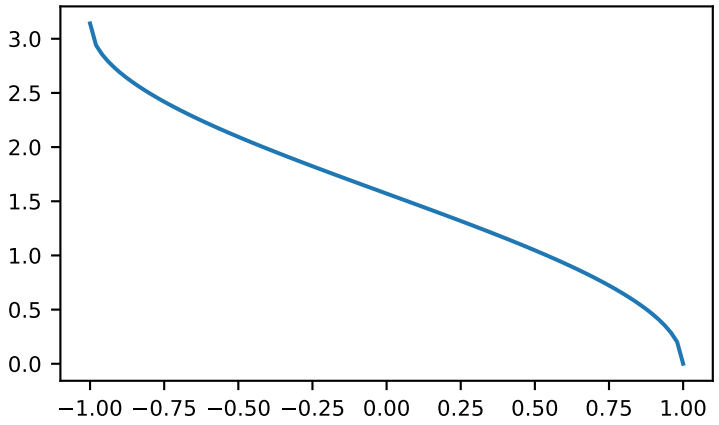
```
>>> import numpy as np
```

We expect the arccos of 1 to be 0, and of -1 to be pi:

```
>>> np.arccos([1, -1])
array([ 0.        ,  3.14159265])
```

Plot arccos:

```
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-1, 1, num=100)
>>> plt.plot(x, np.arccos(x))
>>> plt.axis('tight')
>>> plt.show()
```



numpy.**acos**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arccos'>**

Trigonometric inverse cosine, element-wise.

The inverse of *cos* so that, if `y = cos(x)`, then `x = arccos(y)`.

Parameters

x
: [array_like] *x*-coordinate on the unit circle. For real arguments, the domain is [-1, 1].

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

angle
: [ndarray] The angle of the ray intersecting the unit circle at the given *x*-coordinate in radians [0, pi]. This is a scalar if *x* is a scalar.

See also:

cos*, *arctan*, *arcsin*, *emath.arccos

Notes

arccos is a multivalued function: for each *x* there are infinitely many numbers *z* such that `cos(z) = x`. The convention is to return the angle *z* whose real part lies in *[0, pi]*.

For real-valued input data types, *arccos* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arccos* is a complex analytic function that has branch cuts `[-inf, -1]` and *[1, inf]* and is continuous from above on the former and from below on the latter.

The inverse *cos* is also known as *acos* or cos^-1.

References

M. Abramowitz and I.A. Stegun, "Handbook of Mathematical Functions", 10th printing, 1964, pp. 79. https://personal.math.ubc.ca/~cbm/aands/page_79.htm

Examples

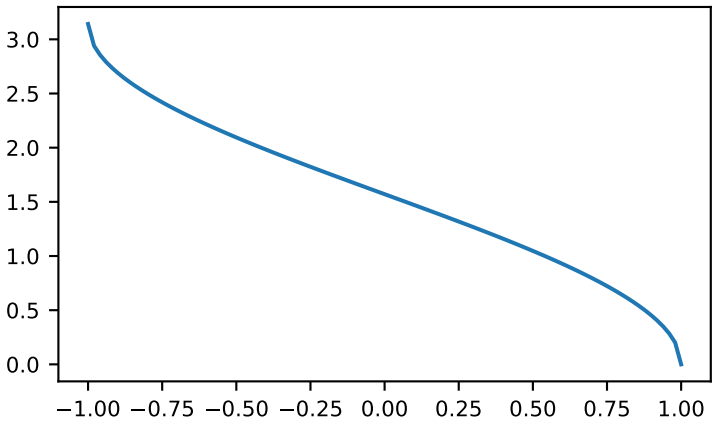
```
>>> import numpy as np
```

We expect the arccos of 1 to be 0, and of -1 to be pi:

```
>>> np.arccos([1, -1])
array([ 0.        ,  3.14159265])
```

Plot arccos:

```
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-1, 1, num=100)
>>> plt.plot(x, np.arccos(x))
>>> plt.axis('tight')
>>> plt.show()
```



numpy.**arctan**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arctan'>**

Trigonometric inverse tangent, element-wise.

The inverse of tan, so that if `y = tan(x)` then `x = arctan(y)`.

Parameters

x
[array_like]

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Out has the same shape as *x*. Its real part is in `[-pi/2, pi/2]` (`arctan(+/-inf)` returns `+/-pi/2`). This is a scalar if *x* is a scalar.

See also:

arctan2
The "four quadrant" arctan of the angle formed by (*x*, *y*) and the positive *x*-axis.

angle
Argument of complex values.

Notes

arctan is a multi-valued function: for each *x* there are infinitely many numbers *z* such that tan(*z*) = *x*. The convention is to return the angle *z* whose real part lies in [-pi/2, pi/2].

For real-valued input data types, *arctan* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arctan* is a complex analytic function that has `[1j, infj]` and `[-1j, -infj]` as branch cuts, and is continuous from the left on the former and from the right on the latter.

The inverse tangent is also known as *atan* or tan^{-1}.

References

Abramowitz, M. and Stegun, I. A., *Handbook of Mathematical Functions*, 10th printing, New York: Dover, 1964, pp. 79. https://personal.math.ubc.ca/~cbm/aands/page_79.htm

Examples

We expect the arctan of 0 to be 0, and of 1 to be pi/4:

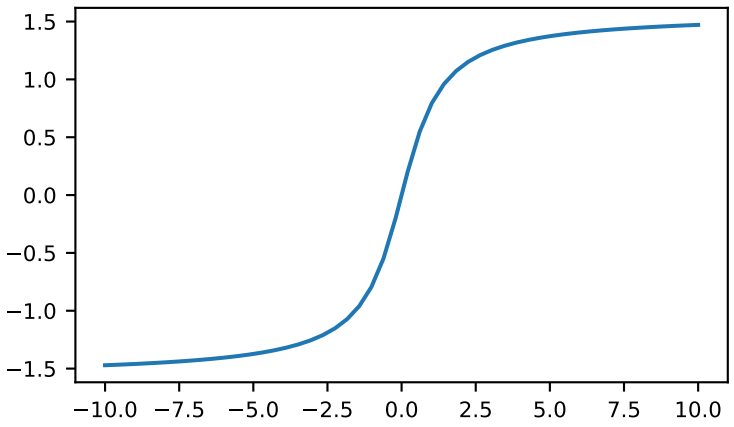
```
>>> import numpy as np
```

```
>>> np.arctan([0, 1])
array([ 0.        ,  0.78539816])
```

```
>>> np.pi/4
0.7853981633974483
```

Plot arctan:

```
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-10, 10)
>>> plt.plot(x, np.arctan(x))
>>> plt.axis('tight')
>>> plt.show()
```



numpy.**atan**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arctan'>**

Trigonometric inverse tangent, element-wise.

The inverse of tan, so that if `y = tan(x)` then `x = arctan(y)`.

Parameters

x

[array_like]

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Out has the same shape as *x*. Its real part is in `[-pi/2, pi/2]` (`arctan(+/-inf)` returns `+/-pi/2`). This is a scalar if *x* is a scalar.

See also:

arctan2
: The "four quadrant" arctan of the angle formed by (*x*, *y*) and the positive *x*-axis.

angle
: Argument of complex values.

Notes

arctan is a multi-valued function: for each *x* there are infinitely many numbers *z* such that tan(*z*) = *x*. The convention is to return the angle *z* whose real part lies in [-pi/2, pi/2].

For real-valued input data types, *arctan* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arctan* is a complex analytic function that has `[1j, infj]` and `[-1j, -infj]` as branch cuts, and is continuous from the left on the former and from the right on the latter.

The inverse tangent is also known as *atan* or tan^{-1}.

References

Abramowitz, M. and Stegun, I. A., *Handbook of Mathematical Functions*, 10th printing, New York: Dover, 1964, pp. 79. https://personal.math.ubc.ca/~cbm/aands/page_79.htm

Examples

We expect the arctan of 0 to be 0, and of 1 to be pi/4:

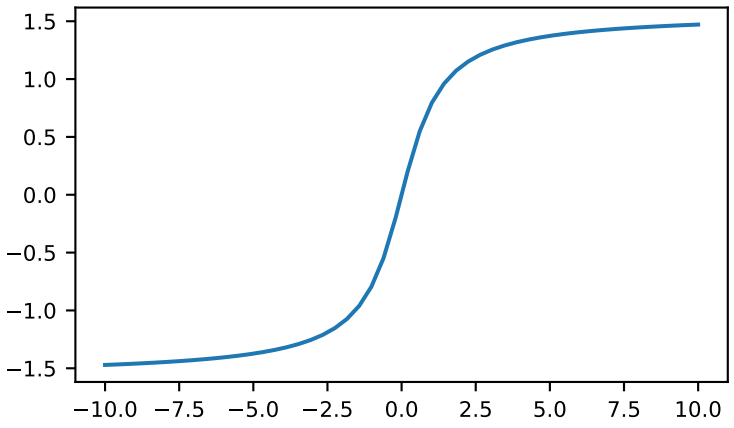
```
>>> import numpy as np
```

```
>>> np.arctan([0, 1])
array([ 0.        ,  0.78539816])
```

```
>>> np.pi/4
0.7853981633974483
```

Plot arctan:

```
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-10, 10)
>>> plt.plot(x, np.arctan(x))
>>> plt.axis('tight')
>>> plt.show()
```



numpy.**hypot**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'hypot'>**

Given the “legs” of a right triangle, return its hypotenuse.

Equivalent to `sqrt(x1**2 + x2**2)`, element-wise. If *x1* or *x2* is scalar_like (i.e., unambiguously cast-able to a scalar type), it is broadcast for use with each element of the other argument. (See Examples)

Parameters

x1, x2
: [array_like] Leg of the triangle(s). If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None,

a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

z
[ndarray] The hypotenuse of the triangle(s). This is a scalar if both *x1* and *x2* are scalars.

Examples

```
>>> import numpy as np
>>> np.hypot(3*np.ones((3, 3)), 4*np.ones((3, 3)))
array([[ 5.,  5.,  5.],
       [ 5.,  5.,  5.],
       [ 5.,  5.,  5.]])
```

Example showing broadcast of scalar_like argument:

```
>>> np.hypot(3*np.ones((3, 3)), [4])
array([[ 5.,  5.,  5.],
       [ 5.,  5.,  5.],
       [ 5.,  5.,  5.]])
```

numpy.**arctan2**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arctan2'>**

Element-wise arc tangent of `x1/x2` choosing the quadrant correctly.

The quadrant (i.e., branch) is chosen so that `arctan2(x1, x2)` is the signed angle in radians between the ray ending at the origin and passing through the point (1,0), and the ray ending at the origin and passing through the point (*x2*, *x1*). (Note the role reversal: the "*y*-coordinate" is the first function parameter, the "*x*-coordinate" is the second.) By IEEE convention, this function is defined for *x2* = +/-0 and for either or both of *x1* and *x2* = +/-inf (see Notes for specific values).

This function is not defined for complex-valued arguments; for the so-called argument of complex values, use *angle*.

Parameters

x1
[array_like, real-valued] *y*-coordinates.

x2
[array_like, real-valued] *x*-coordinates. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

angle
[ndarray] Array of angles in radians, in the range `[-pi, pi]`. This is a scalar if both *x1* and *x2* are scalars.

See also:

arctan*, *tan*, *angle

Notes

arctan2 is identical to the `atan2` function of the underlying C library. The following special values are defined in the C standard: [1]

x1	*x2*	*arctan2(x1,x2)*
+/- 0	+0	+/- 0
+/- 0	-0	+/- pi
> 0	+/-inf	+0 / +pi
< 0	+/-inf	-0 / -pi
+/-inf	+inf	+/- (pi/4)
+/-inf	-inf	+/- (3*pi/4)

Note that +0 and -0 are distinct floating point numbers, as are +inf and -inf.

References

[1]

Examples

Consider four points in different quadrants:

```
>>> import numpy as np
```

```
>>> x = np.array([-1, +1, +1, -1])
>>> y = np.array([-1, -1, +1, +1])
>>> np.arctan2(y, x) * 180 / np.pi
array([-135.,  -45.,   45.,  135.])
```

Note the order of the parameters. `arctan2` is defined also when *x2* = 0 and at several other special points, obtaining values in the range `[-pi, pi]`:

```
>>> np.arctan2([1., -1.], [0., 0.])
array([ 1.57079633, -1.57079633])
>>> np.arctan2([0., 0., np.inf], [+0., -0., np.inf])
array([0.        , 3.14159265, 0.78539816])
```

numpy.**atan2**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arctan2'>**

Element-wise arc tangent of `x1/x2` choosing the quadrant correctly.

The quadrant (i.e., branch) is chosen so that `arctan2(x1, x2)` is the signed angle in radians between the ray ending at the origin and passing through the point (1,0), and the ray ending at the origin and passing through the point (*x2*, *x1*). (Note the role reversal: the "*y*-coordinate" is the first function parameter, the "*x*-coordinate" is the second.) By IEEE convention, this function is defined for *x2* = +/-0 and for either or both of *x1* and *x2* = +/-inf (see Notes for specific values).

This function is not defined for complex-valued arguments; for the so-called argument of complex values, use *angle*.

Parameters

x1
: [array_like, real-valued] *y*-coordinates.

x2
: [array_like, real-valued] *x*-coordinates. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

angle
: [ndarray] Array of angles in radians, in the range `[-pi, pi]`. This is a scalar if both *x1* and *x2* are scalars.

See also:

arctan, ***tan***, ***angle***

Notes

arctan2 is identical to the `atan2` function of the underlying C library. The following special values are defined in the C standard: [1]

x1	*x2*	*arctan2(x1,x2)*
+/- 0	+0	+/- 0
+/- 0	-0	+/- pi
> 0	+/-inf	+0 / +pi
< 0	+/-inf	-0 / -pi
+/-inf	+inf	+/- (pi/4)
+/-inf	-inf	+/- (3*pi/4)

Note that +0 and -0 are distinct floating point numbers, as are +inf and -inf.

References

[1]

Examples

Consider four points in different quadrants:

```
>>> import numpy as np
```

```
>>> x = np.array([-1, +1, +1, -1])
>>> y = np.array([-1, -1, +1, +1])
>>> np.arctan2(y, x) * 180 / np.pi
array([-135.,  -45.,   45.,  135.])
```

Note the order of the parameters. `arctan2` is defined also when *x2* = 0 and at several other special points, obtaining values in the range `[-pi, pi]`:

```
>>> np.arctan2([1., -1.], [0., 0.])
array([ 1.57079633, -1.57079633])
>>> np.arctan2([0., 0., np.inf], [+0., -0., np.inf])
array([0.        , 3.14159265, 0.78539816])
```

numpy.**degrees**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'degrees'>**

Convert angles from radians to degrees.

Parameters

x
: [array_like] Input array in radians.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray of floats] The corresponding degree values; if *out* was supplied this is a reference to it. This is a scalar if *x* is a scalar.

See also:

rad2deg
equivalent function

Examples

Convert a radian array to degrees

```
>>> import numpy as np
```

```
>>> rad = np.arange(12.)*np.pi/6
>>> np.degrees(rad)
array([   0.,   30.,   60.,   90.,  120.,  150.,  180.,  210.,  240.,
        270.,  300.,  330.])
```

```
>>> out = np.zeros((rad.shape))
>>> r = np.degrees(rad, out)
>>> np.all(r == out)
True
```

numpy.**radians**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'radians'>**

Convert angles from degrees to radians.

Parameters

x
[array_like] Input array in degrees.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The corresponding radian values. This is a scalar if *x* is a scalar.

See also:

deg2rad
equivalent function

Examples

```
>>> import numpy as np
```

Convert a degree array to radians

```
>>> deg = np.arange(12.) * 30.
>>> np.radians(deg)
array([ 0.        ,  0.52359878,  1.04719755,  1.57079633,  2.0943951 ,
        2.61799388,  3.14159265,  3.66519143,  4.1887902 ,  4.71238898,
        5.23598776,  5.75958653])
```

```
>>> out = np.zeros((deg.shape))
>>> ret = np.radians(deg, out)
>>> ret is out
True
```

numpy.**unwrap**(*p*, *discont=None*, *axis=-1*, ***, *period=6.283185307179586*)

Unwrap by taking the complement of large deltas with respect to the period.

This unwraps a signal *p* by changing elements which have an absolute difference from their predecessor of more than `max(discont, period/2)` to their *period*-complementary values.

For the default case where *period* is 2π and *discont* is π, this unwraps a radian phase *p* such that adjacent differences are never greater than π by adding $2k\pi$ for some integer k.

Parameters

p
[array_like] Input array.

discont
[float, optional] Maximum discontinuity between values, default is `period/2`. Values below `period/2` are treated as if they were `period/2`. To have an effect different from the default, *discont* should be larger than `period/2`.

axis
[int, optional] Axis along which unwrap will operate, default is the last axis.

period
[float, optional] Size of the range over which the input wraps. By default, it is `2 pi`.

New in version 1.21.0.

Returns

out
[ndarray] Output array.

See also:

rad2deg, *deg2rad*

Notes

If the discontinuity in *p* is smaller than `period/2`, but larger than *discont*, no unwrapping is done because taking the complement would only make the discontinuity larger.

Examples

```
>>> import numpy as np
>>> phase = np.linspace(0, np.pi, num=5)
>>> phase[3:] += np.pi
>>> phase
array([ 0.        ,  0.78539816,  1.57079633,  5.49778714,  6.28318531]) # may␣
↪vary
>>> np.unwrap(phase)
array([ 0.        ,  0.78539816,  1.57079633, -0.78539816,  0.        ]) # may␣
↪vary
>>> np.unwrap([0, 1, 2, -1, 0], period=4)
array([0, 1, 2, 3, 4])
>>> np.unwrap([ 1, 2, 3, 4, 5, 6, 1, 2, 3], period=6)
array([1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> np.unwrap([2, 3, 4, 5, 2, 3, 4, 5], period=4)
array([2, 3, 4, 5, 6, 7, 8, 9])
>>> phase_deg = np.mod(np.linspace(0 ,720, 19), 360) - 180
>>> np.unwrap(phase_deg, period=360)
array([-180., -140., -100.,  -60.,  -20.,   20.,   60.,  100.,  140.,
        180.,  220.,  260.,  300.,  340.,  380.,  420.,  460.,  500.,
        540.])
```

numpy.**deg2rad**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'deg2rad'>**

Convert angles from degrees to radians.

Parameters

x
[array_like] Angles in degrees.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The corresponding angle in radians. This is a scalar if *x* is a scalar.

See also:

rad2deg
Convert angles from radians to degrees.

unwrap
Remove large jumps in angle by wrapping.

Notes

`deg2rad(x)` is `x * pi / 180`.

Examples

```
>>> import numpy as np
>>> np.deg2rad(180)
3.1415926535897931
```

numpy.**rad2deg**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'rad2deg'>**

Convert angles from radians to degrees.

Parameters

x
[array_like] Angle in radians.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The corresponding angle in degrees. This is a scalar if *x* is a scalar.

See also:

deg2rad
Convert angles from degrees to radians.

unwrap
Remove large jumps in angle by wrapping.

Notes

rad2deg(x) is `180 * x / pi`.

Examples

```
>>> import numpy as np
>>> np.rad2deg(np.pi/2)
90.0
```

Hyperbolic functions

sinh(x, /[, out, where, casting, order, ...])	Hyperbolic sine, element-wise.
cosh(x, /[, out, where, casting, order, ...])	Hyperbolic cosine, element-wise.
tanh(x, /[, out, where, casting, order, ...])	Compute hyperbolic tangent element-wise.
arcsinh(x, /[, out, where, casting, order, ...])	Inverse hyperbolic sine element-wise.
asinh(x, /[, out, where, casting, order, ...])	Inverse hyperbolic sine element-wise.
arccosh(x, /[, out, where, casting, order, ...])	Inverse hyperbolic cosine, element-wise.
acosh(x, /[, out, where, casting, order, ...])	Inverse hyperbolic cosine, element-wise.
arctanh(x, /[, out, where, casting, order, ...])	Inverse hyperbolic tangent element-wise.
atanh(x, /[, out, where, casting, order, ...])	Inverse hyperbolic tangent element-wise.

numpy.**sinh**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'sinh'>**

Hyperbolic sine, element-wise.

Equivalent to `1/2 * (np.exp(x) - np.exp(-x))` or `-1j * np.sin(1j*x)`.

Parameters

x
[array_like] Input array.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The corresponding hyperbolic sine values. This is a scalar if *x* is a scalar.

Notes

If *out* is provided, the function writes the result into it, and returns a reference to *out*. (See Examples)

References

M. Abramowitz and I. A. Stegun, Handbook of Mathematical Functions. New York, NY: Dover, 1972, pg. 83.

Examples

```
>>> import numpy as np
>>> np.sinh(0)
0.0
>>> np.sinh(np.pi*1j/2)
1j
>>> np.sinh(np.pi*1j) # (exact value is 0)
1.2246063538223773e-016j
>>> # Discrepancy due to vagaries of floating point arithmetic.
```

```
>>> # Example of providing the optional output parameter
>>> out1 = np.array([0], dtype='d')
>>> out2 = np.sinh([0.1], out1)
>>> out2 is out1
True
```

```
>>> # Example of ValueError due to provision of shape mis-matched `out`
>>> np.sinh(np.zeros((3,3)),np.zeros((2,2)))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operands could not be broadcast together with shapes (3,3) (2,2)
```

numpy.**cosh** (*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'cosh'>**

Hyperbolic cosine, element-wise.

Equivalent to `1/2 * (np.exp(x) + np.exp(-x))` and `np.cos(1j*x)`.

Parameters

x
[array_like] Input array.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

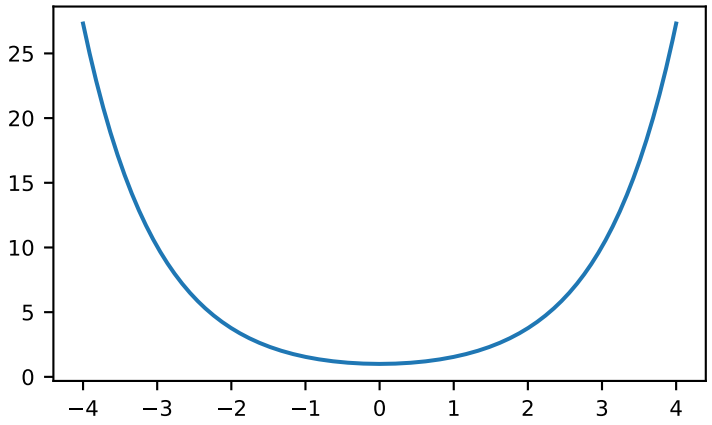
out
[ndarray or scalar] Output array of same shape as *x*. This is a scalar if *x* is a scalar.

Examples

```
>>> import numpy as np
>>> np.cosh(0)
1.0
```

The hyperbolic cosine describes the shape of a hanging cable:

```
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-4, 4, 1000)
>>> plt.plot(x, np.cosh(x))
>>> plt.show()
```



numpy.**tanh**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'tanh'>**

Compute hyperbolic tangent element-wise.

Equivalent to `np.sinh(x)/np.cosh(x)` or `-1j * np.tan(1j*x)`.

Parameters

x
[array_like] Input array.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] The corresponding hyperbolic tangent values. This is a scalar if *x* is a scalar.

Notes

If *out* is provided, the function writes the result into it, and returns a reference to *out*. (See Examples)

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.tanh((0, np.pi*1j, np.pi*1j/2))
array([ 0. +0.00000000e+00j,  0. -1.22460635e-16j,  0. +1.63317787e+16j])
```

```
>>> # Example of providing the optional output parameter illustrating
>>> # that what is returned is a reference to said parameter
>>> out1 = np.array([0], dtype='d')
>>> out2 = np.tanh([0.1], out1)
>>> out2 is out1
True
```

```
>>> # Example of ValueError due to provision of shape mis-matched `out`
>>> np.tanh(np.zeros((3,3)),np.zeros((2,2)))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operands could not be broadcast together with shapes (3,3) (2,2)
```

numpy.**arcsinh**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arcsinh'>**

Inverse hyperbolic sine element-wise.

Parameters

x
: [array_like] Input array.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Array of the same shape as *x*. This is a scalar if *x* is a scalar.

Notes

`arcsinh` is a multivalued function: for each *x* there are infinitely many numbers *z* such that *sinh(z) = x*. The convention is to return the *z* whose imaginary part lies in *[-pi/2, pi/2]*.

For real-valued input data types, `arcsinh` always returns real output. For each value that cannot be expressed as a real number or infinity, it returns `nan` and sets the *invalid* floating point error flag.

For complex-valued input, `arcsinh` is a complex analytical function that has branch cuts *[1j, infj]* and *[-1j, -infj]* and is continuous from the right on the former and from the left on the latter.

The inverse hyperbolic sine is also known as `asinh` or `sinh^-1`.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.arcsinh(np.array([np.e, 10.0]))
array([ 1.72538256,  2.99822295])
```

numpy.**asinh**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arcsinh'>**

Inverse hyperbolic sine element-wise.

Parameters

x
: [array_like] Input array.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None,

a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Array of the same shape as *x*. This is a scalar if *x* is a scalar.

Notes

`arcsinh` is a multivalued function: for each *x* there are infinitely many numbers *z* such that *sinh(z) = x*. The convention is to return the *z* whose imaginary part lies in *[-pi/2, pi/2]*.

For real-valued input data types, `arcsinh` always returns real output. For each value that cannot be expressed as a real number or infinity, it returns `nan` and sets the *invalid* floating point error flag.

For complex-valued input, `arcsinh` is a complex analytical function that has branch cuts *[1j, infj]* and *[-1j, -infj]* and is continuous from the right on the former and from the left on the latter.

The inverse hyperbolic sine is also known as `asinh` or `sinh^-1`.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.arcsinh(np.array([np.e, 10.0]))
array([ 1.72538256,  2.99822295])
```

numpy.**arccosh**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arccosh'>**

Inverse hyperbolic cosine, element-wise.

Parameters

x
[array_like] Input array.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

arccosh
[ndarray] Array of the same shape as *x*. This is a scalar if *x* is a scalar.

See also:

cosh*, *arcsinh*, *sinh*, *arctanh*, *tanh

Notes

arccosh is a multivalued function: for each *x* there are infinitely many numbers *z* such that *cosh(z) = x*. The convention is to return the *z* whose imaginary part lies in `[-pi, pi]` and the real part in `[0, inf]`.

For real-valued input data types, *arccosh* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arccosh* is a complex analytical function that has a branch cut *[-inf, 1]* and is continuous from above on it.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.arccosh([np.e, 10.0])
array([ 1.65745445,  2.99322285])
>>> np.arccosh(1)
0.0
```

numpy.**acosh**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arccosh'>**

Inverse hyperbolic cosine, element-wise.

Parameters

x
[array_like] Input array.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

arccosh
[ndarray] Array of the same shape as *x*. This is a scalar if *x* is a scalar.

See also:

cosh*, *arcsinh*, *sinh*, *arctanh*, *tanh

Notes

arccosh is a multivalued function: for each *x* there are infinitely many numbers *z* such that *cosh(z) = x*. The convention is to return the *z* whose imaginary part lies in `[-pi, pi]` and the real part in `[0, inf]`.

For real-valued input data types, *arccosh* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arccosh* is a complex analytical function that has a branch cut *[-inf, 1]* and is continuous from above on it.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.arccosh([np.e, 10.0])
array([ 1.65745445,  2.99322285])
>>> np.arccosh(1)
0.0
```

numpy.**arctanh**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arctanh'>**

Inverse hyperbolic tangent element-wise.

Parameters

x
[array_like] Input array.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Array of the same shape as *x*. This is a scalar if *x* is a scalar.

See also:

emath.arctanh

Notes

arctanh is a multivalued function: for each *x* there are infinitely many numbers *z* such that `tanh(z) = x`. The convention is to return the *z* whose imaginary part lies in *[-pi/2, pi/2]*.

For real-valued input data types, *arctanh* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arctanh* is a complex analytical function that has branch cuts *[-1, -inf]* and *[1, inf]* and is continuous from above on the former and from below on the latter.

The inverse hyperbolic tangent is also known as *atanh* or `tanh^-1`.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.arctanh([0, -0.5])
array([ 0.        , -0.54930614])
```

numpy.**atanh**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'arctanh'>**

Inverse hyperbolic tangent element-wise.

Parameters

x
[array_like] Input array.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Array of the same shape as *x*. This is a scalar if *x* is a scalar.

See also:

emath.arctanh

Notes

arctanh is a multivalued function: for each *x* there are infinitely many numbers *z* such that `tanh(z) = x`. The convention is to return the *z* whose imaginary part lies in *[-pi/2, pi/2]*.

For real-valued input data types, *arctanh* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *arctanh* is a complex analytical function that has branch cuts *[-1, -inf]* and *[1, inf]* and is continuous from above on the former and from below on the latter.

The inverse hyperbolic tangent is also known as *atanh* or `tanh^-1`.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.arctanh([0, -0.5])
array([ 0.        , -0.54930614])
```

Rounding

round(a[, decimals, out])	Evenly round to the given number of decimals.
around(a[, decimals, out])	Round an array to the given number of decimals.
rint(x, /[, out, where, casting, order, ...])	Round elements of the array to the nearest integer.
fix(x[, out])	Round to nearest integer towards zero.
floor(x, /[, out, where, casting, order, ...])	Return the floor of the input, element-wise.
ceil(x, /[, out, where, casting, order, ...])	Return the ceiling of the input, element-wise.
trunc(x, /[, out, where, casting, order, ...])	Return the truncated value of the input, element-wise.

numpy.**round**(*a*, *decimals=0*, *out=None*)

Evenly round to the given number of decimals.

Parameters

a
[array_like] Input data.

decimals
[int, optional] Number of decimal places to round to (default: 0). If decimals is negative, it specifies the number of positions to the left of the decimal point.

out
[ndarray, optional] Alternative output array in which to place the result. It must have the same shape as the expected output, but the type of the output values will be cast if necessary. See ufuncs-output-type for more details.

Returns

rounded_array
[ndarray] An array of the same type as *a*, containing the rounded values. Unless *out* was specified, a new array is created. A reference to the result is returned.

The real and imaginary parts of complex numbers are rounded separately. The result of rounding a float is a float.

See also:

ndarray.round
equivalent method

around
an alias for this function

ceil, ***fix***, ***floor***, ***rint***, ***trunc***

Notes

For values exactly halfway between rounded decimal values, NumPy rounds to the nearest even value. Thus 1.5 and 2.5 round to 2.0, -0.5 and 0.5 round to 0.0, etc.

`np.round` uses a fast but sometimes inexact algorithm to round floating-point datatypes. For positive *decimals* it is equivalent to `np.true_divide(np.rint(a * 10**decimals), 10**decimals)`, which has error due to the inexact representation of decimal fractions in the IEEE floating point standard [1] and errors introduced when scaling by powers of ten. For instance, note the extra "1" in the following:

```
>>> np.round(56294995342131.5, 3)
56294995342131.51
```

If your goal is to print such values with a fixed number of decimals, it is preferable to use numpy's float printing routines to limit the number of printed decimals:

```
>>> np.format_float_positional(56294995342131.5, precision=3)
'56294995342131.5'
```

The float printing routines use an accurate but much more computationally demanding algorithm to compute the number of digits after the decimal point.

Alternatively, Python's builtin *round* function uses a more accurate but slower algorithm for 64-bit floating point values:

```
>>> round(56294995342131.5, 3)
56294995342131.5
>>> np.round(16.055, 2), round(16.055, 2)  # equals 16.0549999999999997
(16.06, 16.05)
```

References

[1]

Examples

```
>>> import numpy as np
>>> np.round([0.37, 1.64])
array([0., 2.])
>>> np.round([0.37, 1.64], decimals=1)
array([0.4, 1.6])
>>> np.round([.5, 1.5, 2.5, 3.5, 4.5]) # rounds to nearest even value
array([0., 2., 2., 4., 4.])
>>> np.round([1,2,3,11], decimals=1) # ndarray of ints is returned
array([ 1,  2,  3, 11])
>>> np.round([1,2,3,11], decimals=-1)
array([ 0,  0,  0, 10])
```

numpy.**around**(*a*, *decimals=0*, *out=None*)

Round an array to the given number of decimals.

around is an alias of *round*.

See also:

ndarray.round
equivalent method

round
alias for this function

ceil*, *fix*, *floor*, *rint*, *trunc

numpy.**rint**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'rint'>**

Round elements of the array to the nearest integer.

Parameters

x
[array_like] Input array.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain

its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Output array is same shape and type as *x*. This is a scalar if *x* is a scalar.

See also:

fix*, *ceil*, *floor*, *trunc

Notes

For values exactly halfway between rounded decimal values, NumPy rounds to the nearest even value. Thus 1.5 and 2.5 round to 2.0, -0.5 and 0.5 round to 0.0, etc.

Examples

```
>>> import numpy as np
>>> a = np.array([-1.7, -1.5, -0.2, 0.2, 1.5, 1.7, 2.0])
>>> np.rint(a)
array([-2., -2., -0.,  0.,  2.,  2.,  2.])
```

`numpy.`**`fix`**(*x*, *out=None*)

Round to nearest integer towards zero.

Round an array of floats element-wise to nearest integer towards zero. The rounded values have the same data-type as the input.

Parameters

x
[array_like] An array to be rounded

out
[ndarray, optional] A location into which the result is stored. If provided, it must have a shape that the input broadcasts to. If not provided or None, a freshly-allocated array is returned.

Returns

out
[ndarray of floats] An array with the same dimensions and data-type as the input. If second argument is not supplied then a new array is returned with the rounded values.

If a second argument is supplied the result is stored there. The return value `out` is then a reference to that array.

See also:

rint*, *trunc*, *floor*, *ceil
around
Round to given number of decimals

Examples

```
>>> import numpy as np
>>> np.fix(3.14)
3.0
>>> np.fix(3)
3
>>> np.fix([2.1, 2.9, -2.1, -2.9])
array([ 2.,  2., -2., -2.])
```

numpy.**floor**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'floor'>**

Return the floor of the input, element-wise.

The floor of the scalar *x* is the largest integer *i*, such that *i* <= *x*. It is often denoted as $\lfloor x \rfloor$.

Parameters

x
: [array_like] Input data.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray or scalar] The floor of each element in *x*. This is a scalar if *x* is a scalar.

See also:

ceil*, *trunc*, *rint*, *fix

Notes

Some spreadsheet programs calculate the "floor-towards-zero", where `floor(-2.5) == -2`. NumPy instead uses the definition of *floor* where *floor(-2.5) == -3*. The "floor-towards-zero" function is called `fix` in NumPy.

Examples

```
>>> import numpy as np
>>> a = np.array([-1.7, -1.5, -0.2, 0.2, 1.5, 1.7, 2.0])
>>> np.floor(a)
array([-2., -2., -1.,  0.,  1.,  1.,  2.])
```

numpy.**ceil**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'ceil'>**

Return the ceiling of the input, element-wise.

The ceil of the scalar *x* is the smallest integer *i*, such that `i >= x`. It is often denoted as $\lceil x \rceil$.

Parameters

x
[array_like] Input data.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or scalar] The ceiling of each element in *x*. This is a scalar if *x* is a scalar.

See also:

floor, ***trunc***, ***rint***, ***fix***

Examples

```
>>> import numpy as np
```

```
>>> a = np.array([-1.7, -1.5, -0.2, 0.2, 1.5, 1.7, 2.0])
>>> np.ceil(a)
array([-1., -1., -0.,  1.,  2.,  2.,  2.])
```

numpy.**trunc**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'trunc'>**

Return the truncated value of the input, element-wise.

The truncated value of the scalar *x* is the nearest integer *i* which is closer to zero than *x* is. In short, the fractional part of the signed number *x* is discarded.

Parameters

x
: [array_like] Input data.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray or scalar] The truncated value of each element in *x*. This is a scalar if *x* is a scalar.

See also:

ceil*, *floor*, *rint*, *fix

Examples

```
>>> import numpy as np
>>> a = np.array([-1.7, -1.5, -0.2, 0.2, 1.5, 1.7, 2.0])
>>> np.trunc(a)
array([-1., -1., -0.,  0.,  1.,  1.,  2.])
```

Sums, products, differences

prod(a[, axis, dtype, out, keepdims, ...])	Return the product of array elements over a given axis.
sum(a[, axis, dtype, out, keepdims, ...])	Sum of array elements over a given axis.
nanprod(a[, axis, dtype, out, keepdims, ...])	Return the product of array elements over a given axis treating Not a Numbers (NaNs) as ones.
nansum(a[, axis, dtype, out, keepdims, ...])	Return the sum of array elements over a given axis treating Not a Numbers (NaNs) as zero.
cumulative_sum(x, /, *[, axis, dtype, out, ...])	Return the cumulative sum of the elements along a given axis.
cumulative_prod(x, /, *[, axis, dtype, out, ...])	Return the cumulative product of elements along a given axis.
cumprod(a[, axis, dtype, out])	Return the cumulative product of elements along a given axis.
cumsum(a[, axis, dtype, out])	Return the cumulative sum of the elements along a given axis.
nancumprod(a[, axis, dtype, out])	Return the cumulative product of array elements over a given axis treating Not a Numbers (NaNs) as one.
nancumsum(a[, axis, dtype, out])	Return the cumulative sum of array elements over a given axis treating Not a Numbers (NaNs) as zero.
diff(a[, n, axis, prepend, append])	Calculate the n-th discrete difference along the given axis.
ediff1d(ary[, to_end, to_begin])	The differences between consecutive elements of an array.
gradient(f, *varargs[, axis, edge_order])	Return the gradient of an N-dimensional array.
cross(a, b[, axisa, axisb, axisc, axis])	Return the cross product of two (arrays of) vectors.
trapezoid(y[, x, dx, axis])	Integrate along the given axis using the composite trapezoidal rule.

numpy.**prod**(*a*, *axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the product of array elements over a given axis.

Parameters

a
[array_like] Input data.

axis
[None or int or tuple of ints, optional] Axis or axes along which a product is performed. The default, axis=None, will calculate the product of all the elements in the input array. If axis is negative it counts from the last to the first axis.

If axis is a tuple of ints, a product is performed on all of the axes specified in the tuple instead of a single axis or all the axes as before.

dtype
[dtype, optional] The type of the returned array, as well as of the accumulator in which the elements are multiplied. The dtype of *a* is used by default unless *a* has an integer dtype of less precision than the default platform integer. In that case, if *a* is signed then the platform integer is used while if *a* is unsigned then an unsigned integer of the same precision as the platform integer is used.

out
[ndarray, optional] Alternative output array in which to place the result. It must have the same shape as the expected output, but the type of the output values will be cast if necessary.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as di-

mensions with size one. With this option, the result will broadcast correctly against the input array.

If the default value is passed, then *keepdims* will not be passed through to the `prod` method of sub-classes of `ndarray`, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

initial
[scalar, optional] The starting value for this product. See `reduce` for details.

where
[array_like of bool, optional] Elements to include in the product. See `reduce` for details.

Returns

product_along_axis
[ndarray, see `dtype` parameter above.] An array shaped as *a* but with the specified axis removed. Returns a reference to *out* if specified.

See also:

ndarray.prod
equivalent method

ufuncs-output-type

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow. That means that, on a 32-bit platform:

```
>>> x = np.array([536870910, 536870910, 536870910, 536870910])
>>> np.prod(x)
16 # may vary
```

The product of an empty array is the neutral element 1:

```
>>> np.prod([])
1.0
```

Examples

By default, calculate the product of all elements:

```
>>> import numpy as np
>>> np.prod([1.,2.])
2.0
```

Even when the input array is two-dimensional:

```
>>> a = np.array([[1., 2.], [3., 4.]])
>>> np.prod(a)
24.0
```

But we can also specify the axis over which to multiply:

```
>>> np.prod(a, axis=1)
array([  2.,  12.])
>>> np.prod(a, axis=0)
array([3., 8.])
```

Or select specific elements to include:

```
>>> np.prod([1., np.nan, 3.], where=[True, False, True])
3.0
```

If the type of *x* is unsigned, then the output type is the unsigned platform integer:

```
>>> x = np.array([1, 2, 3], dtype=np.uint8)
>>> np.prod(x).dtype == np.uint
True
```

If *x* is of a signed integer type, then the output type is the default platform integer:

```
>>> x = np.array([1, 2, 3], dtype=np.int8)
>>> np.prod(x).dtype == int
True
```

You can also start the product with a value other than one:

```
>>> np.prod([1, 2], initial=5)
10
```

numpy.**sum**(*a*, *axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Sum of array elements over a given axis.

Parameters

a
: [array_like] Elements to sum.

axis
: [None or int or tuple of ints, optional] Axis or axes along which a sum is performed. The default, axis=None, will sum all of the elements of the input array. If axis is negative it counts from the last to the first axis. If axis is a tuple of ints, a sum is performed on all of the axes specified in the tuple instead of a single axis or all the axes as before.

dtype
: [dtype, optional] The type of the returned array and of the accumulator in which the elements are summed. The dtype of *a* is used by default unless *a* has an integer dtype of less precision than the default platform integer. In that case, if *a* is signed then the platform integer is used while if *a* is unsigned then an unsigned integer of the same precision as the platform integer is used.

out
: [ndarray, optional] Alternative output array in which to place the result. It must have the same shape as the expected output, but the type of the output values will be cast if necessary.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

If the default value is passed, then *keepdims* will not be passed through to the `sum` method of sub-classes of `ndarray`, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

initial
[scalar, optional] Starting value for the sum. See `reduce` for details.

where
[array_like of bool, optional] Elements to include in the sum. See `reduce` for details.

Returns

sum_along_axis
[ndarray] An array with the same shape as *a*, with the specified axis removed. If *a* is a 0-d array, or if *axis* is None, a scalar is returned. If an output array is specified, a reference to *out* is returned.

See also:

ndarray.sum
Equivalent method.

add
`numpy.add.reduce` equivalent function.

cumsum
Cumulative sum of array elements.

trapezoid
Integration of array values using composite trapezoidal rule.

mean*, *average

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

The sum of an empty array is the neutral element 0:

```
>>> np.sum([])
0.0
```

For floating point numbers the numerical precision of sum (and `np.add.reduce`) is in general limited by directly adding each number individually to the result causing rounding errors in every step. However, often numpy will use a numerically better approach (partial pairwise summation) leading to improved precision in many use-cases. This improved precision is always provided when no `axis` is given. When `axis` is given, it will depend on which axis is summed. Technically, to provide the best speed possible, the improved precision is only used when the summation is along the fast axis in memory. Note that the exact precision may vary depending on other parameters. In contrast to NumPy, Python's `math.fsum` function uses a slower but more precise approach to summation. Especially when summing a large number of lower precision floating point numbers, such as `float32`, numerical errors can become significant. In such cases it can be advisable to use *dtype="float64"* to use a higher precision for the output.

Examples

```
>>> import numpy as np
>>> np.sum([0.5, 1.5])
2.0
>>> np.sum([0.5, 0.7, 0.2, 1.5], dtype=np.int32)
np.int32(1)
>>> np.sum([[0, 1], [0, 5]])
6
>>> np.sum([[0, 1], [0, 5]], axis=0)
array([0, 6])
>>> np.sum([[0, 1], [0, 5]], axis=1)
array([1, 5])
>>> np.sum([[0, 1], [np.nan, 5]], where=[False, True], axis=1)
array([1., 5.])
```

If the accumulator is too small, overflow occurs:

```
>>> np.ones(128, dtype=np.int8).sum(dtype=np.int8)
np.int8(-128)
```

You can also start the sum with a value other than zero:

```
>>> np.sum([10], initial=5)
15
```

numpy.**nanprod**(*a*, *axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the product of array elements over a given axis treating Not a Numbers (NaNs) as ones.

One is returned for slices that are all-NaN or empty.

Parameters

a
: [array_like] Array containing numbers whose product is desired. If *a* is not an array, a conversion is attempted.

axis
: [{int, tuple of int, None}, optional] Axis or axes along which the product is computed. The default is to compute the product of the flattened array.

dtype
: [data-type, optional] The type of the returned array and of the accumulator in which the elements are summed. By default, the dtype of *a* is used. An exception is when *a* has an integer type with less precision than the platform (u)intp. In that case, the default will be either (u)int32 or (u)int64 depending on whether the platform is 32 or 64 bits. For inexact inputs, dtype must be inexact.

out
: [ndarray, optional] Alternate output array in which to place the result. The default is `None`. If provided, it must have the same shape as the expected output, but the type will be cast if necessary. See ufuncs-output-type for more details. The casting of NaN to integer can yield unexpected results.

keepdims
: [bool, optional] If True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *arr*.

initial
[scalar, optional] The starting value for this product. See *reduce* for details.

New in version 1.22.0.

where
[array_like of bool, optional] Elements to include in the product. See *reduce* for details.

New in version 1.22.0.

Returns

nanprod
[ndarray] A new array holding the result is returned unless *out* is specified, in which case it is returned.

See also:

numpy.prod
Product across array propagating NaNs.

isnan
Show which elements are NaN.

Examples

```
>>> import numpy as np
>>> np.nanprod(1)
1
>>> np.nanprod([1])
1
>>> np.nanprod([1, np.nan])
1.0
>>> a = np.array([[1, 2], [3, np.nan]])
>>> np.nanprod(a)
6.0
>>> np.nanprod(a, axis=0)
array([3., 2.])
```

numpy.**nansum**(*a*, *axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the sum of array elements over a given axis treating Not a Numbers (NaNs) as zero.

In NumPy versions <= 1.9.0 Nan is returned for slices that are all-NaN or empty. In later versions zero is returned.

Parameters

a
[array_like] Array containing numbers whose sum is desired. If *a* is not an array, a conversion is attempted.

axis
[{int, tuple of int, None}, optional] Axis or axes along which the sum is computed. The default is to compute the sum of the flattened array.

dtype
[data-type, optional] The type of the returned array and of the accumulator in which the elements are summed. By default, the dtype of *a* is used. An exception is when *a* has an integer type with less precision than the platform (u)intp. In that case, the default will be either (u)int32

or (u)int64 depending on whether the platform is 32 or 64 bits. For inexact inputs, dtype must be inexact.

out
: [ndarray, optional] Alternate output array in which to place the result. The default is `None`. If provided, it must have the same shape as the expected output, but the type will be cast if necessary. See ufuncs-output-type for more details. The casting of NaN to integer can yield unexpected results.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*.

  If the value is anything but the default, then *keepdims* will be passed through to the *mean* or *sum* methods of sub-classes of *ndarray*. If the sub-classes methods does not implement *keepdims* any exceptions will be raised.

initial
: [scalar, optional] Starting value for the sum. See *reduce* for details.

  New in version 1.22.0.

where
: [array_like of bool, optional] Elements to include in the sum. See *reduce* for details.

  New in version 1.22.0.

Returns

nansum
: [ndarray.] A new array holding the result is returned unless *out* is specified, in which it is returned. The result has the same size as *a*, and the same shape as *a* if *axis* is not None or *a* is a 1-d array.

See also:

numpy.sum
: Sum across array propagating NaNs.

isnan
: Show which elements are NaN.

isfinite
: Show which elements are not NaN or +/-inf.

Notes

If both positive and negative infinity are present, the sum will be Not A Number (NaN).

Examples

```
>>> import numpy as np
>>> np.nansum(1)
1
>>> np.nansum([1])
1
>>> np.nansum([1, np.nan])
1.0
>>> a = np.array([[1, 1], [1, np.nan]])
>>> np.nansum(a)
3.0
>>> np.nansum(a, axis=0)
array([2.,  1.])
>>> np.nansum([1, np.nan, np.inf])
inf
>>> np.nansum([1, np.nan, -np.inf])
-inf
>>> from numpy.testing import suppress_warnings
>>> with np.errstate(invalid="ignore"):
...     np.nansum([1, np.nan, np.inf, -np.inf]) # both +/- infinity present
np.float64(nan)
```

numpy.**cumulative_sum**(*x*, */*, *, *axis=None*, *dtype=None*, *out=None*, *include_initial=False*)

Return the cumulative sum of the elements along a given axis.

This function is an Array API compatible alternative to *numpy.cumsum*.

Parameters

x
: [array_like] Input array.

axis
: [int, optional] Axis along which the cumulative sum is computed. The default (None) is only allowed for one-dimensional arrays. For arrays with more than one dimension `axis` is required.

dtype
: [dtype, optional] Type of the returned array and of the accumulator in which the elements are summed. If `dtype` is not specified, it defaults to the dtype of `x`, unless `x` has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used.

out
: [ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary. See ufuncs-output-type for more details.

include_initial
: [bool, optional] Boolean indicating whether to include the initial value (zeros) as the first value in the output. With `include_initial=True` the shape of the output is different than the shape of the input. Default: `False`.

Returns

cumulative_sum_along_axis
: [ndarray] A new array holding the result is returned unless `out` is specified, in which case a reference to `out` is returned. The result has the same shape as `x` if `include_initial=False`.

See also:

sum
Sum array elements.

trapezoid
Integration of array values using composite trapezoidal rule.

diff
Calculate the n-th discrete difference along given axis.

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

`cumulative_sum(a)[-1]` may not be equal to `sum(a)` for floating-point values since `sum` may use a pairwise summation routine, reducing the roundoff-error. See *sum* for more information.

Examples

```
>>> a = np.array([1, 2, 3, 4, 5, 6])
>>> a
array([1, 2, 3, 4, 5, 6])
>>> np.cumulative_sum(a)
array([ 1,  3,  6, 10, 15, 21])
>>> np.cumulative_sum(a, dtype=float)  # specifies type of output value(s)
array([  1.,   3.,   6.,  10.,  15.,  21.])
```

```
>>> b = np.array([[1, 2, 3], [4, 5, 6]])
>>> np.cumulative_sum(b,axis=0)  # sum over rows for each of the 3 columns
array([[1, 2, 3],
       [5, 7, 9]])
>>> np.cumulative_sum(b,axis=1)  # sum over columns for each of the 2 rows
array([[ 1,  3,  6],
       [ 4,  9, 15]])
```

`cumulative_sum(c)[-1]` may not be equal to `sum(c)`

```
>>> c = np.array([1, 2e-9, 3e-9] * 1000000)
>>> np.cumulative_sum(c)[-1]
1000000.0050045159
>>> c.sum()
1000000.0050000029
```

numpy.**cumulative_prod**(*x*, */*, ***, *axis=None*, *dtype=None*, *out=None*, *include_initial=False*)

Return the cumulative product of elements along a given axis.

This function is an Array API compatible alternative to *numpy.cumprod*.

Parameters

x
[array_like] Input array.

axis
[int, optional] Axis along which the cumulative product is computed. The default (None) is

only allowed for one-dimensional arrays. For arrays with more than one dimension `axis` is required.

dtype
: [dtype, optional] Type of the returned array, as well as of the accumulator in which the elements are multiplied. If `dtype` is not specified, it defaults to the dtype of `x`, unless `x` has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used instead.

out
: [ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type of the resulting values will be cast if necessary. See ufuncs-output-type for more details.

include_initial
: [bool, optional] Boolean indicating whether to include the initial value (ones) as the first value in the output. With `include_initial=True` the shape of the output is different than the shape of the input. Default: `False`.

Returns

cumulative_prod_along_axis
: [ndarray] A new array holding the result is returned unless `out` is specified, in which case a reference to `out` is returned. The result has the same shape as `x` if `include_initial=False`.

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

```
>>> a = np.array([1, 2, 3])
>>> np.cumulative_prod(a)  # intermediate results 1, 1*2
...                        # total product 1*2*3 = 6
array([1, 2, 6])
>>> a = np.array([1, 2, 3, 4, 5, 6])
>>> np.cumulative_prod(a, dtype=float) # specify type of output
array([   1.,    2.,    6.,   24.,  120.,  720.])
```

The cumulative product for each column (i.e., over the rows) of `b`:

```
>>> b = np.array([[1, 2, 3], [4, 5, 6]])
>>> np.cumulative_prod(b, axis=0)
array([[ 1,  2,  3],
       [ 4, 10, 18]])
```

The cumulative product for each row (i.e. over the columns) of `b`:

```
>>> np.cumulative_prod(b, axis=1)
array([[  1,   2,   6],
       [  4,  20, 120]])
```

`numpy.`**`cumprod`**(*a*, *axis=None*, *dtype=None*, *out=None*)

Return the cumulative product of elements along a given axis.

Parameters

a
[array_like] Input array.

axis
[int, optional] Axis along which the cumulative product is computed. By default the input is flattened.

dtype
[dtype, optional] Type of the returned array, as well as of the accumulator in which the elements are multiplied. If *dtype* is not specified, it defaults to the dtype of *a*, unless *a* has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used instead.

out
[ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type of the resulting values will be cast if necessary.

Returns

cumprod
[ndarray] A new array holding the result is returned unless *out* is specified, in which case a reference to out is returned.

See also:

cumulative_prod
Array API compatible alternative for `cumprod`.

ufuncs-output-type

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

Examples

```
>>> import numpy as np
>>> a = np.array([1,2,3])
>>> np.cumprod(a) # intermediate results 1, 1*2
...               # total product 1*2*3 = 6
array([1, 2, 6])
>>> a = np.array([[1, 2, 3], [4, 5, 6]])
>>> np.cumprod(a, dtype=float) # specify type of output
array([   1.,    2.,    6.,   24.,  120.,  720.])
```

The cumulative product for each column (i.e., over the rows) of *a*:

```
>>> np.cumprod(a, axis=0)
array([[ 1,  2,  3],
       [ 4, 10, 18]])
```

The cumulative product for each row (i.e. over the columns) of *a*:

```
>>> np.cumprod(a,axis=1)
array([[  1,   2,   6],
       [  4,  20, 120]])
```

numpy.**cumsum**(*a*, *axis=None*, *dtype=None*, *out=None*)

Return the cumulative sum of the elements along a given axis.

Parameters

a
[array_like] Input array.

axis
[int, optional] Axis along which the cumulative sum is computed. The default (None) is to compute the cumsum over the flattened array.

dtype
[dtype, optional] Type of the returned array and of the accumulator in which the elements are summed. If *dtype* is not specified, it defaults to the dtype of *a*, unless *a* has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used.

out
[ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary. See ufuncs-output-type for more details.

Returns

cumsum_along_axis
[ndarray.] A new array holding the result is returned unless *out* is specified, in which case a reference to *out* is returned. The result has the same size as *a*, and the same shape as *a* if *axis* is not None or *a* is a 1-d array.

See also:

cumulative_sum
Array API compatible alternative for `cumsum`.

sum
Sum array elements.

trapezoid
Integration of array values using composite trapezoidal rule.

diff
Calculate the n-th discrete difference along given axis.

Notes

Arithmetic is modular when using integer types, and no error is raised on overflow.

`cumsum(a)[-1]` may not be equal to `sum(a)` for floating-point values since `sum` may use a pairwise summation routine, reducing the roundoff-error. See *sum* for more information.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,2,3], [4,5,6]])
>>> a
array([[1, 2, 3],
       [4, 5, 6]])
>>> np.cumsum(a)
array([ 1,  3,  6, 10, 15, 21])
>>> np.cumsum(a, dtype=float)     # specifies type of output value(s)
array([  1.,   3.,   6.,  10.,  15.,  21.])
```

```
>>> np.cumsum(a,axis=0)      # sum over rows for each of the 3 columns
array([[1, 2, 3],
       [5, 7, 9]])
>>> np.cumsum(a,axis=1)      # sum over columns for each of the 2 rows
array([[ 1,  3,  6],
       [ 4,  9, 15]])
```

`cumsum(b)[-1]` may not be equal to `sum(b)`

```
>>> b = np.array([1, 2e-9, 3e-9] * 1000000)
>>> b.cumsum()[-1]
1000000.0050045159
>>> b.sum()
1000000.0050000029
```

`numpy.`**`nancumprod`**(*a*, *axis=None*, *dtype=None*, *out=None*)

Return the cumulative product of array elements over a given axis treating Not a Numbers (NaNs) as one. The cumulative product does not change when NaNs are encountered and leading NaNs are replaced by ones.

Ones are returned for slices that are all-NaN or empty.

Parameters

a
: [array_like] Input array.

axis
: [int, optional] Axis along which the cumulative product is computed. By default the input is flattened.

dtype
: [dtype, optional] Type of the returned array, as well as of the accumulator in which the elements are multiplied. If *dtype* is not specified, it defaults to the dtype of *a*, unless *a* has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used instead.

out
: [ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type of the resulting values will be cast if necessary.

Returns

nancumprod
: [ndarray] A new array holding the result is returned unless *out* is specified, in which case it is returned.

See also:

numpy.cumprod
Cumulative product across array propagating NaNs.

isnan
Show which elements are NaN.

Examples

```
>>> import numpy as np
>>> np.nancumprod(1)
array([1])
>>> np.nancumprod([1])
array([1])
>>> np.nancumprod([1, np.nan])
array([1.,  1.])
>>> a = np.array([[1, 2], [3, np.nan]])
>>> np.nancumprod(a)
array([1.,  2.,  6.,  6.])
>>> np.nancumprod(a, axis=0)
array([[1.,  2.],
       [3.,  2.]])
>>> np.nancumprod(a, axis=1)
array([[1.,  2.],
       [3.,  3.]])
```

numpy.**nancumsum**(*a*, *axis=None*, *dtype=None*, *out=None*)

Return the cumulative sum of array elements over a given axis treating Not a Numbers (NaNs) as zero. The cumulative sum does not change when NaNs are encountered and leading NaNs are replaced by zeros.

Zeros are returned for slices that are all-NaN or empty.

Parameters

a
[array_like] Input array.

axis
[int, optional] Axis along which the cumulative sum is computed. The default (None) is to compute the cumsum over the flattened array.

dtype
[dtype, optional] Type of the returned array and of the accumulator in which the elements are summed. If *dtype* is not specified, it defaults to the dtype of *a*, unless *a* has an integer dtype with a precision less than that of the default platform integer. In that case, the default platform integer is used.

out
[ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output but the type will be cast if necessary. See ufuncs-output-type for more details.

Returns

nancumsum
[ndarray.] A new array holding the result is returned unless *out* is specified, in which it is returned. The result has the same size as *a*, and the same shape as *a* if *axis* is not None or *a* is a 1-d array.

See also:

numpy.cumsum
Cumulative sum across array propagating NaNs.

isnan
Show which elements are NaN.

Examples

```
>>> import numpy as np
>>> np.nancumsum(1)
array([1])
>>> np.nancumsum([1])
array([1])
>>> np.nancumsum([1, np.nan])
array([1.,  1.])
>>> a = np.array([[1, 2], [3, np.nan]])
>>> np.nancumsum(a)
array([1.,  3.,  6.,  6.])
>>> np.nancumsum(a, axis=0)
array([[1.,  2.],
       [4.,  2.]])
>>> np.nancumsum(a, axis=1)
array([[1.,  3.],
       [3.,  3.]])
```

numpy.**diff**(*a*, *n=1*, *axis=-1*, *prepend=<no value>*, *append=<no value>*)

Calculate the n-th discrete difference along the given axis.

The first difference is given by `out[i] = a[i+1] - a[i]` along the given axis, higher differences are calculated by using *diff* recursively.

Parameters

a
[array_like] Input array

n
[int, optional] The number of times values are differenced. If zero, the input is returned as-is.

axis
[int, optional] The axis along which the difference is taken, default is the last axis.

prepend, append
[array_like, optional] Values to prepend or append to *a* along axis prior to performing the difference. Scalar values are expanded to arrays with length 1 in the direction of axis and the shape of the input array in along all other axes. Otherwise the dimension and shape must match *a* except along axis.

Returns

diff
[ndarray] The n-th differences. The shape of the output is the same as *a* except along *axis* where the dimension is smaller by *n*. The type of the output is the same as the type of the difference between any two elements of *a*. This is the same as the type of *a* in most cases. A notable exception is *datetime64*, which results in a *timedelta64* output array.

See also:

gradient, ***ediff1d***, ***cumsum***

Notes

Type is preserved for boolean arrays, so the result will contain *False* when consecutive elements are the same and *True* when they differ.

For unsigned integer arrays, the results will also be unsigned. This should not be surprising, as the result is consistent with calculating the difference directly:

```
>>> u8_arr = np.array([1, 0], dtype=np.uint8)
>>> np.diff(u8_arr)
array([255], dtype=uint8)
>>> u8_arr[1,...] - u8_arr[0,...]
np.uint8(255)
```

If this is not desirable, then the array should be cast to a larger integer type first:

```
>>> i16_arr = u8_arr.astype(np.int16)
>>> np.diff(i16_arr)
array([-1], dtype=int16)
```

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 4, 7, 0])
>>> np.diff(x)
array([ 1,  2,  3, -7])
>>> np.diff(x, n=2)
array([  1,   1, -10])
```

```
>>> x = np.array([[1, 3, 6, 10], [0, 5, 6, 8]])
>>> np.diff(x)
array([[2, 3, 4],
       [5, 1, 2]])
>>> np.diff(x, axis=0)
array([[-1,  2,  0, -2]])
```

```
>>> x = np.arange('1066-10-13', '1066-10-16', dtype=np.datetime64)
>>> np.diff(x)
array([1, 1], dtype='timedelta64[D]')
```

numpy.**ediff1d**(*ary*, *to_end=None*, *to_begin=None*)

The differences between consecutive elements of an array.

Parameters

ary
[array_like] If necessary, will be flattened before the differences are taken.

to_end
[array_like, optional] Number(s) to append at the end of the returned differences.

to_begin
[array_like, optional] Number(s) to prepend at the beginning of the returned differences.

Returns

ediff1d
[ndarray] The differences. Loosely, this is `ary.flat[1:] - ary.flat[:-1]`.

See also:

diff*, *gradient

Notes

When applied to masked arrays, this function drops the mask information if the *to_begin* and/or *to_end* parameters are used.

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 4, 7, 0])
>>> np.ediff1d(x)
array([ 1,  2,  3, -7])
```

```
>>> np.ediff1d(x, to_begin=-99, to_end=np.array([88, 99]))
array([-99,   1,   2, ...,  -7,  88,  99])
```

The returned array is always 1D.

```
>>> y = [[1, 2, 4], [1, 6, 24]]
>>> np.ediff1d(y)
array([ 1,  2, -3,  5, 18])
```

numpy.**gradient**(*f*, **varargs*, *axis=None*, *edge_order=1*)

Return the gradient of an N-dimensional array.

The gradient is computed using second order accurate central differences in the interior points and either first or second order accurate one-sides (forward or backwards) differences at the boundaries. The returned gradient hence has the same shape as the input array.

Parameters

f
[array_like] An N-dimensional array containing samples of a scalar function.

varargs
[list of scalar or array, optional] Spacing between f values. Default unitary spacing for all dimensions. Spacing can be specified using:

1. single scalar to specify a sample distance for all dimensions.
2. N scalars to specify a constant sample distance for each dimension. i.e. *dx*, *dy*, *dz*, …
3. N arrays to specify the coordinates of the values along each dimension of F. The length of the array must match the size of the corresponding dimension
4. Any combination of N scalars/arrays with the meaning of 2. and 3.

If *axis* is given, the number of varargs must equal the number of axes. Default: 1. (see Examples below).

edge_order
[{1, 2}, optional] Gradient is calculated using N-th order accurate differences at the boundaries. Default: 1.

axis
[None or int or tuple of ints, optional] Gradient is calculated only along the given axis or axes The default (axis = None) is to calculate the gradient for all the axes of the input array. axis may be negative, in which case it counts from the last to the first axis.

Returns

gradient
[ndarray or tuple of ndarray] A tuple of ndarrays (or a single ndarray if there is only one dimension) corresponding to the derivatives of f with respect to each dimension. Each derivative has the same shape as f.

Notes

Assuming that $f \in C^3$ (i.e., f has at least 3 continuous derivatives) and let h_* be a non-homogeneous stepsize, we minimize the "consistency error" η_i between the true gradient and its estimate from a linear combination of the neighboring grid-points:

$$\eta_i = f_i^{(1)} - [\alpha f(x_i) + \beta f(x_i + h_d) + \gamma f(x_i - h_s)]$$

By substituting $f(x_i + h_d)$ and $f(x_i - h_s)$ with their Taylor series expansion, this translates into solving the following the linear system:

$$\begin{cases} \alpha + \beta + \gamma = 0 \\ \beta h_d - \gamma h_s = 1 \\ \beta h_d^2 + \gamma h_s^2 = 0 \end{cases}$$

The resulting approximation of $f_i^{(1)}$ is the following:

$$\hat{f}_i^{(1)} = \frac{h_s^2 f(x_i + h_d) + (h_d^2 - h_s^2) f(x_i) - h_d^2 f(x_i - h_s)}{h_s h_d (h_d + h_s)} + \mathcal{O}\left(\frac{h_d h_s^2 + h_s h_d^2}{h_d + h_s}\right)$$

It is worth noting that if $h_s = h_d$ (i.e., data are evenly spaced) we find the standard second order approximation:

$$\hat{f}_i^{(1)} = \frac{f(x_{i+1}) - f(x_{i-1})}{2h} + \mathcal{O}(h^2)$$

With a similar procedure the forward/backward approximations used for boundaries can be derived.

References

[1], [2], [3]

Examples

```
>>> import numpy as np
>>> f = np.array([1, 2, 4, 7, 11, 16])
>>> np.gradient(f)
array([1. , 1.5, 2.5, 3.5, 4.5, 5. ])
>>> np.gradient(f, 2)
array([0.5 ,  0.75,  1.25,  1.75,  2.25,  2.5 ])
```

Spacing can be also specified with an array that represents the coordinates of the values F along the dimensions. For instance a uniform spacing:

```
>>> x = np.arange(f.size)
>>> np.gradient(f, x)
array([1. ,  1.5,  2.5,  3.5,  4.5,  5. ])
```

Or a non uniform one:

```
>>> x = np.array([0., 1., 1.5, 3.5, 4., 6.])
>>> np.gradient(f, x)
array([1. ,  3. ,  3.5,  6.7,  6.9,  2.5])
```

For two dimensional arrays, the return will be two arrays ordered by axis. In this example the first array stands for the gradient in rows and the second one in columns direction:

```
>>> np.gradient(np.array([[1, 2, 6], [3, 4, 5]]))
(array([[ 2.,  2., -1.],
        [ 2.,  2., -1.]]),
 array([[1. , 2.5, 4. ],
        [1. , 1. , 1. ]]))
```

In this example the spacing is also specified: uniform for axis=0 and non uniform for axis=1

```
>>> dx = 2.
>>> y = [1., 1.5, 3.5]
>>> np.gradient(np.array([[1, 2, 6], [3, 4, 5]]), dx, y)
(array([[ 1. ,  1. , -0.5],
        [ 1. ,  1. , -0.5]]),
 array([[2. , 2. , 2. ],
        [2. , 1.7, 0.5]]))
```

It is possible to specify how boundaries are treated using *edge_order*

```
>>> x = np.array([0, 1, 2, 3, 4])
>>> f = x**2
>>> np.gradient(f, edge_order=1)
array([1.,  2.,  4.,  6.,  7.])
>>> np.gradient(f, edge_order=2)
array([0., 2., 4., 6., 8.])
```

The *axis* keyword can be used to specify a subset of axes of which the gradient is calculated

```
>>> np.gradient(np.array([[1, 2, 6], [3, 4, 5]]), axis=0)
array([[ 2.,  2., -1.],
       [ 2.,  2., -1.]])
```

The *varargs* argument defines the spacing between sample points in the input array. It can take two forms:

1. An array, specifying coordinates, which may be unevenly spaced:

```
>>> x = np.array([0., 2., 3., 6., 8.])
>>> y = x ** 2
>>> np.gradient(y, x, edge_order=2)
array([ 0.,  4.,  6., 12., 16.])
```

2. A scalar, representing the fixed sample distance:

```
>>> dx = 2
>>> x = np.array([0., 2., 4., 6., 8.])
>>> y = x ** 2
>>> np.gradient(y, dx, edge_order=2)
array([ 0.,  4.,  8., 12., 16.])
```

It's possible to provide different data for spacing along each dimension. The number of arguments must match the number of dimensions in the input data.

```
>>> dx = 2
>>> dy = 3
>>> x = np.arange(0, 6, dx)
>>> y = np.arange(0, 9, dy)
>>> xs, ys = np.meshgrid(x, y)
>>> zs = xs + 2 * ys
>>> np.gradient(zs, dy, dx)  # Passing two scalars
(array([[2., 2., 2.],
        [2., 2., 2.],
        [2., 2., 2.]]),
 array([[1., 1., 1.],
        [1., 1., 1.],
        [1., 1., 1.]]))
```

Mixing scalars and arrays is also allowed:

```
>>> np.gradient(zs, y, dx)  # Passing one array and one scalar
(array([[2., 2., 2.],
        [2., 2., 2.],
        [2., 2., 2.]]),
 array([[1., 1., 1.],
        [1., 1., 1.],
        [1., 1., 1.]]))
```

numpy.**cross**(*a*, *b*, *axisa=-1*, *axisb=-1*, *axisc=-1*, *axis=None*)

Return the cross product of two (arrays of) vectors.

The cross product of a and b in R^3 is a vector perpendicular to both a and b. If a and b are arrays of vectors, the vectors are defined by the last axis of a and b by default, and these axes can have dimensions 2 or 3. Where the dimension of either a or b is 2, the third component of the input vector is assumed to be zero and the cross product calculated accordingly. In cases where both input vectors have dimension 2, the z-component of the cross product is returned.

Parameters

a
[array_like] Components of the first vector(s).

b
[array_like] Components of the second vector(s).

axisa
[int, optional] Axis of a that defines the vector(s). By default, the last axis.

axisb
[int, optional] Axis of b that defines the vector(s). By default, the last axis.

axisc
[int, optional] Axis of c containing the cross product vector(s). Ignored if both input vectors have dimension 2, as the return is scalar. By default, the last axis.

axis
[int, optional] If defined, the axis of *a*, *b* and *c* that defines the vector(s) and cross product(s). Overrides *axisa*, *axisb* and *axisc*.

Returns

c
[ndarray] Vector cross product(s).

Raises

ValueError
When the dimension of the vector(s) in *a* and/or *b* does not equal 2 or 3.

See also:

inner
Inner product

outer
Outer product.

linalg.cross
An Array API compatible variation of `np.cross`, which accepts (arrays of) 3-element vectors only.

ix_
Construct index arrays.

Notes

Supports full broadcasting of the inputs.

Dimension-2 input arrays were deprecated in 2.0.0. If you do need this functionality, you can use:

```
def cross2d(x, y):
    return x[..., 0] * y[..., 1] - x[..., 1] * y[..., 0]
```

Examples

Vector cross-product.

```
>>> import numpy as np
>>> x = [1, 2, 3]
>>> y = [4, 5, 6]
>>> np.cross(x, y)
array([-3,  6, -3])
```

One vector with dimension 2.

```
>>> x = [1, 2]
>>> y = [4, 5, 6]
>>> np.cross(x, y)
array([12, -6, -3])
```

Equivalently:

```
>>> x = [1, 2, 0]
>>> y = [4, 5, 6]
>>> np.cross(x, y)
array([12, -6, -3])
```

Both vectors with dimension 2.

```
>>> x = [1,2]
>>> y = [4,5]
>>> np.cross(x, y)
array(-3)
```

Multiple vector cross-products. Note that the direction of the cross product vector is defined by the *right-hand rule*.

```
>>> x = np.array([[1,2,3], [4,5,6]])
>>> y = np.array([[4,5,6], [1,2,3]])
>>> np.cross(x, y)
array([[-3,  6, -3],
       [ 3, -6,  3]])
```

The orientation of *c* can be changed using the *axisc* keyword.

```
>>> np.cross(x, y, axisc=0)
array([[-3,  3],
       [ 6, -6],
       [-3,  3]])
```

Change the vector definition of *x* and *y* using *axisa* and *axisb*.

```
>>> x = np.array([[1,2,3], [4,5,6], [7, 8, 9]])
>>> y = np.array([[7, 8, 9], [4,5,6], [1,2,3]])
>>> np.cross(x, y)
array([[ -6,  12,  -6],
       [  0,   0,   0],
       [  6, -12,   6]])
>>> np.cross(x, y, axisa=0, axisb=0)
array([[-24,  48, -24],
       [-30,  60, -30],
       [-36,  72, -36]])
```

numpy.**trapezoid**(*y*, *x=None*, *dx=1.0*, *axis=-1*)

Integrate along the given axis using the composite trapezoidal rule.

If *x* is provided, the integration happens in sequence along its elements - they are not sorted.

Integrate *y* (*x*) along each 1d slice on the given axis, compute $\int y(x)dx$. When *x* is specified, this integrates along the parametric curve, computing $\int_t y(t)dt = \int_t y(t)\left.\frac{dx}{dt}\right|_{x=x(t)} dt$.

New in version 2.0.0.

Parameters

y
: [array_like] Input array to integrate.

x
: [array_like, optional] The sample points corresponding to the *y* values. If *x* is None, the sample points are assumed to be evenly spaced *dx* apart. The default is None.

dx
: [scalar, optional] The spacing between sample points when *x* is None. The default is 1.

axis
: [int, optional] The axis along which to integrate.

Returns

trapezoid
: [float or ndarray] Definite integral of *y* = n-dimensional array as approximated along a single axis by the trapezoidal rule. If *y* is a 1-dimensional array, then the result is a float. If *n* is greater than 1, then the result is an *n*-1 dimensional array.

See also:

sum, ***cumsum***

Notes

Image [2] illustrates trapezoidal rule – y-axis locations of points will be taken from *y* array, by default x-axis distances between points will be 1.0, alternatively they can be provided with *x* array or with *dx* scalar. Return value will be equal to combined area under the red lines.

References

[1], [2]

Examples

```
>>> import numpy as np
```

Use the trapezoidal rule on evenly spaced points:

```
>>> np.trapezoid([1, 2, 3])
4.0
```

The spacing between sample points can be selected by either the `x` or `dx` arguments:

```
>>> np.trapezoid([1, 2, 3], x=[4, 6, 8])
8.0
>>> np.trapezoid([1, 2, 3], dx=2)
8.0
```

Using a decreasing `x` corresponds to integrating in reverse:

```
>>> np.trapezoid([1, 2, 3], x=[8, 6, 4])
-8.0
```

More generally `x` is used to integrate along a parametric curve. We can estimate the integral $\int_0^1 x^2 = 1/3$ using:

```
>>> x = np.linspace(0, 1, num=50)
>>> y = x**2
>>> np.trapezoid(y, x)
0.33340274885464394
```

Or estimate the area of a circle, noting we repeat the sample which closes the curve:

```
>>> theta = np.linspace(0, 2 * np.pi, num=1000, endpoint=True)
>>> np.trapezoid(np.cos(theta), x=np.sin(theta))
3.141571941375841
```

`np.trapezoid` can be applied along a specified axis to do multiple computations in one call:

```
>>> a = np.arange(6).reshape(2, 3)
>>> a
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.trapezoid(a, axis=0)
array([1.5, 2.5, 3.5])
>>> np.trapezoid(a, axis=1)
array([2.,  8.])
```

Exponents and logarithms

exp(x, /[, out, where, casting, order, ...])	Calculate the exponential of all elements in the input array.
expm1(x, /[, out, where, casting, order, ...])	Calculate `exp(x) - 1` for all elements in the array.
exp2(x, /[, out, where, casting, order, ...])	Calculate *2**p* for all *p* in the input array.
log(x, /[, out, where, casting, order, ...])	Natural logarithm, element-wise.
log10(x, /[, out, where, casting, order, ...])	Return the base 10 logarithm of the input array, element-wise.
log2(x, /[, out, where, casting, order, ...])	Base-2 logarithm of *x*.
log1p(x, /[, out, where, casting, order, ...])	Return the natural logarithm of one plus the input array, element-wise.
logaddexp(x1, x2, /[, out, where, casting, ...])	Logarithm of the sum of exponentiations of the inputs.
logaddexp2(x1, x2, /[, out, where, casting, ...])	Logarithm of the sum of exponentiations of the inputs in base-2.

numpy.**exp**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'exp'>**

Calculate the exponential of all elements in the input array.

Parameters

x
: [array_like] Input values.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Output array, element-wise exponential of *x*. This is a scalar if *x* is a scalar.

See also:

expm1
Calculate `exp(x) - 1` for all elements in the array.

exp2
Calculate `2**x` for all elements in the array.

Notes

The irrational number `e` is also known as Euler's number. It is approximately 2.718281, and is the base of the natural logarithm, `ln` (this means that, if $x = \ln y = \log_e y$, then $e^x = y$. For real input, `exp(x)` is always positive.

For complex arguments, `x = a + ib`, we can write $e^x = e^a e^{ib}$. The first term, e^a, is already known (it is the real argument, described above). The second term, e^{ib}, is $\cos b + i \sin b$, a function with magnitude 1 and a periodic phase.

References

[1], [2]

Examples

Plot the magnitude and phase of `exp(x)` in the complex plane:

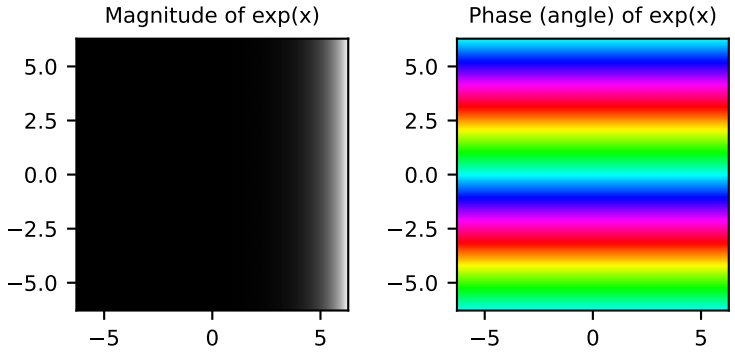
```
>>> import numpy as np
```

```
>>> import matplotlib.pyplot as plt
```

```
>>> x = np.linspace(-2*np.pi, 2*np.pi, 100)
>>> xx = x + 1j * x[:, np.newaxis] # a + ib over complex plane
>>> out = np.exp(xx)
```

```
>>> plt.subplot(121)
>>> plt.imshow(np.abs(out),
...            extent=[-2*np.pi, 2*np.pi, -2*np.pi, 2*np.pi], cmap='gray')
>>> plt.title('Magnitude of exp(x)')
```

```
>>> plt.subplot(122)
>>> plt.imshow(np.angle(out),
...            extent=[-2*np.pi, 2*np.pi, -2*np.pi, 2*np.pi], cmap='hsv')
>>> plt.title('Phase (angle) of exp(x)')
>>> plt.show()
```



numpy.**expm1**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'expm1'>**

Calculate `exp(x) - 1` for all elements in the array.

Parameters

x
[array_like] Input values.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Element-wise exponential minus one: `out = exp(x) - 1`. This is a scalar if *x* is a scalar.

See also:

log1p
`log(1 + x)`, the inverse of expm1.

Notes

This function provides greater precision than `exp(x) - 1` for small values of `x`.

Examples

The true value of `exp(1e-10) - 1` is `1.00000000005e-10` to about 32 significant digits. This example shows the superiority of expm1 in this case.

```
>>> import numpy as np
```

```
>>> np.expm1(1e-10)
1.00000000005e-10
>>> np.exp(1e-10) - 1
1.000000082740371e-10
```

numpy.**exp2** (*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'exp2'>**

Calculate *2**p* for all *p* in the input array.

Parameters

x
[array_like] Input values.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] Element-wise 2 to the power *x*. This is a scalar if *x* is a scalar.

See also:

power

Examples

```
>>> import numpy as np
>>> np.exp2([2, 3])
array([ 4.,  8.])
```

numpy.**log**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'log'>**

Natural logarithm, element-wise.

The natural logarithm `log` is the inverse of the exponential function, so that *log(exp(x)) = x*. The natural logarithm is logarithm in base `e`.

Parameters

x
: [array_like] Input value.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] The natural logarithm of *x*, element-wise. This is a scalar if *x* is a scalar.

See also:

log10*, *log2*, *log1p*, *emath.log

Notes

Logarithm is a multivalued function: for each *x* there is an infinite number of *z* such that *exp(z) = x*. The convention is to return the *z* whose imaginary part lies in *(-pi, pi]*.

For real-valued input data types, `log` always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, `log` is a complex analytical function that has a branch cut *[-inf, 0]* and is continuous from above on it. `log` handles the floating-point negative zero as an infinitesimal negative number, conforming to the C99 standard.

In the cases where the input has a negative real part and a very small negative complex part (approaching 0), the result is so close to *-pi* that it evaluates to exactly *-pi*.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.log([1, np.e, np.e**2, 0])
array([  0.,   1.,   2., -inf])
```

numpy.**log10**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'log10'>**

Return the base 10 logarithm of the input array, element-wise.

Parameters

x
[array_like] Input values.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The logarithm to the base 10 of *x*, element-wise. NaNs are returned where x is negative. This is a scalar if *x* is a scalar.

See also:

emath.log10

Notes

Logarithm is a multivalued function: for each *x* there is an infinite number of *z* such that *10**z = x*. The convention is to return the *z* whose imaginary part lies in *(-pi, pi]*.

For real-valued input data types, *log10* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *log10* is a complex analytical function that has a branch cut *[-inf, 0]* and is continuous from above on it. *log10* handles the floating-point negative zero as an infinitesimal negative number, conforming to the C99 standard.

In the cases where the input has a negative real part and a very small negative complex part (approaching 0), the result is so close to *-pi* that it evaluates to exactly *-pi*.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.log10([1e-15, -3.])
array([-15.,  nan])
```

numpy.**log2**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'log2'>**

Base-2 logarithm of *x*.

Parameters

x
[array_like] Input values.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Base-2 logarithm of *x*. This is a scalar if *x* is a scalar.

See also:

log*, *log10*, *log1p*, *emath.log2

Notes

Logarithm is a multivalued function: for each *x* there is an infinite number of *z* such that *2**z = x*. The convention is to return the *z* whose imaginary part lies in *(-pi, pi]*.

For real-valued input data types, *log2* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *log2* is a complex analytical function that has a branch cut *[-inf, 0]* and is continuous from above on it. *log2* handles the floating-point negative zero as an infinitesimal negative number, conforming to the C99 standard.

In the cases where the input has a negative real part and a very small negative complex part (approaching 0), the result is so close to *-pi* that it evaluates to exactly *-pi*.

Examples

```
>>> import numpy as np
>>> x = np.array([0, 1, 2, 2**4])
>>> np.log2(x)
array([-inf,   0.,   1.,   4.])
```

```
>>> xi = np.array([0+1.j, 1, 2+0.j, 4.j])
>>> np.log2(xi)
array([ 0.+2.26618007j,  0.+0.j        ,  1.+0.j        ,  2.+2.26618007j])
```

numpy.**log1p**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'log1p'>**

Return the natural logarithm of one plus the input array, element-wise.

Calculates `log(1 + x)`.

Parameters

x
[array_like] Input values.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] Natural logarithm of *1 + x*, element-wise. This is a scalar if *x* is a scalar.

See also:

expm1
`exp(x) - 1`, the inverse of *log1p*.

Notes

For real-valued input, *log1p* is accurate also for *x* so small that *1 + x == 1* in floating-point accuracy.

Logarithm is a multivalued function: for each *x* there is an infinite number of *z* such that *exp(z) = 1 + x*. The convention is to return the *z* whose imaginary part lies in *[-pi, pi]*.

For real-valued input data types, *log1p* always returns real output. For each value that cannot be expressed as a real number or infinity, it yields `nan` and sets the *invalid* floating point error flag.

For complex-valued input, *log1p* is a complex analytical function that has a branch cut *[-inf, -1]* and is continuous from above on it. *log1p* handles the floating-point negative zero as an infinitesimal negative number, conforming to the C99 standard.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> np.log1p(1e-99)
1e-99
>>> np.log(1 + 1e-99)
0.0
```

numpy.**logaddexp**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'logaddexp'>**

Logarithm of the sum of exponentiations of the inputs.

Calculates `log(exp(x1) + exp(x2))`. This function is useful in statistics where the calculated probabilities of events may be so small as to exceed the range of normal floating point numbers. In such cases the logarithm of the calculated probability is stored. This function allows adding probabilities stored in such a fashion.

Parameters

x1, x2
: [array_like] Input values. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

result
: [ndarray] Logarithm of `exp(x1) + exp(x2)`. This is a scalar if both *x1* and *x2* are scalars.

See also:

logaddexp2
: Logarithm of the sum of exponentiations of inputs in base 2.

Examples

```
>>> import numpy as np
>>> prob1 = np.log(1e-50)
>>> prob2 = np.log(2.5e-50)
>>> prob12 = np.logaddexp(prob1, prob2)
>>> prob12
-113.87649168120691
>>> np.exp(prob12)
3.5000000000000057e-50
```

numpy.**logaddexp2**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'logaddexp2'>**

Logarithm of the sum of exponentiations of the inputs in base-2.

Calculates `log2(2**x1 + 2**x2)`. This function is useful in machine learning when the calculated probabilities of events may be so small as to exceed the range of normal floating point numbers. In such cases the base-2 logarithm of the calculated probability can be used instead. This function allows adding probabilities stored in such a fashion.

Parameters

x1, x2
: [array_like] Input values. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

result
: [ndarray] Base-2 logarithm of `2**x1 + 2**x2`. This is a scalar if both *x1* and *x2* are scalars.

See also:

logaddexp
: Logarithm of the sum of exponentiations of the inputs.

Examples

```
>>> import numpy as np
>>> prob1 = np.log2(1e-50)
>>> prob2 = np.log2(2.5e-50)
>>> prob12 = np.logaddexp2(prob1, prob2)
>>> prob1, prob2, prob12
(-166.09640474436813, -164.77447664948076, -164.28904982231052)
>>> 2**prob12
3.4999999999999914e-50
```

Other special functions

i0(x)	Modified Bessel function of the first kind, order 0.
sinc(x)	Return the normalized sinc function.

numpy.**i0**(*x*)

Modified Bessel function of the first kind, order 0.

Usually denoted I_0.

Parameters

x
[array_like of float] Argument of the Bessel function.

Returns

out
[ndarray, shape = x.shape, dtype = float] The modified Bessel function evaluated at each of the elements of *x*.

See also:

scipy.special.i0, **scipy.special.iv**, **scipy.special.ive**

Notes

The scipy implementation is recommended over this function: it is a proper ufunc written in C, and more than an order of magnitude faster.

We use the algorithm published by Clenshaw [1] and referenced by Abramowitz and Stegun [2], for which the function domain is partitioned into the two intervals [0,8] and (8,inf), and Chebyshev polynomial expansions are employed in each interval. Relative error on the domain [0,30] using IEEE arithmetic is documented [3] as having a peak of 5.8e-16 with an rms of 1.4e-16 (n = 30000).

References

[1], [2], [3]

Examples

```
>>> import numpy as np
>>> np.i0(0.)
array(1.0)
>>> np.i0([0, 1, 2, 3])
array([1.        , 1.26606588, 2.2795853 , 4.88079259])
```

numpy.**sinc**(*x*)

Return the normalized sinc function.

The sinc function is equal to $\sin(\pi x)/(\pi x)$ for any argument $x \neq 0$. `sinc(0)` takes the limit value 1, making `sinc` not only everywhere continuous but also infinitely differentiable.

Note: Note the normalization factor of `pi` used in the definition. This is the most commonly used definition in signal processing. Use `sinc(x / np.pi)` to obtain the unnormalized sinc function $\sin(x)/x$ that is more common in mathematics.

Parameters

x
[ndarray] Array (possibly multi-dimensional) of values for which to calculate `sinc(x)`.

Returns

out
[ndarray] `sinc(x)`, which has the same shape as the input.

Notes

The name sinc is short for "sine cardinal" or "sinus cardinalis".

The sinc function is used in various signal processing applications, including in anti-aliasing, in the construction of a Lanczos resampling filter, and in interpolation.

For bandlimited interpolation of discrete-time signals, the ideal interpolation kernel is proportional to the sinc function.

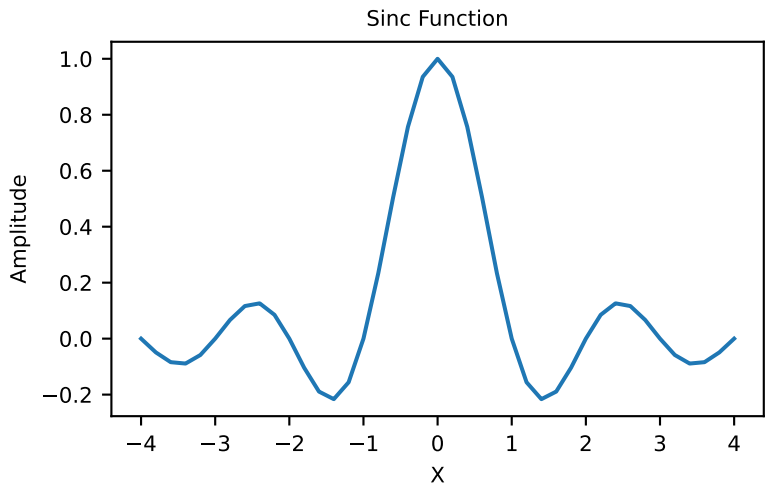
References

[1], [2]

Examples

```
>>> import numpy as np
>>> import matplotlib.pyplot as plt
>>> x = np.linspace(-4, 4, 41)
>>> np.sinc(x)
 array([-3.89804309e-17,  -4.92362781e-02,  -8.40918587e-02, # may vary
        -8.90384387e-02,  -5.84680802e-02,   3.89804309e-17,
         6.68206631e-02,   1.16434881e-01,   1.26137788e-01,
         8.50444803e-02,  -3.89804309e-17,  -1.03943254e-01,
        -1.89206682e-01,  -2.16236208e-01,  -1.55914881e-01,
         3.89804309e-17,   2.33872321e-01,   5.04551152e-01,
         7.56826729e-01,   9.35489284e-01,   1.00000000e+00,
         9.35489284e-01,   7.56826729e-01,   5.04551152e-01,
         2.33872321e-01,   3.89804309e-17,  -1.55914881e-01,
        -2.16236208e-01,  -1.89206682e-01,  -1.03943254e-01,
        -3.89804309e-17,   8.50444803e-02,   1.26137788e-01,
         1.16434881e-01,   6.68206631e-02,   3.89804309e-17,
        -5.84680802e-02,  -8.90384387e-02,  -8.40918587e-02,
        -4.92362781e-02,  -3.89804309e-17])
```

```
>>> plt.plot(x, np.sinc(x))
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.title("Sinc Function")
Text(0.5, 1.0, 'Sinc Function')
>>> plt.ylabel("Amplitude")
Text(0, 0.5, 'Amplitude')
>>> plt.xlabel("X")
Text(0.5, 0, 'X')
>>> plt.show()
```



Floating point routines

signbit(x, /[, out, where, casting, order, ...])	Returns element-wise True where signbit is set (less than zero).
copysign(x1, x2, /[, out, where, casting, ...])	Change the sign of x1 to that of x2, element-wise.
frexp(x[, out1, out2], / [[, out, where, ...])	Decompose the elements of x into mantissa and twos exponent.
ldexp(x1, x2, /[, out, where, casting, ...])	Returns x1 * 2**x2, element-wise.
nextafter(x1, x2, /[, out, where, casting, ...])	Return the next floating-point value after x1 towards x2, element-wise.
spacing(x, /[, out, where, casting, order, ...])	Return the distance between x and the nearest adjacent number.

numpy.**signbit**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'signbit'>**

Returns element-wise True where signbit is set (less than zero).

Parameters

x
[array_like] The input value(s).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

result
[ndarray of bool] Output array, or reference to *out* if that was supplied. This is a scalar if *x* is a scalar.

Examples

```
>>> import numpy as np
>>> np.signbit(-1.2)
True
>>> np.signbit(np.array([1, -2.3, 2.1]))
array([False,  True, False])
```

numpy.**copysign**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'copysign'>**

Change the sign of x1 to that of x2, element-wise.

If *x2* is a scalar, its sign will be copied to all elements of *x1*.

Parameters

x1
[array_like] Values to change the sign of.

x2
[array_like] The sign of *x2* is copied to *x1*. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] The values of *x1* with the sign of *x2*. This is a scalar if both *x1* and *x2* are scalars.

Examples

```
>>> import numpy as np
>>> np.copysign(1.3, -1)
-1.3
>>> 1/np.copysign(0, 1)
inf
>>> 1/np.copysign(0, -1)
-inf
```

```
>>> np.copysign([-1, 0, 1], -1.1)
array([-1., -0., -1.])
>>> np.copysign([-1, 0, 1], np.arange(3)-1)
array([-1.,  0.,  1.])
```

numpy.**frexp**(*x*, [*out1*, *out2*,]/, [*out=(None, None)*,]*, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'frexp'>**

Decompose the elements of x into mantissa and twos exponent.

Returns (*mantissa*, *exponent*), where `x = mantissa * 2**exponent`. The mantissa lies in the open interval(-1, 1), while the twos exponent is a signed integer.

Parameters

x
[array_like] Array of numbers to be decomposed.

out1
[ndarray, optional] Output array for the mantissa. Must have the same shape as *x*.

out2
[ndarray, optional] Output array for the exponent. Must have the same shape as *x*.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

mantissa
[ndarray] Floating values between -1 and 1. This is a scalar if *x* is a scalar.

exponent
[ndarray] Integer exponents of 2. This is a scalar if *x* is a scalar.

See also:

ldexp
Compute `y = x1 * 2**x2`, the inverse of *frexp*.

Notes

Complex dtypes are not supported, they will raise a TypeError.

Examples

```
>>> import numpy as np
>>> x = np.arange(9)
>>> y1, y2 = np.frexp(x)
>>> y1
array([ 0.   ,  0.5  ,  0.5  ,  0.75 ,  0.5  ,  0.625,  0.75 ,  0.875,
        0.5  ])
>>> y2
array([0, 1, 2, 2, 3, 3, 3, 3, 4], dtype=int32)
>>> y1 * 2**y2
array([ 0.,  1.,  2.,  3.,  4.,  5.,  6.,  7.,  8.])
```

numpy.**ldexp**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'ldexp'>**

Returns x1 * 2**x2, element-wise.

The mantissas *x1* and twos exponents *x2* are used to construct floating point numbers `x1 * 2**x2`.

Parameters

x1
[array_like] Array of multipliers.

x2
[array_like, int] Array of twos exponents. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or scalar] The result of `x1 * 2**x2`. This is a scalar if both *x1* and *x2* are scalars.

See also:

frexp
Return (y1, y2) from `x = y1 * 2**y2`, inverse to *ldexp*.

Notes

Complex dtypes are not supported, they will raise a TypeError.

ldexp is useful as the inverse of *frexp*, if used by itself it is more clear to simply use the expression `x1 * 2**x2`.

Examples

```
>>> import numpy as np
>>> np.ldexp(5, np.arange(4))
array([ 5., 10., 20., 40.], dtype=float16)
```

```
>>> x = np.arange(6)
>>> np.ldexp(*np.frexp(x))
array([ 0.,  1.,  2.,  3.,  4.,  5.])
```

numpy.**nextafter**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'nextafter'>**

Return the next floating-point value after x1 towards x2, element-wise.

Parameters

x1
[array_like] Values to find the next representable value of.

x2
[array_like] The direction where to look for the next representable value of *x1*. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] The next representable values of *x1* in the direction of *x2*. This is a scalar if both *x1* and *x2* are scalars.

Examples

```
>>> import numpy as np
>>> eps = np.finfo(np.float64).eps
>>> np.nextafter(1, 2) == eps + 1
True
>>> np.nextafter([1, 2], [2, 1]) == [eps + 1, 2 - eps]
array([ True,  True])
```

numpy.**spacing**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'spacing'>**

Return the distance between x and the nearest adjacent number.

Parameters

x
[array_like] Values to find the spacing of.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] The spacing of values of *x*. This is a scalar if *x* is a scalar.

Notes

It can be considered as a generalization of EPS: `spacing(np.float64(1)) == np.finfo(np.float64).eps`, and there should not be any representable number between `x + spacing(x)` and x for any finite x.

Spacing of +- inf and NaN is NaN.

Examples

```
>>> import numpy as np
>>> np.spacing(1) == np.finfo(np.float64).eps
True
```

Rational routines

lcm(x1, x2, /[, out, where, casting, order, ...])	Returns the lowest common multiple of `|x1|` and `|x2|`
gcd(x1, x2, /[, out, where, casting, order, ...])	Returns the greatest common divisor of `|x1|` and `|x2|`

numpy.**lcm**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'lcm'>**

Returns the lowest common multiple of `|x1|` and `|x2|`

Parameters

x1, x2
[array_like, int] Arrays of values. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

Returns

y
[ndarray or scalar] The lowest common multiple of the absolute value of the inputs This is a scalar if both *x1* and *x2* are scalars.

See also:

gcd
The greatest common divisor

Examples

```
>>> import numpy as np
>>> np.lcm(12, 20)
60
>>> np.lcm.reduce([3, 12, 20])
60
>>> np.lcm.reduce([40, 12, 20])
120
>>> np.lcm(np.arange(6), 20)
array([ 0, 20, 20, 60, 20, 20])
```

numpy.**gcd**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'gcd'>**

Returns the greatest common divisor of `|x1|` and `|x2|`

Parameters

x1, x2
[array_like, int] Arrays of values. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

Returns

y
[ndarray or scalar] The greatest common divisor of the absolute value of the inputs This is a scalar if both *x1* and *x2* are scalars.

See also:

lcm
The lowest common multiple

Examples

```
>>> import numpy as np
>>> np.gcd(12, 20)
4
>>> np.gcd.reduce([15, 25, 35])
5
>>> np.gcd(np.arange(6), 20)
array([20,  1,  2,  1,  4,  5])
```

Arithmetic operations

add(x1, x2, /[, out, where, casting, order, ...])	Add arguments element-wise.
reciprocal(x, /[, out, where, casting, ...])	Return the reciprocal of the argument, element-wise.
positive(x, /[, out, where, casting, order, ...])	Numerical positive, element-wise.
negative(x, /[, out, where, casting, order, ...])	Numerical negative, element-wise.
multiply(x1, x2, /[, out, where, casting, ...])	Multiply arguments element-wise.
divide(x1, x2, /[, out, where, casting, ...])	Divide arguments element-wise.
power(x1, x2, /[, out, where, casting, ...])	First array elements raised to powers from second array, element-wise.
pow(x1, x2, /[, out, where, casting, order, ...])	First array elements raised to powers from second array, element-wise.
subtract(x1, x2, /[, out, where, casting, ...])	Subtract arguments, element-wise.
true_divide(x1, x2, /[, out, where, ...])	Divide arguments element-wise.
floor_divide(x1, x2, /[, out, where, ...])	Return the largest integer smaller or equal to the division of the inputs.
float_power(x1, x2, /[, out, where, ...])	First array elements raised to powers from second array, element-wise.
fmod(x1, x2, /[, out, where, casting, ...])	Returns the element-wise remainder of division.
mod(x1, x2, /[, out, where, casting, order, ...])	Returns the element-wise remainder of division.
modf(x[, out1, out2], / [[, out, where, ...])	Return the fractional and integral parts of an array, element-wise.
remainder(x1, x2, /[, out, where, casting, ...])	Returns the element-wise remainder of division.
divmod(x1, x2[, out1, out2], / [[, out, ...])	Return element-wise quotient and remainder simultaneously.

numpy.**add**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'add'>**

Add arguments element-wise.

Parameters

x1, x2
[array_like] The arrays to be added. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

add
[ndarray or scalar] The sum of *x1* and *x2*, element-wise. This is a scalar if both *x1* and *x2* are scalars.

Notes

Equivalent to *x1* + *x2* in terms of array broadcasting.

Examples

```
>>> import numpy as np
>>> np.add(1.0, 4.0)
5.0
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> np.add(x1, x2)
array([[  0.,   2.,   4.],
       [  3.,   5.,   7.],
       [  6.,   8.,  10.]])
```

The + operator can be used as a shorthand for `np.add` on ndarrays.

```
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> x1 + x2
array([[ 0.,  2.,  4.],
       [ 3.,  5.,  7.],
       [ 6.,  8., 10.]])
```

numpy.**reciprocal**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'reciprocal'>**

Return the reciprocal of the argument, element-wise.

Calculates `1/x`.

Parameters

x
: [array_like] Input array.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] Return array. This is a scalar if *x* is a scalar.

Notes

Note: This function is not designed to work with integers.

For integer arguments with absolute value larger than 1 the result is always zero because of the way Python handles integer division. For integer zero the result is an overflow.

Examples

```
>>> import numpy as np
>>> np.reciprocal(2.)
0.5
>>> np.reciprocal([1, 2., 3.33])
array([ 1.       ,  0.5      ,  0.3003003])
```

numpy.**positive**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'positive'>**

Numerical positive, element-wise.

Parameters

x
: [array_like or scalar] Input array.

Returns

y
: [ndarray or scalar] Returned array or scalar: $y = +x$. This is a scalar if x is a scalar.

Notes

Equivalent to *x.copy()*, but only defined for types that support arithmetic.

Examples

```
>>> import numpy as np
```

```
>>> x1 = np.array(([1., -1.]))
>>> np.positive(x1)
array([ 1., -1.])
```

The unary + operator can be used as a shorthand for `np.positive` on ndarrays.

```
>>> x1 = np.array(([1., -1.]))
>>> +x1
array([ 1., -1.])
```

numpy.**negative**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'negative'>**

Numerical negative, element-wise.

Parameters

x
: [array_like or scalar] Input array.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray or scalar] Returned array or scalar: *y* = *-x*. This is a scalar if *x* is a scalar.

Examples

```
>>> import numpy as np
>>> np.negative([1.,-1.])
array([-1.,  1.])
```

The unary − operator can be used as a shorthand for `np.negative` on ndarrays.

```
>>> x1 = np.array(([1., -1.]))
>>> -x1
array([-1.,  1.])
```

numpy.**multiply**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'multiply'>**

Multiply arguments element-wise.

Parameters

x1, x2
: [array_like] Input arrays to be multiplied. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The product of *x1* and *x2*, element-wise. This is a scalar if both *x1* and *x2* are scalars.

Notes

Equivalent to *x1* * *x2* in terms of array broadcasting.

Examples

```
>>> import numpy as np
>>> np.multiply(2.0, 4.0)
8.0
```

```
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> np.multiply(x1, x2)
array([[  0.,   1.,   4.],
       [  0.,   4.,  10.],
       [  0.,   7.,  16.]])
```

The `*` operator can be used as a shorthand for `np.multiply` on ndarrays.

```
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> x1 * x2
array([[  0.,   1.,   4.],
       [  0.,   4.,  10.],
       [  0.,   7.,  16.]])
```

numpy.**divide**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'divide'>**

Divide arguments element-wise.

Parameters

x1
[array_like] Dividend array.

x2
[array_like] Divisor array. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain

its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or scalar] The quotient `x1/x2`, element-wise. This is a scalar if both *x1* and *x2* are scalars.

See also:

seterr
Set whether to raise or warn on overflow, underflow and division by zero.

Notes

Equivalent to `x1 / x2` in terms of array-broadcasting.

The `true_divide(x1, x2)` function is an alias for `divide(x1, x2)`.

Examples

```
>>> import numpy as np
>>> np.divide(2.0, 4.0)
0.5
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> np.divide(x1, x2)
array([[nan, 1. , 1. ],
       [inf, 4. , 2.5],
       [inf, 7. , 4. ]])
```

The `/` operator can be used as a shorthand for `np.divide` on ndarrays.

```
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = 2 * np.ones(3)
>>> x1 / x2
array([[0. , 0.5, 1. ],
       [1.5, 2. , 2.5],
       [3. , 3.5, 4. ]])
```

numpy.**power**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'power'>**

First array elements raised to powers from second array, element-wise.

Raise each base in *x1* to the positionally-corresponding power in *x2*. *x1* and *x2* must be broadcastable to the same shape.

An integer type raised to a negative integer power will raise a `ValueError`.

Negative values raised to a non-integral value will return `nan`. To get complex results, cast the input to complex, or specify the `dtype` to be `complex` (see the example below).

Parameters

x1
: [array_like] The bases.

x2
: [array_like] The exponents. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] The bases in *x1* raised to the exponents in *x2*. This is a scalar if both *x1* and *x2* are scalars.

See also:

float_power
: power function that promotes integers to float

Examples

```
>>> import numpy as np
```

Cube each element in an array.

```
>>> x1 = np.arange(6)
>>> x1
[0, 1, 2, 3, 4, 5]
>>> np.power(x1, 3)
array([  0,   1,   8,  27,  64, 125])
```

Raise the bases to different exponents.

```
>>> x2 = [1.0, 2.0, 3.0, 3.0, 2.0, 1.0]
>>> np.power(x1, x2)
array([  0.,   1.,   8.,  27.,  16.,   5.])
```

The effect of broadcasting.

```
>>> x2 = np.array([[1, 2, 3, 3, 2, 1], [1, 2, 3, 3, 2, 1]])
>>> x2
array([[1, 2, 3, 3, 2, 1],
       [1, 2, 3, 3, 2, 1]])
```

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```
>>> np.power(x1, x2)
array([[ 0,  1,  8, 27, 16,  5],
       [ 0,  1,  8, 27, 16,  5]])
```

The `**` operator can be used as a shorthand for `np.power` on ndarrays.

```
>>> x2 = np.array([1, 2, 3, 3, 2, 1])
>>> x1 = np.arange(6)
>>> x1 ** x2
array([ 0,  1,  8, 27, 16,  5])
```

Negative values raised to a non-integral value will result in `nan` (and a warning will be generated).

```
>>> x3 = np.array([-1.0, -4.0])
>>> with np.errstate(invalid='ignore'):
...     p = np.power(x3, 1.5)
...
>>> p
array([nan, nan])
```

To get complex results, give the argument `dtype=complex`.

```
>>> np.power(x3, 1.5, dtype=complex)
array([-1.83697020e-16-1.j, -1.46957616e-15-8.j])
```

numpy.**pow**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'power'>**

First array elements raised to powers from second array, element-wise.

Raise each base in *x1* to the positionally-corresponding power in *x2*. *x1* and *x2* must be broadcastable to the same shape.

An integer type raised to a negative integer power will raise a `ValueError`.

Negative values raised to a non-integral value will return `nan`. To get complex results, cast the input to complex, or specify the `dtype` to be `complex` (see the example below).

Parameters

x1
: [array_like] The bases.

x2
: [array_like] The exponents. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The bases in *x1* raised to the exponents in *x2*. This is a scalar if both *x1* and *x2* are scalars.

See also:

float_power
power function that promotes integers to float

Examples

```
>>> import numpy as np
```

Cube each element in an array.

```
>>> x1 = np.arange(6)
>>> x1
[0, 1, 2, 3, 4, 5]
>>> np.power(x1, 3)
array([  0,   1,   8,  27,  64, 125])
```

Raise the bases to different exponents.

```
>>> x2 = [1.0, 2.0, 3.0, 3.0, 2.0, 1.0]
>>> np.power(x1, x2)
array([  0.,   1.,   8.,  27.,  16.,   5.])
```

The effect of broadcasting.

```
>>> x2 = np.array([[1, 2, 3, 3, 2, 1], [1, 2, 3, 3, 2, 1]])
>>> x2
array([[1, 2, 3, 3, 2, 1],
       [1, 2, 3, 3, 2, 1]])
>>> np.power(x1, x2)
array([[ 0,  1,  8, 27, 16,  5],
       [ 0,  1,  8, 27, 16,  5]])
```

The `**` operator can be used as a shorthand for `np.power` on ndarrays.

```
>>> x2 = np.array([1, 2, 3, 3, 2, 1])
>>> x1 = np.arange(6)
>>> x1 ** x2
array([ 0,  1,  8, 27, 16,  5])
```

Negative values raised to a non-integral value will result in `nan` (and a warning will be generated).

```
>>> x3 = np.array([-1.0, -4.0])
>>> with np.errstate(invalid='ignore'):
...     p = np.power(x3, 1.5)
...
>>> p
array([nan, nan])
```

To get complex results, give the argument `dtype=complex`.

```
>>> np.power(x3, 1.5, dtype=complex)
array([-1.83697020e-16-1.j, -1.46957616e-15-8.j])
```

numpy.**subtract**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'subtract'>**

Subtract arguments, element-wise.

Parameters

x1, x2
[array_like] The arrays to be subtracted from each other. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The difference of *x1* and *x2*, element-wise. This is a scalar if both *x1* and *x2* are scalars.

Notes

Equivalent to `x1 - x2` in terms of array broadcasting.

Examples

```
>>> import numpy as np
>>> np.subtract(1.0, 4.0)
-3.0
```

```
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> np.subtract(x1, x2)
array([[ 0.,  0.,  0.],
       [ 3.,  3.,  3.],
       [ 6.,  6.,  6.]])
```

The `-` operator can be used as a shorthand for `np.subtract` on ndarrays.

```
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> x1 - x2
array([[0., 0., 0.],
       [3., 3., 3.],
       [6., 6., 6.]])
```

numpy.**true_divide**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'divide'>**

Divide arguments element-wise.

Parameters

x1
[array_like] Dividend array.

x2
[array_like] Divisor array. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or scalar] The quotient `x1/x2`, element-wise. This is a scalar if both *x1* and *x2* are scalars.

See also:

seterr
Set whether to raise or warn on overflow, underflow and division by zero.

Notes

Equivalent to `x1 / x2` in terms of array-broadcasting.

The `true_divide(x1, x2)` function is an alias for `divide(x1, x2)`.

Examples

```
>>> import numpy as np
>>> np.divide(2.0, 4.0)
0.5
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = np.arange(3.0)
>>> np.divide(x1, x2)
array([[nan, 1. , 1. ],
       [inf, 4. , 2.5],
       [inf, 7. , 4. ]])
```

The `/` operator can be used as a shorthand for `np.divide` on ndarrays.

```
>>> x1 = np.arange(9.0).reshape((3, 3))
>>> x2 = 2 * np.ones(3)
>>> x1 / x2
array([[0. , 0.5, 1. ],
       [1.5, 2. , 2.5],
       [3. , 3.5, 4. ]])
```

numpy.**floor_divide**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'floor_divide'>**

Return the largest integer smaller or equal to the division of the inputs. It is equivalent to the Python `//` operator and pairs with the Python `%` (*remainder*), function so that `a = a % b + b * (a // b)` up to roundoff.

Parameters

x1
: [array_like] Numerator.

x2
: [array_like] Denominator. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] y = floor(*x1*/*x2*) This is a scalar if both *x1* and *x2* are scalars.

See also:

remainder
: Remainder complementary to floor_divide.

divmod
Simultaneous floor division and remainder.

divide
Standard division.

floor
Round a number to the nearest integer toward minus infinity.

ceil
Round a number to the nearest integer toward infinity.

Examples

```
>>> import numpy as np
>>> np.floor_divide(7,3)
2
>>> np.floor_divide([1., 2., 3., 4.], 2.5)
array([ 0.,  0.,  1.,  1.])
```

The `//` operator can be used as a shorthand for `np.floor_divide` on ndarrays.

```
>>> x1 = np.array([1., 2., 3., 4.])
>>> x1 // 2.5
array([0., 0., 1., 1.])
```

numpy.**float_power**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'float_power'>**

First array elements raised to powers from second array, element-wise.

Raise each base in *x1* to the positionally-corresponding power in *x2*. *x1* and *x2* must be broadcastable to the same shape. This differs from the power function in that integers, float16, and float32 are promoted to floats with a minimum precision of float64 so that the result is always inexact. The intent is that the function will return a usable result for negative powers and seldom overflow for positive powers.

Negative values raised to a non-integral value will return `nan`. To get complex results, cast the input to complex, or specify the `dtype` to be `complex` (see the example below).

Parameters

x1
[array_like] The bases.

x2
[array_like] The exponents. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The bases in *x1* raised to the exponents in *x2*. This is a scalar if both *x1* and *x2* are scalars.

See also:

power
power function that preserves type

Examples

```
>>> import numpy as np
```

Cube each element in a list.

```
>>> x1 = range(6)
>>> x1
[0, 1, 2, 3, 4, 5]
>>> np.float_power(x1, 3)
array([   0.,    1.,    8.,   27.,   64.,  125.])
```

Raise the bases to different exponents.

```
>>> x2 = [1.0, 2.0, 3.0, 3.0, 2.0, 1.0]
>>> np.float_power(x1, x2)
array([  0.,   1.,   8.,  27.,  16.,   5.])
```

The effect of broadcasting.

```
>>> x2 = np.array([[1, 2, 3, 3, 2, 1], [1, 2, 3, 3, 2, 1]])
>>> x2
array([[1, 2, 3, 3, 2, 1],
       [1, 2, 3, 3, 2, 1]])
>>> np.float_power(x1, x2)
array([[  0.,   1.,   8.,  27.,  16.,   5.],
       [  0.,   1.,   8.,  27.,  16.,   5.]])
```

Negative values raised to a non-integral value will result in `nan` (and a warning will be generated).

```
>>> x3 = np.array([-1, -4])
>>> with np.errstate(invalid='ignore'):
...     p = np.float_power(x3, 1.5)
...
>>> p
array([nan, nan])
```

To get complex results, give the argument `dtype=complex`.

```
>>> np.float_power(x3, 1.5, dtype=complex)
array([-1.83697020e-16-1.j, -1.46957616e-15-8.j])
```

numpy.**fmod**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'fmod'>**

Returns the element-wise remainder of division.

This is the NumPy implementation of the C library function fmod, the remainder has the same sign as the dividend *x1*. It is equivalent to the Matlab(TM) `rem` function and should not be confused with the Python modulus operator `x1 % x2`.

Parameters

x1
[array_like] Dividend.

x2
[array_like] Divisor. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[array_like] The remainder of the division of *x1* by *x2*. This is a scalar if both *x1* and *x2* are scalars.

See also:

remainder
Equivalent to the Python `%` operator.

divide

Notes

The result of the modulo operation for negative dividend and divisors is bound by conventions. For *fmod*, the sign of result is the sign of the dividend, while for *remainder* the sign of the result is the sign of the divisor. The *fmod* function is equivalent to the Matlab(TM) `rem` function.

Examples

```
>>> import numpy as np
>>> np.fmod([-3, -2, -1, 1, 2, 3], 2)
array([-1,  0, -1,  1,  0,  1])
>>> np.remainder([-3, -2, -1, 1, 2, 3], 2)
array([1, 0, 1, 1, 0, 1])
```

```
>>> np.fmod([5, 3], [2, 2.])
array([ 1.,  1.])
>>> a = np.arange(-3, 3).reshape(3, 2)
>>> a
array([[-3, -2],
       [-1,  0],
       [ 1,  2]])
>>> np.fmod(a, [2,2])
array([[-1,  0],
       [-1,  0],
       [ 1,  0]])
```

numpy.**mod**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'remainder'>**

Returns the element-wise remainder of division.

Computes the remainder complementary to the *floor_divide* function. It is equivalent to the Python modulus operator `x1 % x2` and has the same sign as the divisor *x2*. The MATLAB function equivalent to `np.remainder` is `mod`.

Warning: This should not be confused with:

- Python 3.7's `math.remainder` and C's `remainder`, which computes the IEEE remainder, which are the complement to `round(x1 / x2)`.
- The MATLAB `rem` function and or the C `%` operator which is the complement to `int(x1 / x2)`.

Parameters

x1
: [array_like] Dividend array.

x2
: [array_like] Divisor array. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The element-wise remainder of the quotient `floor_divide(x1, x2)`. This is a scalar if both *x1* and *x2* are scalars.

See also:

floor_divide
Equivalent of Python `//` operator.

divmod
Simultaneous floor division and remainder.

fmod
Equivalent of the MATLAB `rem` function.

divide*, *floor

Notes

Returns 0 when *x2* is 0 and both *x1* and *x2* are (arrays of) integers. `mod` is an alias of `remainder`.

Examples

```
>>> import numpy as np
>>> np.remainder([4, 7], [2, 3])
array([0, 1])
>>> np.remainder(np.arange(7), 5)
array([0, 1, 2, 3, 4, 0, 1])
```

The `%` operator can be used as a shorthand for `np.remainder` on ndarrays.

```
>>> x1 = np.arange(7)
>>> x1 % 5
array([0, 1, 2, 3, 4, 0, 1])
```

numpy.**modf**(*x*, [*out1*, *out2*,]/, [*out=(None, None)*,]*, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'modf'>**

Return the fractional and integral parts of an array, element-wise.

The fractional and integral parts are negative if the given number is negative.

Parameters

x
[array_like] Input array.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y1
[ndarray] Fractional part of *x*. This is a scalar if *x* is a scalar.

y2
[ndarray] Integral part of *x*. This is a scalar if *x* is a scalar.

See also:

divmod
`divmod(x, 1)` is equivalent to `modf` with the return values switched, except it always has a positive remainder.

Notes

For integer input the return values are floats.

Examples

```
>>> import numpy as np
>>> np.modf([0, 3.5])
(array([ 0. ,  0.5]), array([ 0.,  3.]))
>>> np.modf(-0.5)
(-0.5, -0)
```

numpy.**remainder**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'remainder'>**

Returns the element-wise remainder of division.

Computes the remainder complementary to the *floor_divide* function. It is equivalent to the Python modulus operator `x1 % x2` and has the same sign as the divisor *x2*. The MATLAB function equivalent to `np.remainder` is `mod`.

Warning: This should not be confused with:

- Python 3.7's `math.remainder` and C's `remainder`, which computes the IEEE remainder, which are the complement to `round(x1 / x2)`.
- The MATLAB `rem` function and or the C `%` operator which is the complement to `int(x1 / x2)`.

Parameters

x1
[array_like] Dividend array.

x2
: [array_like] Divisor array. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] The element-wise remainder of the quotient `floor_divide(x1, x2)`. This is a scalar if both *x1* and *x2* are scalars.

See also:

floor_divide
: Equivalent of Python `//` operator.

divmod
: Simultaneous floor division and remainder.

fmod
: Equivalent of the MATLAB `rem` function.

divide, ***floor***

Notes

Returns 0 when *x2* is 0 and both *x1* and *x2* are (arrays of) integers. `mod` is an alias of `remainder`.

Examples

```
>>> import numpy as np
>>> np.remainder([4, 7], [2, 3])
array([0, 1])
>>> np.remainder(np.arange(7), 5)
array([0, 1, 2, 3, 4, 0, 1])
```

The `%` operator can be used as a shorthand for `np.remainder` on ndarrays.

```
>>> x1 = np.arange(7)
>>> x1 % 5
array([0, 1, 2, 3, 4, 0, 1])
```

numpy.**divmod**(*x1*, *x2*, [*out1*, *out2*,]/, [*out=(None, None)*,]*, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'divmod'>**

Return element-wise quotient and remainder simultaneously.

`np.divmod(x, y)` is equivalent to `(x // y, x % y)`, but faster because it avoids redundant work. It is used to implement the Python built-in function `divmod` on NumPy arrays.

Parameters

x1
[array_like] Dividend array.

x2
[array_like] Divisor array. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out1
[ndarray] Element-wise quotient resulting from floor division. This is a scalar if both *x1* and *x2* are scalars.

out2
[ndarray] Element-wise remainder from floor division. This is a scalar if both *x1* and *x2* are scalars.

See also:

floor_divide
Equivalent to Python's `//` operator.

remainder
Equivalent to Python's `%` operator.

modf
Equivalent to `divmod(x, 1)` for positive `x` with the return values switched.

Examples

```
>>> import numpy as np
>>> np.divmod(np.arange(5), 3)
(array([0, 0, 0, 1, 1]), array([0, 1, 2, 0, 1]))
```

The *divmod* function can be used as a shorthand for `np.divmod` on ndarrays.

```
>>> x = np.arange(5)
>>> divmod(x, 3)
(array([0, 0, 0, 1, 1]), array([0, 1, 2, 0, 1]))
```

Handling complex numbers

angle(z[, deg])	Return the angle of the complex argument.
real(val)	Return the real part of the complex argument.
imag(val)	Return the imaginary part of the complex argument.
conj(x, /[, out, where, casting, order, ...])	Return the complex conjugate, element-wise.
conjugate(x, /[, out, where, casting, ...])	Return the complex conjugate, element-wise.

`numpy.`**`angle`**(*z*, *deg=False*)

Return the angle of the complex argument.

Parameters

z
[array_like] A complex number or sequence of complex numbers.

deg
[bool, optional] Return angle in degrees if True, radians if False (default).

Returns

angle
[ndarray or scalar] The counterclockwise angle from the positive real axis on the complex plane in the range `(-pi, pi]`, with dtype as numpy.float64.

See also:

arctan2
absolute

Notes

This function passes the imaginary and real parts of the argument to *arctan2* to compute the result; consequently, it follows the convention of *arctan2* when the magnitude of the argument is zero. See example.

Examples

```
>>> import numpy as np
>>> np.angle([1.0, 1.0j, 1+1j])               # in radians
array([ 0.        ,  1.57079633,  0.78539816]) # may vary
>>> np.angle(1+1j, deg=True)                  # in degrees
45.0
>>> np.angle([0., -0., complex(0., -0.), complex(-0., -0.)])  # convention
array([ 0.        ,  3.14159265, -0.        , -3.14159265])
```

numpy.**real**(*val*)

Return the real part of the complex argument.

Parameters

val
[array_like] Input array.

Returns

out
[ndarray or scalar] The real component of the complex argument. If *val* is real, the type of *val* is used for the output. If *val* has complex elements, the returned type is float.

See also:

real_if_close, ***imag***, ***angle***

Examples

```
>>> import numpy as np
>>> a = np.array([1+2j, 3+4j, 5+6j])
>>> a.real
array([1.,  3.,  5.])
>>> a.real = 9
>>> a
array([9.+2.j,  9.+4.j,  9.+6.j])
>>> a.real = np.array([9, 8, 7])
>>> a
array([9.+2.j,  8.+4.j,  7.+6.j])
>>> np.real(1 + 1j)
1.0
```

numpy.**imag**(*val*)

Return the imaginary part of the complex argument.

Parameters

val
[array_like] Input array.

Returns

out
[ndarray or scalar] The imaginary component of the complex argument. If *val* is real, the type of *val* is used for the output. If *val* has complex elements, the returned type is float.

See also:

real, *angle*, *real_if_close*

Examples

```
>>> import numpy as np
>>> a = np.array([1+2j, 3+4j, 5+6j])
>>> a.imag
array([2.,  4.,  6.])
>>> a.imag = np.array([8, 10, 12])
>>> a
array([1. +8.j,  3.+10.j,  5.+12.j])
>>> np.imag(1 + 1j)
1.0
```

numpy.**conj**(*x*, /, *out=None*, *, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'conjugate'>**

Return the complex conjugate, element-wise.

The complex conjugate of a complex number is obtained by changing the sign of its imaginary part.

Parameters

x
[array_like] Input value.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The complex conjugate of *x*, with same dtype as *y*. This is a scalar if *x* is a scalar.

Notes

conj is an alias for *conjugate*:

```
>>> np.conj is np.conjugate
True
```

Examples

```
>>> import numpy as np
>>> np.conjugate(1+2j)
(1-2j)
```

```
>>> x = np.eye(2) + 1j * np.eye(2)
>>> np.conjugate(x)
array([[ 1.-1.j,  0.-0.j],
       [ 0.-0.j,  1.-1.j]])
```

numpy.**conjugate**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'conjugate'>**

Return the complex conjugate, element-wise.

The complex conjugate of a complex number is obtained by changing the sign of its imaginary part.

Parameters

x
[array_like] Input value.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The complex conjugate of *x*, with same dtype as *y*. This is a scalar if *x* is a scalar.

Notes

conj is an alias for *conjugate*:

```
>>> np.conj is np.conjugate
True
```

Examples

```
>>> import numpy as np
>>> np.conjugate(1+2j)
(1-2j)
```

```
>>> x = np.eye(2) + 1j * np.eye(2)
>>> np.conjugate(x)
array([[ 1.-1.j,  0.-0.j],
       [ 0.-0.j,  1.-1.j]])
```

Extrema finding

maximum(x1, x2, /[, out, where, casting, ...])	Element-wise maximum of array elements.
max(a[, axis, out, keepdims, initial, where])	Return the maximum of an array or maximum along an axis.
amax(a[, axis, out, keepdims, initial, where])	Return the maximum of an array or maximum along an axis.
fmax(x1, x2, /[, out, where, casting, ...])	Element-wise maximum of array elements.
nanmax(a[, axis, out, keepdims, initial, where])	Return the maximum of an array or maximum along an axis, ignoring any NaNs.
minimum(x1, x2, /[, out, where, casting, ...])	Element-wise minimum of array elements.
min(a[, axis, out, keepdims, initial, where])	Return the minimum of an array or minimum along an axis.
amin(a[, axis, out, keepdims, initial, where])	Return the minimum of an array or minimum along an axis.
fmin(x1, x2, /[, out, where, casting, ...])	Element-wise minimum of array elements.
nanmin(a[, axis, out, keepdims, initial, where])	Return minimum of an array or minimum along an axis, ignoring any NaNs.

numpy.**maximum**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'maximum'>**

Element-wise maximum of array elements.

Compare two arrays and return a new array containing the element-wise maxima. If one of the elements being compared is a NaN, then that element is returned. If both elements are NaNs then the first is returned. The latter distinction is important for complex NaNs, which are defined as at least one of the real or imaginary parts being a NaN. The net effect is that NaNs are propagated.

Parameters

x1, x2
[array_like] The arrays holding the elements to be compared. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain

its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or scalar] The maximum of *x1* and *x2*, element-wise. This is a scalar if both *x1* and *x2* are scalars.

See also:

minimum
Element-wise minimum of two arrays, propagates NaNs.

fmax
Element-wise maximum of two arrays, ignores NaNs.

amax
The maximum value of an array along a given axis, propagates NaNs.

nanmax
The maximum value of an array along a given axis, ignores NaNs.

fmin*, *amin*, *nanmin

Notes

The maximum is equivalent to `np.where(x1 >= x2, x1, x2)` when neither x1 nor x2 are nans, but it is faster and does proper broadcasting.

Examples

```
>>> import numpy as np
>>> np.maximum([2, 3, 4], [1, 5, 2])
array([2, 5, 4])
```

```
>>> np.maximum(np.eye(2), [0.5, 2]) # broadcasting
array([[ 1. ,  2. ],
       [ 0.5,  2. ]])
```

```
>>> np.maximum([np.nan, 0, np.nan], [0, np.nan, np.nan])
array([nan, nan, nan])
>>> np.maximum(np.inf, 1)
inf
```

numpy.**max**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the maximum of an array or maximum along an axis.

Parameters

a
[array_like] Input data.

axis
: [None or int or tuple of ints, optional] Axis or axes along which to operate. By default, flattened input is used. If this is a tuple of ints, the maximum is selected over multiple axes, instead of a single axis or all the axes as before.

out
: [ndarray, optional] Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output. See ufuncs-output-type for more details.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

  If the default value is passed, then *keepdims* will not be passed through to the `max` method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

initial
: [scalar, optional] The minimum value of an output element. Must be present to allow computation on empty slice. See *reduce* for details.

where
: [array_like of bool, optional] Elements to compare for the maximum. See *reduce* for details.

Returns

max
: [ndarray or scalar] Maximum of *a*. If *axis* is None, the result is a scalar value. If *axis* is an int, the result is an array of dimension `a.ndim - 1`. If *axis* is a tuple, the result is an array of dimension `a.ndim - len(axis)`.

See also:

amin
: The minimum value of an array along a given axis, propagating any NaNs.

nanmax
: The maximum value of an array along a given axis, ignoring any NaNs.

maximum
: Element-wise maximum of two arrays, propagating any NaNs.

fmax
: Element-wise maximum of two arrays, ignoring any NaNs.

argmax
: Return the indices of the maximum values.

nanmin, ***minimum***, ***fmin***

Notes

NaN values are propagated, that is if at least one item is NaN, the corresponding max value will be NaN as well. To ignore NaN values (MATLAB behavior), please use nanmax.

Don't use *max* for element-wise comparison of 2 arrays; when `a.shape[0]` is 2, `maximum(a[0], a[1])` is faster than `max(a, axis=0)`.

Examples

```
>>> import numpy as np
>>> a = np.arange(4).reshape((2,2))
>>> a
array([[0, 1],
       [2, 3]])
>>> np.max(a)           # Maximum of the flattened array
3
>>> np.max(a, axis=0)   # Maxima along the first axis
array([2, 3])
>>> np.max(a, axis=1)   # Maxima along the second axis
array([1, 3])
>>> np.max(a, where=[False, True], initial=-1, axis=0)
array([-1,  3])
>>> b = np.arange(5, dtype=float)
>>> b[2] = np.nan
>>> np.max(b)
np.float64(nan)
>>> np.max(b, where=~np.isnan(b), initial=-1)
4.0
>>> np.nanmax(b)
4.0
```

You can use an initial value to compute the maximum of an empty slice, or to initialize it to a different value:

```
>>> np.max([[-50], [10]], axis=-1, initial=0)
array([ 0, 10])
```

Notice that the initial value is used as one of the elements for which the maximum is determined, unlike for the default argument Python's max function, which is only used for empty iterables.

```
>>> np.max([5], initial=6)
6
>>> max([5], default=6)
5
```

`numpy.`**`amax`**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the maximum of an array or maximum along an axis.

amax is an alias of *max*.

See also:

max
alias of this function

ndarray.max
equivalent method

numpy.**fmax**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'fmax'>**

Element-wise maximum of array elements.

Compare two arrays and return a new array containing the element-wise maxima. If one of the elements being compared is a NaN, then the non-nan element is returned. If both elements are NaNs then the first is returned. The latter distinction is important for complex NaNs, which are defined as at least one of the real or imaginary parts being a NaN. The net effect is that NaNs are ignored when possible.

Parameters

x1, x2
[array_like] The arrays holding the elements to be compared. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or scalar] The maximum of *x1* and *x2*, element-wise. This is a scalar if both *x1* and *x2* are scalars.

See also:

fmin
Element-wise minimum of two arrays, ignores NaNs.

maximum
Element-wise maximum of two arrays, propagates NaNs.

amax
The maximum value of an array along a given axis, propagates NaNs.

nanmax
The maximum value of an array along a given axis, ignores NaNs.

minimum, ***amin***, ***nanmin***

Notes

The fmax is equivalent to `np.where(x1 >= x2, x1, x2)` when neither x1 nor x2 are NaNs, but it is faster and does proper broadcasting.

Examples

```
>>> import numpy as np
>>> np.fmax([2, 3, 4], [1, 5, 2])
array([ 2,  5,  4])
```

```
>>> np.fmax(np.eye(2), [0.5, 2])
array([[ 1. ,  2. ],
       [ 0.5,  2. ]])
```

```
>>> np.fmax([np.nan, 0, np.nan],[0, np.nan, np.nan])
array([ 0.,  0., nan])
```

numpy.**nanmax**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the maximum of an array or maximum along an axis, ignoring any NaNs. When all-NaN slices are encountered a `RuntimeWarning` is raised and NaN is returned for that slice.

Parameters

a
: [array_like] Array containing numbers whose maximum is desired. If *a* is not an array, a conversion is attempted.

axis
: [{int, tuple of int, None}, optional] Axis or axes along which the maximum is computed. The default is to compute the maximum of the flattened array.

out
: [ndarray, optional] Alternate output array in which to place the result. The default is `None`; if provided, it must have the same shape as the expected output, but the type will be cast if necessary. See ufuncs-output-type for more details.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*. If the value is anything but the default, then *keepdims* will be passed through to the *max* method of sub-classes of *ndarray*. If the sub-classes methods does not implement *keepdims* any exceptions will be raised.

initial
: [scalar, optional] The minimum value of an output element. Must be present to allow computation on empty slice. See *reduce* for details.

  New in version 1.22.0.

where
: [array_like of bool, optional] Elements to compare for the maximum. See *reduce* for details.

  New in version 1.22.0.

Returns

nanmax
[ndarray] An array with the same shape as *a*, with the specified axis removed. If *a* is a 0-d array, or if axis is None, an ndarray scalar is returned. The same dtype as *a* is returned.

See also:

nanmin
The minimum value of an array along a given axis, ignoring any NaNs.

amax
The maximum value of an array along a given axis, propagating any NaNs.

fmax
Element-wise maximum of two arrays, ignoring any NaNs.

maximum
Element-wise maximum of two arrays, propagating any NaNs.

isnan
Shows which elements are Not a Number (NaN).

isfinite
Shows which elements are neither NaN nor infinity.

amin, ***fmin***, ***minimum***

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity. Positive infinity is treated as a very large number and negative infinity is treated as a very small (i.e. negative) number.

If the input has a integer type the function is equivalent to np.max.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, np.nan]])
>>> np.nanmax(a)
3.0
>>> np.nanmax(a, axis=0)
array([3.,  2.])
>>> np.nanmax(a, axis=1)
array([2.,  3.])
```

When positive infinity and negative infinity are present:

```
>>> np.nanmax([1, 2, np.nan, -np.inf])
2.0
>>> np.nanmax([1, 2, np.nan, np.inf])
inf
```

numpy.**minimum**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'minimum'>**

Element-wise minimum of array elements.

Compare two arrays and return a new array containing the element-wise minima. If one of the elements being compared is a NaN, then that element is returned. If both elements are NaNs then the first is returned. The latter

distinction is important for complex NaNs, which are defined as at least one of the real or imaginary parts being a NaN. The net effect is that NaNs are propagated.

Parameters

x1, x2
[array_like] The arrays holding the elements to be compared. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or scalar] The minimum of *x1* and *x2*, element-wise. This is a scalar if both *x1* and *x2* are scalars.

See also:

maximum
Element-wise maximum of two arrays, propagates NaNs.

fmin
Element-wise minimum of two arrays, ignores NaNs.

amin
The minimum value of an array along a given axis, propagates NaNs.

nanmin
The minimum value of an array along a given axis, ignores NaNs.

fmax*, *amax*, *nanmax

Notes

The minimum is equivalent to `np.where(x1 <= x2, x1, x2)` when neither x1 nor x2 are NaNs, but it is faster and does proper broadcasting.

Examples

```
>>> import numpy as np
>>> np.minimum([2, 3, 4], [1, 5, 2])
array([1, 3, 2])
```

```
>>> np.minimum(np.eye(2), [0.5, 2]) # broadcasting
array([[ 0.5,  0. ],
       [ 0. ,  1. ]])
```

```
>>> np.minimum([np.nan, 0, np.nan],[0, np.nan, np.nan])
array([nan, nan, nan])
>>> np.minimum(-np.inf, 1)
-inf
```

numpy.**min**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the minimum of an array or minimum along an axis.

Parameters

a
[array_like] Input data.

axis
[None or int or tuple of ints, optional] Axis or axes along which to operate. By default, flattened input is used.

If this is a tuple of ints, the minimum is selected over multiple axes, instead of a single axis or all the axes as before.

out
[ndarray, optional] Alternative output array in which to place the result. Must be of the same shape and buffer length as the expected output. See ufuncs-output-type for more details.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

If the default value is passed, then *keepdims* will not be passed through to the `min` method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

initial
[scalar, optional] The maximum value of an output element. Must be present to allow computation on empty slice. See *reduce* for details.

where
[array_like of bool, optional] Elements to compare for the minimum. See *reduce* for details.

Returns

min
[ndarray or scalar] Minimum of *a*. If *axis* is None, the result is a scalar value. If *axis* is an int, the result is an array of dimension `a.ndim - 1`. If *axis* is a tuple, the result is an array of dimension `a.ndim - len(axis)`.

See also:

amax
: The maximum value of an array along a given axis, propagating any NaNs.

nanmin
: The minimum value of an array along a given axis, ignoring any NaNs.

minimum
: Element-wise minimum of two arrays, propagating any NaNs.

fmin
: Element-wise minimum of two arrays, ignoring any NaNs.

argmin
: Return the indices of the minimum values.

nanmax, ***maximum***, ***fmax***

Notes

NaN values are propagated, that is if at least one item is NaN, the corresponding min value will be NaN as well. To ignore NaN values (MATLAB behavior), please use nanmin.

Don't use *min* for element-wise comparison of 2 arrays; when `a.shape[0]` is 2, `minimum(a[0], a[1])` is faster than `min(a, axis=0)`.

Examples

```
>>> import numpy as np
>>> a = np.arange(4).reshape((2,2))
>>> a
array([[0, 1],
       [2, 3]])
>>> np.min(a)           # Minimum of the flattened array
0
>>> np.min(a, axis=0)   # Minima along the first axis
array([0, 1])
>>> np.min(a, axis=1)   # Minima along the second axis
array([0, 2])
>>> np.min(a, where=[False, True], initial=10, axis=0)
array([10,  1])
```

```
>>> b = np.arange(5, dtype=float)
>>> b[2] = np.nan
>>> np.min(b)
np.float64(nan)
>>> np.min(b, where=~np.isnan(b), initial=10)
0.0
>>> np.nanmin(b)
0.0
```

```
>>> np.min([[-50], [10]], axis=-1, initial=0)
array([-50,   0])
```

Notice that the initial value is used as one of the elements for which the minimum is determined, unlike for the default argument Python's max function, which is only used for empty iterables.

Notice that this isn't the same as Python's `default` argument.

```
>>> np.min([6], initial=5)
5
>>> min([6], default=5)
6
```

numpy.**amin**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return the minimum of an array or minimum along an axis.

amin is an alias of *min*.

See also:

min
alias of this function

ndarray.min
equivalent method

numpy.**fmin**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'fmin'>**

Element-wise minimum of array elements.

Compare two arrays and return a new array containing the element-wise minima. If one of the elements being compared is a NaN, then the non-nan element is returned. If both elements are NaNs then the first is returned. The latter distinction is important for complex NaNs, which are defined as at least one of the real or imaginary parts being a NaN. The net effect is that NaNs are ignored when possible.

Parameters

x1, x2
[array_like] The arrays holding the elements to be compared. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or scalar] The minimum of *x1* and *x2*, element-wise. This is a scalar if both *x1* and *x2* are scalars.

See also:

fmax
Element-wise maximum of two arrays, ignores NaNs.

minimum
Element-wise minimum of two arrays, propagates NaNs.

amin
The minimum value of an array along a given axis, propagates NaNs.

nanmin
The minimum value of an array along a given axis, ignores NaNs.

maximum, ***amax***, ***nanmax***

Notes

The fmin is equivalent to `np.where(x1 <= x2, x1, x2)` when neither x1 nor x2 are NaNs, but it is faster and does proper broadcasting.

Examples

```
>>> import numpy as np
>>> np.fmin([2, 3, 4], [1, 5, 2])
array([1, 3, 2])
```

```
>>> np.fmin(np.eye(2), [0.5, 2])
array([[ 0.5,  0. ],
       [ 0. ,  1. ]])
```

```
>>> np.fmin([np.nan, 0, np.nan],[0, np.nan, np.nan])
array([ 0.,  0., nan])
```

numpy.**nanmin**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*, *initial=<no value>*, *where=<no value>*)

Return minimum of an array or minimum along an axis, ignoring any NaNs. When all-NaN slices are encountered a `RuntimeWarning` is raised and Nan is returned for that slice.

Parameters

a
[array_like] Array containing numbers whose minimum is desired. If *a* is not an array, a conversion is attempted.

axis
[{int, tuple of int, None}, optional] Axis or axes along which the minimum is computed. The default is to compute the minimum of the flattened array.

out
[ndarray, optional] Alternate output array in which to place the result. The default is `None`; if provided, it must have the same shape as the expected output, but the type will be cast if necessary. See ufuncs-output-type for more details.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*.

If the value is anything but the default, then *keepdims* will be passed through to the *min* method of sub-classes of *ndarray*. If the sub-classes methods does not implement *keepdims* any exceptions will be raised.

initial
: [scalar, optional] The maximum value of an output element. Must be present to allow computation on empty slice. See *reduce* for details.

  New in version 1.22.0.

where
: [array_like of bool, optional] Elements to compare for the minimum. See *reduce* for details.

  New in version 1.22.0.

Returns

nanmin
: [ndarray] An array with the same shape as *a*, with the specified axis removed. If *a* is a 0-d array, or if axis is None, an ndarray scalar is returned. The same dtype as *a* is returned.

See also:

nanmax
: The maximum value of an array along a given axis, ignoring any NaNs.

amin
: The minimum value of an array along a given axis, propagating any NaNs.

fmin
: Element-wise minimum of two arrays, ignoring any NaNs.

minimum
: Element-wise minimum of two arrays, propagating any NaNs.

isnan
: Shows which elements are Not a Number (NaN).

isfinite
: Shows which elements are neither NaN nor infinity.

amax, ***fmax***, ***maximum***

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity. Positive infinity is treated as a very large number and negative infinity is treated as a very small (i.e. negative) number.

If the input has a integer type the function is equivalent to np.min.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, np.nan]])
>>> np.nanmin(a)
1.0
>>> np.nanmin(a, axis=0)
array([1.,  2.])
>>> np.nanmin(a, axis=1)
array([1.,  3.])
```

When positive infinity and negative infinity are present:

```
>>> np.nanmin([1, 2, np.nan, np.inf])
1.0
>>> np.nanmin([1, 2, np.nan, -np.inf])
-inf
```

Miscellaneous

convolve(a, v[, mode])	Returns the discrete, linear convolution of two one-dimensional sequences.
clip(a[, a_min, a_max, out, min, max])	Clip (limit) the values in an array.
sqrt(x, /[, out, where, casting, order, ...])	Return the non-negative square-root of an array, element-wise.
cbrt(x, /[, out, where, casting, order, ...])	Return the cube-root of an array, element-wise.
square(x, /[, out, where, casting, order, ...])	Return the element-wise square of the input.
absolute(x, /[, out, where, casting, order, ...])	Calculate the absolute value element-wise.
fabs(x, /[, out, where, casting, order, ...])	Compute the absolute values element-wise.
sign(x, /[, out, where, casting, order, ...])	Returns an element-wise indication of the sign of a number.
heaviside(x1, x2, /[, out, where, casting, ...])	Compute the Heaviside step function.
nan_to_num(x[, copy, nan, posinf, neginf])	Replace NaN with zero and infinity with large finite numbers (default behaviour) or with the numbers defined by the user using the nan, *posinf* and/or *neginf* keywords.
real_if_close(a[, tol])	If input is complex with all imaginary parts close to zero, return real parts.
interp(x, xp, fp[, left, right, period])	One-dimensional linear interpolation for monotonically increasing sample points.
bitwise_count(x, /[, out, where, casting, ...])	Computes the number of 1-bits in the absolute value of x.

numpy.**convolve**(*a*, *v*, *mode='full'*)

Returns the discrete, linear convolution of two one-dimensional sequences.

The convolution operator is often seen in signal processing, where it models the effect of a linear time-invariant system on a signal [1]. In probability theory, the sum of two independent random variables is distributed according to the convolution of their individual distributions.

If *v* is longer than *a*, the arrays are swapped before computation.

Parameters

a
[(N,) array_like] First one-dimensional input array.

v
[(M,) array_like] Second one-dimensional input array.

mode
[{'full', 'valid', 'same'}, optional]

'full':
By default, mode is 'full'. This returns the convolution at each point of overlap, with an output shape of (N+M-1,). At the end-points of the convolution, the signals do not overlap completely, and boundary effects may be seen.

'same':
Mode 'same' returns output of length `max(M, N)`. Boundary effects are still visible.

'valid':
Mode 'valid' returns output of length `max(M, N) - min(M, N) + 1`. The convolution product is only given for points where the signals overlap completely. Values outside the signal boundary have no effect.

Returns

out
[ndarray] Discrete, linear convolution of *a* and *v*.

See also:

`scipy.signal.fftconvolve`
Convolve two arrays using the Fast Fourier Transform.

`scipy.linalg.toeplitz`
Used to construct the convolution operator.

`polymul`
Polynomial multiplication. Same output as convolve, but also accepts poly1d objects as input.

Notes

The discrete convolution operation is defined as

$$(a * v)_n = \sum_{m=-\infty}^{\infty} a_m v_{n-m}$$

It can be shown that a convolution $x(t) * y(t)$ in time/space is equivalent to the multiplication $X(f)Y(f)$ in the Fourier domain, after appropriate padding (padding is necessary to prevent circular convolution). Since multiplication is more efficient (faster) than convolution, the function `scipy.signal.fftconvolve` exploits the FFT to calculate the convolution of large data-sets.

References

[1]

Examples

Note how the convolution operator flips the second array before "sliding" the two across one another:

```
>>> import numpy as np
>>> np.convolve([1, 2, 3], [0, 1, 0.5])
array([0. , 1. , 2.5, 4. , 1.5])
```

Only return the middle values of the convolution. Contains boundary effects, where zeros are taken into account:

```
>>> np.convolve([1,2,3],[0,1,0.5], 'same')
array([1. ,  2.5,  4. ])
```

The two arrays are of the same length, so there is only one position where they completely overlap:

```
>>> np.convolve([1,2,3],[0,1,0.5], 'valid')
array([2.5])
```

numpy.**clip**(*a*, *a_min=<no value>*, *a_max=<no value>*, *out=None*, ***, *min=<no value>*, *max=<no value>*, ***kwargs*)

Clip (limit) the values in an array.

Given an interval, values outside the interval are clipped to the interval edges. For example, if an interval of `[0, 1]` is specified, values smaller than 0 become 0, and values larger than 1 become 1.

Equivalent to but faster than `np.minimum(a_max, np.maximum(a, a_min))`.

No check is performed to ensure `a_min < a_max`.

Parameters

a
[array_like] Array containing elements to clip.

a_min, a_max
[array_like or None] Minimum and maximum value. If `None`, clipping is not performed on the corresponding edge. If both `a_min` and `a_max` are `None`, the elements of the returned array stay the same. Both are broadcasted against `a`.

out
[ndarray, optional] The results will be placed in this array. It may be the input array for in-place clipping. *out* must be of the right shape to hold the output. Its type is preserved.

min, max
[array_like or None] Array API compatible alternatives for `a_min` and `a_max` arguments. Either `a_min` and `a_max` or `min` and `max` can be passed at the same time. Default: `None`.

New in version 2.1.0.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

clipped_array
[ndarray] An array with the elements of *a*, but where values < *a_min* are replaced with *a_min*, and those > *a_max* with *a_max*.

See also:

ufuncs-output-type

Notes

When *a_min* is greater than *a_max*, `clip` returns an array in which all values are equal to *a_max*, as shown in the second example.

Examples

```
>>> import numpy as np
>>> a = np.arange(10)
>>> a
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> np.clip(a, 1, 8)
array([1, 1, 2, 3, 4, 5, 6, 7, 8, 8])
>>> np.clip(a, 8, 1)
array([1, 1, 1, 1, 1, 1, 1, 1, 1, 1])
>>> np.clip(a, 3, 6, out=a)
array([3, 3, 3, 3, 4, 5, 6, 6, 6, 6])
>>> a
array([3, 3, 3, 3, 4, 5, 6, 6, 6, 6])
>>> a = np.arange(10)
>>> a
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> np.clip(a, [3, 4, 1, 1, 1, 4, 4, 4, 4, 4], 8)
array([3, 4, 2, 3, 4, 5, 6, 7, 8, 8])
```

numpy.**sqrt**(*x*, /, *out=None*, *, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'sqrt'>**

Return the non-negative square-root of an array, element-wise.

Parameters

x
: [array_like] The values whose square-roots are required.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] An array of the same shape as *x*, containing the positive square-root of each element in *x*. If any element in *x* is complex, a complex array is returned (and the square-roots of negative reals are calculated). If all of the elements in *x* are real, so is *y*, with negative elements returning `nan`. If *out* was provided, *y* is a reference to it. This is a scalar if *x* is a scalar.

See also:

emath.sqrt
: A version which returns complex numbers when given negative reals. Note that 0.0 and -0.0 are handled differently for complex inputs.

Notes

sqrt has–consistent with common convention–as its branch cut the real "interval" [*-inf*, 0), and is continuous from above on it. A branch cut is a curve in the complex plane across which a given complex function fails to be continuous.

Examples

```
>>> import numpy as np
>>> np.sqrt([1,4,9])
array([ 1.,  2.,  3.])
```

```
>>> np.sqrt([4, -1, -3+4J])
array([ 2.+0.j,  0.+1.j,  1.+2.j])
```

```
>>> np.sqrt([4, -1, np.inf])
array([ 2., nan, inf])
```

numpy.**cbrt**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'cbrt'>**

Return the cube-root of an array, element-wise.

Parameters

x
: [array_like] The values whose cube-roots are required.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

y
: [ndarray] An array of the same shape as *x*, containing the cube root of each element in *x*. If *out* was provided, *y* is a reference to it. This is a scalar if *x* is a scalar.

Examples

```
>>> import numpy as np
>>> np.cbrt([1,8,27])
array([ 1.,  2.,  3.])
```

numpy.**square**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'square'>**

Return the element-wise square of the input.

Parameters

x
: [array_like] Input data.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

out
: [ndarray or scalar] Element-wise *x*x*, of the same shape and dtype as *x*. This is a scalar if *x* is a scalar.

See also:

numpy.linalg.matrix_power
sqrt
power

Examples

```
>>> import numpy as np
>>> np.square([-1j, 1])
array([-1.-0.j,  1.+0.j])
```

numpy.**absolute**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'absolute'>**

Calculate the absolute value element-wise.

`np.abs` is a shorthand for this function.

Parameters

x
: [array_like] Input array.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
: [array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
: For other keyword-only arguments, see the *ufunc docs*.

Returns

absolute
: [ndarray] An ndarray containing the absolute value of each element in *x*. For complex input, `a + ib`, the absolute value is $\sqrt{a^2 + b^2}$. This is a scalar if *x* is a scalar.

Examples

```
>>> import numpy as np
>>> x = np.array([-1.2, 1.2])
>>> np.absolute(x)
array([ 1.2,  1.2])
>>> np.absolute(1.2 + 1j)
1.5620499351813308
```

Plot the function over `[-10, 10]`:

```
>>> import matplotlib.pyplot as plt
```

```
>>> x = np.linspace(start=-10, stop=10, num=101)
>>> plt.plot(x, np.absolute(x))
>>> plt.show()
```

Plot the function over the complex plane:

```
>>> xx = x + 1j * x[:, np.newaxis]
>>> plt.imshow(np.abs(xx), extent=[-10, 10, -10, 10], cmap='gray')
>>> plt.show()
```

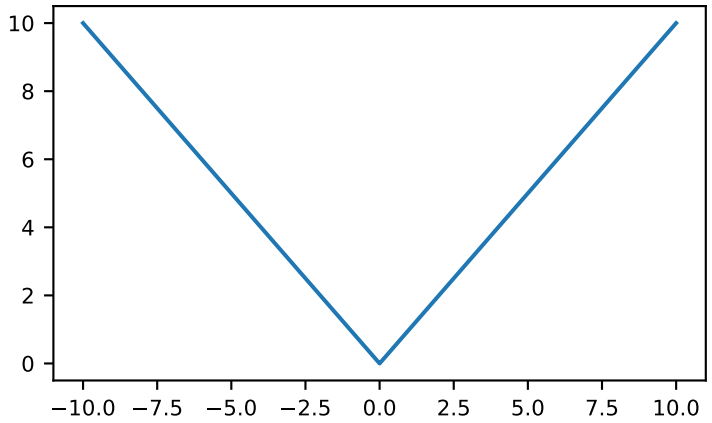
The `abs` function can be used as a shorthand for `np.absolute` on ndarrays.

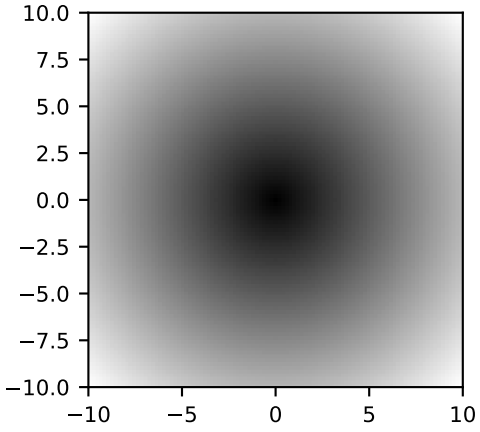
```
>>> x = np.array([-1.2, 1.2])
>>> abs(x)
array([1.2, 1.2])
```

`numpy.`**`fabs`**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'fabs'>**

Compute the absolute values element-wise.

This function returns the absolute values (positive magnitude) of the data in *x*. Complex values are not handled, use *absolute* to find the absolute values of complex data.


10
8
6
4
2
0
−10.0
−7.5
−5.0
−2.5
0.0
2.5
5.0
7.5
10.0


10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
−10
−5
0
5
10

Parameters

x
[array_like] The array of numbers for which the absolute values are required. If *x* is a scalar, the result *y* will also be a scalar.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray or scalar] The absolute values of *x*, the returned values are always floats. This is a scalar if *x* is a scalar.

See also:

absolute
Absolute values including *complex* types.

Examples

```
>>> import numpy as np
>>> np.fabs(-1)
1.0
>>> np.fabs([-1.2, 1.2])
array([ 1.2,  1.2])
```

numpy.**sign**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'sign'>**

Returns an element-wise indication of the sign of a number.

The *sign* function returns `-1 if x < 0, 0 if x==0, 1 if x > 0`. nan is returned for nan inputs.

For complex inputs, the *sign* function returns `x / abs(x)`, the generalization of the above (and `0 if x==0`).

Changed in version 2.0.0: Definition of complex sign changed to follow the Array API standard.

Parameters

x
[array_like] Input values.

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The sign of *x*. This is a scalar if *x* is a scalar.

Notes

There is more than one definition of sign in common use for complex numbers. The definition used here, $x/|x|$, is the more common and useful one, but is different from the one used in numpy prior to version 2.0, $x/\sqrt{x*x}$, which is equivalent to `sign(x.real) + 0j if x.real != 0 else sign(x.imag) + 0j`.

Examples

```
>>> import numpy as np
>>> np.sign([-5., 4.5])
array([-1.,  1.])
>>> np.sign(0)
0
>>> np.sign([3-4j, 8j])
array([0.6-0.8j, 0. +1.j ])
```

numpy.**heaviside**(*x1*, *x2*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'heaviside'>**

Compute the Heaviside step function.

The Heaviside step function [1] is defined as:

```
                      0   if x1 < 0
heaviside(x1, x2) =  x2   if x1 == 0
                      1   if x1 > 0
```

where *x2* is often taken to be 0.5, but 0 and 1 are also sometimes used.

Parameters

x1
[array_like] Input values.

x2
[array_like] The value of the function when x1 is 0. If `x1.shape != x2.shape`, they must be broadcastable to a common shape (which becomes the shape of the output).

out
[ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None, a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

out
[ndarray or scalar] The output array, element-wise Heaviside step function of *x1*. This is a scalar if both *x1* and *x2* are scalars.

References

[1]

Examples

```
>>> import numpy as np
>>> np.heaviside([-1.5, 0, 2.0], 0.5)
array([ 0. ,  0.5,  1. ])
>>> np.heaviside([-1.5, 0, 2.0], 1)
array([ 0.,  1.,  1.])
```

numpy.**nan_to_num**(*x*, *copy=True*, *nan=0.0*, *posinf=None*, *neginf=None*)

Replace NaN with zero and infinity with large finite numbers (default behaviour) or with the numbers defined by the user using the *nan*, *posinf* and/or *neginf* keywords.

If *x* is inexact, NaN is replaced by zero or by the user defined value in *nan* keyword, infinity is replaced by the largest finite floating point values representable by `x.dtype` or by the user defined value in *posinf* keyword and -infinity is replaced by the most negative finite floating point values representable by `x.dtype` or by the user defined value in *neginf* keyword.

For complex dtypes, the above is applied to each of the real and imaginary components of *x* separately.

If *x* is not inexact, then no replacements are made.

Parameters

x
[scalar or array_like] Input data.

copy
[bool, optional] Whether to create a copy of *x* (True) or to replace values in-place (False). The in-place operation only occurs if casting to an array does not require a copy. Default is True.

nan
[int, float, optional] Value to be used to fill NaN values. If no value is passed then NaN values will be replaced with 0.0.

posinf
[int, float, optional] Value to be used to fill positive infinity values. If no value is passed then positive infinity values will be replaced with a very large number.

neginf
: [int, float, optional] Value to be used to fill negative infinity values. If no value is passed then negative infinity values will be replaced with a very small (or negative) number.

Returns

out
: [ndarray] *x*, with the non-finite values replaced. If *copy* is False, this may be *x* itself.

See also:

isinf
: Shows which elements are positive or negative infinity.

isneginf
: Shows which elements are negative infinity.

isposinf
: Shows which elements are positive infinity.

isnan
: Shows which elements are Not a Number (NaN).

isfinite
: Shows which elements are finite (not NaN, not infinity)

Notes

NumPy uses the IEEE Standard for Binary Floating-Point for Arithmetic (IEEE 754). This means that Not a Number is not equivalent to infinity.

Examples

```
>>> import numpy as np
>>> np.nan_to_num(np.inf)
1.7976931348623157e+308
>>> np.nan_to_num(-np.inf)
-1.7976931348623157e+308
>>> np.nan_to_num(np.nan)
0.0
>>> x = np.array([np.inf, -np.inf, np.nan, -128, 128])
>>> np.nan_to_num(x)
array([ 1.79769313e+308, -1.79769313e+308,  0.00000000e+000, # may vary
       -1.28000000e+002,  1.28000000e+002])
>>> np.nan_to_num(x, nan=-9999, posinf=33333333, neginf=33333333)
array([ 3.3333333e+07,  3.3333333e+07, -9.9990000e+03,
       -1.2800000e+02,  1.2800000e+02])
>>> y = np.array([complex(np.inf, np.nan), np.nan, complex(np.nan, np.inf)])
array([  1.79769313e+308,  -1.79769313e+308,   0.00000000e+000, # may vary
     -1.28000000e+002,   1.28000000e+002])
>>> np.nan_to_num(y)
array([  1.79769313e+308 +0.00000000e+000j, # may vary
         0.00000000e+000 +0.00000000e+000j,
         0.00000000e+000 +1.79769313e+308j])
>>> np.nan_to_num(y, nan=111111, posinf=222222)
array([222222.+111111.j, 111111.     +0.j, 111111.+222222.j])
```

numpy.**real_if_close**(*a*, *tol=100*)

If input is complex with all imaginary parts close to zero, return real parts.

"Close to zero" is defined as *tol* * (machine epsilon of the type for *a*).

Parameters

a
[array_like] Input array.

tol
[float] Tolerance in machine epsilons for the complex part of the elements in the array. If the tolerance is <=1, then the absolute tolerance is used.

Returns

out
[ndarray] If *a* is real, the type of *a* is used for the output. If *a* has complex elements, the returned type is float.

See also:

real, ***imag***, ***angle***

Notes

Machine epsilon varies from machine to machine and between data types but Python floats on most platforms have a machine epsilon equal to 2.2204460492503131e-16. You can use 'np.finfo(float).eps' to print out the machine epsilon for floats.

Examples

```
>>> import numpy as np
>>> np.finfo(float).eps
2.2204460492503131e-16 # may vary
```

```
>>> np.real_if_close([2.1 + 4e-14j, 5.2 + 3e-15j], tol=1000)
array([2.1, 5.2])
>>> np.real_if_close([2.1 + 4e-13j, 5.2 + 3e-15j], tol=1000)
array([2.1+4.e-13j, 5.2 + 3e-15j])
```

numpy.**interp**(*x*, *xp*, *fp*, *left=None*, *right=None*, *period=None*)

One-dimensional linear interpolation for monotonically increasing sample points.

Returns the one-dimensional piecewise linear interpolant to a function with given discrete data points (*xp*, *fp*), evaluated at *x*.

Parameters

x
[array_like] The x-coordinates at which to evaluate the interpolated values.

xp
[1-D sequence of floats] The x-coordinates of the data points, must be increasing if argument *period* is not specified. Otherwise, *xp* is internally sorted after normalizing the periodic boundaries with `xp = xp % period`.

fp
: [1-D sequence of float or complex] The y-coordinates of the data points, same length as *xp*.

left
: [optional float or complex corresponding to fp] Value to return for $x < xp[0]$, default is *fp[0]*.

right
: [optional float or complex corresponding to fp] Value to return for $x > xp[-1]$, default is *fp[-1]*.

period
: [None or float, optional] A period for the x-coordinates. This parameter allows the proper interpolation of angular x-coordinates. Parameters *left* and *right* are ignored if *period* is specified.

Returns

y
: [float or complex (corresponding to fp) or ndarray] The interpolated values, same shape as *x*.

Raises

ValueError
: If *xp* and *fp* have different length If *xp* or *fp* are not 1-D sequences If *period* == *0*

Warning: The x-coordinate sequence is expected to be increasing, but this is not explicitly enforced. However, if the sequence *xp* is non-increasing, interpolation results are meaningless.

Note that, since NaN is unsortable, *xp* also cannot contain NaNs.

A simple check for *xp* being strictly increasing is:

```
np.all(np.diff(xp) > 0)
```

See also:

`scipy.interpolate`

Examples

```
>>> import numpy as np
>>> xp = [1, 2, 3]
>>> fp = [3, 2, 0]
>>> np.interp(2.5, xp, fp)
1.0
>>> np.interp([0, 1, 1.5, 2.72, 3.14], xp, fp)
array([3.  , 3.  , 2.5 , 0.56, 0.  ])
>>> UNDEF = -99.0
>>> np.interp(3.14, xp, fp, right=UNDEF)
-99.0
```

Plot an interpolant to the sine function:

```
>>> x = np.linspace(0, 2*np.pi, 10)
>>> y = np.sin(x)
>>> xvals = np.linspace(0, 2*np.pi, 50)
>>> yinterp = np.interp(xvals, x, y)
>>> import matplotlib.pyplot as plt
```

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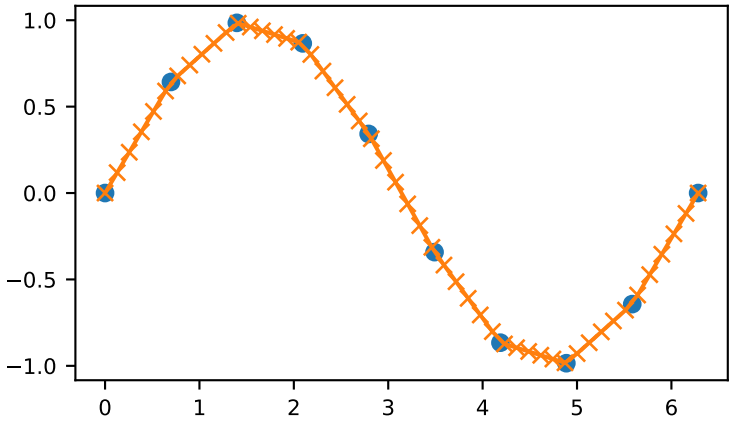
```
>>> plt.plot(x, y, 'o')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.plot(xvals, yinterp, '-x')
[<matplotlib.lines.Line2D object at 0x...>]
>>> plt.show()
```



Interpolation with periodic x-coordinates:

```
>>> x = [-180, -170, -185, 185, -10, -5, 0, 365]
>>> xp = [190, -190, 350, -350]
>>> fp = [5, 10, 3, 4]
>>> np.interp(x, xp, fp, period=360)
array([7.5 , 5.  , 8.75, 6.25, 3.  , 3.25, 3.5 , 3.75])
```

Complex interpolation:

```
>>> x = [1.5, 4.0]
>>> xp = [2,3,5]
>>> fp = [1.0j, 0, 2+3j]
>>> np.interp(x, xp, fp)
array([0.+1.j , 1.+1.5j])
```

numpy.**bitwise_count**(*x*, */*, *out=None*, ***, *where=True*, *casting='same_kind'*, *order='K'*, *dtype=None*, *subok=True*[, *signature*]) **= <ufunc 'bitwise_count'>**

Computes the number of 1-bits in the absolute value of `x`. Analogous to the builtin *int.bit_count* or `popcount` in C++.

Parameters

x
: [array_like, unsigned int] Input array.

out
: [ndarray, None, or tuple of ndarray and None, optional] A location into which the result is stored. If provided, it must have a shape that the inputs broadcast to. If not provided or None,

a freshly-allocated array is returned. A tuple (possible only as a keyword argument) must have length equal to the number of outputs.

where
[array_like, optional] This condition is broadcast over the input. At locations where the condition is True, the *out* array will be set to the ufunc result. Elsewhere, the *out* array will retain its original value. Note that if an uninitialized *out* array is created via the default `out=None`, locations within it where the condition is False will remain uninitialized.

****kwargs**
For other keyword-only arguments, see the *ufunc docs*.

Returns

y
[ndarray] The corresponding number of 1-bits in the input. Returns uint8 for all integer types This is a scalar if *x* is a scalar.

References

[1], [2], [3]

Examples

```
>>> import numpy as np
>>> np.bitwise_count(1023)
np.uint8(10)
>>> a = np.array([2**i - 1 for i in range(16)])
>>> np.bitwise_count(a)
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15],
      dtype=uint8)
```

1.4.13 Miscellaneous routines

Performance tuning

setbufsize(size)	Set the size of the buffer used in ufuncs.
getbufsize()	Return the size of the buffer used in ufuncs.

numpy.**setbufsize**(*size*)
Set the size of the buffer used in ufuncs.

Changed in version 2.0: The scope of setting the buffer is tied to the *numpy.errstate* context. Exiting a `with errstate():` will also restore the bufsize.

Parameters

size
[int] Size of buffer.

Returns

bufsize
[int] Previous size of ufunc buffer in bytes.

Examples

When exiting a *numpy.errstate* context manager the bufsize is restored:

```
>>> import numpy as np
>>> with np.errstate():
...     np.setbufsize(4096)
...     print(np.getbufsize())
...
8192
4096
>>> np.getbufsize()
8192
```

numpy.**getbufsize**()

Return the size of the buffer used in ufuncs.

Returns

getbufsize
[int] Size of ufunc buffer in bytes.

Examples

```
>>> import numpy as np
>>> np.getbufsize()
8192
```

Memory ranges

shares_memory(a, b, /[, max_work])	Determine if two arrays share memory.
may_share_memory(a, b, /[, max_work])	Determine if two arrays might share memory

numpy.**shares_memory**(*a*, *b*, */*, *max_work=None*)

Determine if two arrays share memory.

> **Warning:** This function can be exponentially slow for some inputs, unless *max_work* is set to zero or a positive integer. If in doubt, use *numpy.may_share_memory* instead.

Parameters

a, b
[ndarray] Input arrays

max_work
[int, optional] Effort to spend on solving the overlap problem (maximum number of candidate solutions to consider). The following special values are recognized:

max_work=-1 (default)
The problem is solved exactly. In this case, the function returns True only if there is an element shared between the arrays. Finding the exact solution may take extremely long in some cases.

max_work=0
Only the memory bounds of a and b are checked. This is equivalent to using `may_share_memory()`.

Returns

out
[bool]

Raises

numpy.exceptions.TooHardError
Exceeded max_work.

See also:

may_share_memory

Examples

```
>>> import numpy as np
>>> x = np.array([1, 2, 3, 4])
>>> np.shares_memory(x, np.array([5, 6, 7]))
False
>>> np.shares_memory(x[::2], x)
True
>>> np.shares_memory(x[::2], x[1::2])
False
```

Checking whether two arrays share memory is NP-complete, and runtime may increase exponentially in the number of dimensions. Hence, *max_work* should generally be set to a finite number, as it is possible to construct examples that take extremely long to run:

```
>>> from numpy.lib.stride_tricks import as_strided
>>> x = np.zeros([192163377], dtype=np.int8)
>>> x1 = as_strided(
...     x, strides=(36674, 61119, 85569), shape=(1049, 1049, 1049))
>>> x2 = as_strided(
...     x[64023025:], strides=(12223, 12224, 1), shape=(1049, 1049, 1))
>>> np.shares_memory(x1, x2, max_work=1000)
Traceback (most recent call last):
...
numpy.exceptions.TooHardError: Exceeded max_work
```

Running `np.shares_memory(x1, x2)` without *max_work* set takes around 1 minute for this case. It is possible to find problems that take still significantly longer.

numpy.**may_share_memory**(*a*, *b*, */*, *max_work=None*)

Determine if two arrays might share memory

A return of True does not necessarily mean that the two arrays share any element. It just means that they *might*.

Only the memory bounds of a and b are checked by default.

Parameters

a, b
[ndarray] Input arrays

max_work
[int, optional] Effort to spend on solving the overlap problem. See *shares_memory* for details. Default for `may_share_memory` is to do a bounds check.

Returns

out
[bool]

See also:

shares_memory

Examples

```
>>> import numpy as np
>>> np.may_share_memory(np.array([1,2]), np.array([5,8,9]))
False
>>> x = np.zeros([3, 4])
>>> np.may_share_memory(x[:,0], x[:,1])
True
```

Utility

get_include()	Return the directory that contains the NumPy *.h header files.
show_config([mode])	Show libraries and system information on which NumPy was built and is being used
show_runtime()	Print information about various resources in the system including available intrinsic support and BLAS/LAPACK library in use
broadcast_shapes(*args)	Broadcast the input shapes into a single shape.

`numpy.`**`get_include`**`()`

Return the directory that contains the NumPy *.h header files.

Extension modules that need to compile against NumPy may need to use this function to locate the appropriate include directory.

Notes

When using `setuptools`, for example in `setup.py`:

```
import numpy as np
...
Extension('extension_name', ...
          include_dirs=[np.get_include()])
...
```

Note that a CLI tool `numpy-config` was introduced in NumPy 2.0, using that is likely preferred for build systems other than `setuptools`:

```
$ numpy-config --cflags
-I/path/to/site-packages/numpy/_core/include

# Or rely on pkg-config:
$ export PKG_CONFIG_PATH=$(numpy-config --pkgconfigdir)
$ pkg-config --cflags
-I/path/to/site-packages/numpy/_core/include
```

Examples

```
>>> np.get_include()
'.../site-packages/numpy/core/include'  # may vary
```

numpy.**show_config**(*mode='stdout'*)

Show libraries and system information on which NumPy was built and is being used

Parameters

mode
[{*'stdout'*, *'dicts'*}, optional.] Indicates how to display the config information. *'stdout'* prints to console, *'dicts'* returns a dictionary of the configuration.

Returns

out
[{*dict*, *None*}] If mode is *'dicts'*, a dict is returned, else None

See also:

get_include
Returns the directory containing NumPy C header files.

Notes

1. The *'stdout'* mode will give more readable output if `pyyaml` is installed

numpy.**show_runtime**()

Print information about various resources in the system including available intrinsic support and BLAS/LAPACK library in use

New in version 1.24.0.

See also:

show_config
Show libraries in the system on which NumPy was built.

Notes

1. Information is derived with the help of threadpoolctl library if available.
2. SIMD related information is derived from `__cpu_features__`, `__cpu_baseline__` and `__cpu_dispatch__`

`numpy.broadcast_shapes(*args)`

Broadcast the input shapes into a single shape.

Learn more about broadcasting here.

New in version 1.20.0.

Parameters

***args**
[tuples of ints, or ints] The shapes to be broadcast against each other.

Returns

tuple
Broadcasted shape.

Raises

ValueError
If the shapes are not compatible and cannot be broadcast according to NumPy's broadcasting rules.

See also:

broadcast
broadcast_arrays
broadcast_to

Examples

```
>>> import numpy as np
>>> np.broadcast_shapes((1, 2), (3, 1), (3, 2))
(3, 2)
```

```
>>> np.broadcast_shapes((6, 7), (5, 6, 1), (7,), (5, 1, 7))
(5, 6, 7)
```

NumPy-specific help function

info([object, maxwidth, output, toplevel])	Get help information for an array, function, class, or module.

`numpy.info(object=None, maxwidth=76, output=None, toplevel='numpy')`

Get help information for an array, function, class, or module.

Parameters

object
: [object or str, optional] Input object or name to get information about. If *object* is an *ndarray* instance, information about the array is printed. If *object* is a numpy object, its docstring is given. If it is a string, available modules are searched for matching objects. If None, information about *info* itself is returned.

maxwidth
: [int, optional] Printing width.

output
: [file like object, optional] File like object that the output is written to, default is `None`, in which case `sys.stdout` will be used. The object has to be opened in 'w' or 'a' mode.

toplevel
: [str, optional] Start search at this level.

Notes

When used interactively with an object, `np.info(obj)` is equivalent to `help(obj)` on the Python prompt or `obj?` on the IPython prompt.

Examples

```
>>> np.info(np.polyval)
   polyval(p, x)
     Evaluate the polynomial p at x.
     ...
```

When using a string for *object* it is possible to get multiple results.

```
>>> np.info('fft')
     *** Found in numpy ***
Core FFT routines
...
     *** Found in numpy.fft ***
 fft(a, n=None, axis=-1)
...
     *** Repeat reference found in numpy.fft.fftpack ***
     *** Total of 3 references found. ***
```

When the argument is an array, information about the array is printed.

```
>>> a = np.array([[1 + 2j, 3, -4], [-5j, 6, 0]], dtype=np.complex64)
>>> np.info(a)
class:  ndarray
shape:  (2, 3)
strides:  (24, 8)
itemsize:  8
aligned:  True
contiguous:  True
fortran:  False
data pointer: 0x562b6e0d2860  # may vary
byteorder:  little
byteswap:  False
type: complex64
```

1.4.14 Polynomials

Polynomials in NumPy can be *created*, *manipulated*, and even *fitted* using the *convenience classes* of the *numpy.polynomial* package, introduced in NumPy 1.4.

Prior to NumPy 1.4, *numpy.poly1d* was the class of choice and it is still available in order to maintain backward compatibility. However, the newer *polynomial package* is more complete and its *convenience classes* provide a more consistent, better-behaved interface for working with polynomial expressions. Therefore *numpy.polynomial* is recommended for new coding.

Note: Terminology

The term *polynomial module* refers to the old API defined in `numpy.lib.polynomial`, which includes the *numpy.poly1d* class and the polynomial functions prefixed with *poly* accessible from the *numpy* namespace (e.g. *numpy.polyadd*, *numpy.polyval*, *numpy.polyfit*, etc.).

The term *polynomial package* refers to the new API defined in *numpy.polynomial*, which includes the convenience classes for the different kinds of polynomials (*Polynomial*, *Chebyshev*, etc.).

Transitioning from `numpy.poly1d` to `numpy.polynomial`

As noted above, the *poly1d class* and associated functions defined in `numpy.lib.polynomial`, such as *numpy.polyfit* and *numpy.poly*, are considered legacy and should **not** be used in new code. Since NumPy version 1.4, the *numpy.polynomial* package is preferred for working with polynomials.

Quick Reference

The following table highlights some of the main differences between the legacy polynomial module and the polynomial package for common tasks. The *Polynomial* class is imported for brevity:

```
from numpy.polynomial import Polynomial
```

How to…	Legacy (*numpy.poly1d*)	*numpy.polynomial*
Create a polynomial object from coefficients[1]	`p = np.poly1d([1, 2, 3])`	`p = Polynomial([3, 2, 1])`
Create a polynomial object from roots	`r = np.poly([-1, 1]) p = np.poly1d(r)`	`p = Polynomial.fromroots([-1, 1])`
Fit a polynomial of degree `deg` to data	`np.polyfit(x, y, deg)`	`Polynomial.fit(x, y, deg)`

Transition Guide

There are significant differences between `numpy.lib.polynomial` and *numpy.polynomial*. The most significant difference is the ordering of the coefficients for the polynomial expressions. The various routines in *numpy.polynomial* all deal with series whose coefficients go from degree zero upward, which is the *reverse order* of the poly1d convention. The easy way to remember this is that indices correspond to degree, i.e., `coef[i]` is the coefficient of the term of degree *i*.

Though the difference in convention may be confusing, it is straightforward to convert from the legacy polynomial API to the new. For example, the following demonstrates how you would convert a *numpy.poly1d* instance representing the expression $x^2 + 2x + 3$ to a *Polynomial* instance representing the same expression:

[1] Note the reversed ordering of the coefficients

```
>>> import numpy as np
```

```
>>> p1d = np.poly1d([1, 2, 3])
>>> p = np.polynomial.Polynomial(p1d.coef[::-1])
```

In addition to the `coef` attribute, polynomials from the polynomial package also have `domain` and `window` attributes. These attributes are most relevant when fitting polynomials to data, though it should be noted that polynomials with different `domain` and `window` attributes are not considered equal, and can't be mixed in arithmetic:

```
>>> p1 = np.polynomial.Polynomial([1, 2, 3])
>>> p1
Polynomial([1., 2., 3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> p2 = np.polynomial.Polynomial([1, 2, 3], domain=[-2, 2])
>>> p1 == p2
False
>>> p1 + p2
Traceback (most recent call last):
    ...
TypeError: Domains differ
```

See the documentation for the convenience classes for further details on the `domain` and `window` attributes.

Another major difference between the legacy polynomial module and the polynomial package is polynomial fitting. In the old module, fitting was done via the *`polyfit`* function. In the polynomial package, the *`fit`* class method is preferred. For example, consider a simple linear fit to the following data:

```
In [1]: rng = np.random.default_rng()

In [2]: x = np.arange(10)

In [3]: y = np.arange(10) + rng.standard_normal(10)
```

With the legacy polynomial module, a linear fit (i.e. polynomial of degree 1) could be applied to these data with *`polyfit`*:

```
In [4]: np.polyfit(x, y, deg=1)
Out[4]: array([ 1.09956784, -1.06170122])
```

With the new polynomial API, the *`fit`* class method is preferred:

```
In [5]: p_fitted = np.polynomial.Polynomial.fit(x, y, deg=1)

In [6]: p_fitted
Out[6]: Polynomial([3.88635405, 4.94805526], domain=[0., 9.], window=[-1.,  1.],␣
↪symbol='x')
```

Note that the coefficients are given *in the scaled domain* defined by the linear mapping between the `window` and `domain`. *`convert`* can be used to get the coefficients in the unscaled data domain.

```
In [7]: p_fitted.convert()
Out[7]: Polynomial([-1.06170122,  1.09956784], domain=[-1.,  1.], window=[-1.,  1.],␣
↪symbol='x')
```

Documentation for the `polynomial` package

In addition to standard power series polynomials, the polynomial package provides several additional kinds of polynomials including Chebyshev, Hermite (two subtypes), Laguerre, and Legendre polynomials. Each of these has an associated *convenience class* available from the *numpy.polynomial* namespace that provides a consistent interface for working with polynomials regardless of their type.

Using the convenience classes

The convenience classes provided by the polynomial package are:

Name	Provides
Polynomial	Power series
Chebyshev	Chebyshev series
Legendre	Legendre series
Laguerre	Laguerre series
Hermite	Hermite series
HermiteE	HermiteE series

The series in this context are finite sums of the corresponding polynomial basis functions multiplied by coefficients. For instance, a power series looks like

$$p(x) = 1 + 2x + 3x^2$$

and has coefficients $[1, 2, 3]$. The Chebyshev series with the same coefficients looks like

$$p(x) = 1T_0(x) + 2T_1(x) + 3T_2(x)$$

and more generally

$$p(x) = \sum_{i=0}^{n} c_i T_i(x)$$

where in this case the T_n are the Chebyshev functions of degree n, but could just as easily be the basis functions of any of the other classes. The convention for all the classes is that the coefficient $c[i]$ goes with the basis function of degree i.

All of the classes are immutable and have the same methods, and especially they implement the Python numeric operators +, -, *, //, %, divmod, **, ==, and !=. The last two can be a bit problematic due to floating point roundoff errors. We now give a quick demonstration of the various operations using NumPy version 1.7.0.

Basics

First we need a polynomial class and a polynomial instance to play with. The classes can be imported directly from the polynomial package or from the module of the relevant type. Here we import from the package and use the conventional Polynomial class because of its familiarity:

```
>>> from numpy.polynomial import Polynomial as P
>>> p = P([1,2,3])
>>> p
Polynomial([1., 2., 3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

Note that there are three parts to the long version of the printout. The first is the coefficients, the second is the domain, and the third is the window:

```
>>> p.coef
array([1., 2., 3.])
>>> p.domain
array([-1.,  1.])
>>> p.window
array([-1.,  1.])
```

Printing a polynomial yields the polynomial expression in a more familiar format:

```
>>> print(p)
1.0 + 2.0·x + 3.0·x²
```

Note that the string representation of polynomials uses Unicode characters by default (except on Windows) to express powers and subscripts. An ASCII-based representation is also available (default on Windows). The polynomial string format can be toggled at the package-level with the *set_default_printstyle* function:

```
>>> np.polynomial.set_default_printstyle('ascii')
>>> print(p)
1.0 + 2.0 x + 3.0 x**2
```

or controlled for individual polynomial instances with string formatting:

```
>>> print(f"{p:unicode}")
1.0 + 2.0·x + 3.0·x²
```

We will deal with the domain and window when we get to fitting, for the moment we ignore them and run through the basic algebraic and arithmetic operations.

Addition and Subtraction:

```
>>> p + p
Polynomial([2., 4., 6.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> p - p
Polynomial([0.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

Multiplication:

```
>>> p * p
Polynomial([ 1.,  4.,  10.,  12.,  9.], domain=[-1.,  1.], window=[-1.,  1.],␣
↪symbol='x')
```

Powers:

```
>>> p**2
Polynomial([ 1.,  4., 10., 12.,  9.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x
↪')
```

Division:

Floor division, '//', is the division operator for the polynomial classes, polynomials are treated like integers in this regard. For Python versions < 3.x the '/' operator maps to '//', as it does for Python, for later versions the '/' will only work for division by scalars. At some point it will be deprecated:

```
>>> p // P([-1, 1])
Polynomial([5.,  3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

Remainder:

```
>>> p % P([-1, 1])
Polynomial([6.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

Divmod:

```
>>> quo, rem = divmod(p, P([-1, 1]))
>>> quo
Polynomial([5.,  3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> rem
Polynomial([6.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

Evaluation:

```
>>> x = np.arange(5)
>>> p(x)
array([  1.,   6.,  17.,  34.,  57.])
>>> x = np.arange(6).reshape(3,2)
>>> p(x)
array([[ 1.,   6.],
       [17.,  34.],
       [57.,  86.]])
```

Substitution:

Substitute a polynomial for x and expand the result. Here we substitute p in itself leading to a new polynomial of degree 4 after expansion. If the polynomials are regarded as functions this is composition of functions:

```
>>> p(p)
Polynomial([ 6., 16., 36., 36., 27.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x
↪')
```

Roots:

```
>>> p.roots()
array([-0.33333333-0.47140452j, -0.33333333+0.47140452j])
```

It isn't always convenient to explicitly use Polynomial instances, so tuples, lists, arrays, and scalars are automatically cast in the arithmetic operations:

```
>>> p + [1, 2, 3]
Polynomial([2., 4., 6.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> [1, 2, 3] * p
Polynomial([ 1.,  4., 10., 12.,  9.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x
↪')
>>> p / 2
Polynomial([0.5, 1. , 1.5], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

Polynomials that differ in domain, window, or class can't be mixed in arithmetic:

```
>>> from numpy.polynomial import Chebyshev as T
>>> p + P([1], domain=[0,1])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 213, in __add__
TypeError: Domains differ
>>> p + P([1], window=[0,1])
Traceback (most recent call last):
```

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```
  File "<stdin>", line 1, in <module>
  File "<string>", line 215, in __add__
TypeError: Windows differ
>>> p + T([1])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 211, in __add__
TypeError: Polynomial types differ
```

But different types can be used for substitution. In fact, this is how conversion of Polynomial classes among themselves is done for type, domain, and window casting:

```
>>> p(T([0, 1]))
Chebyshev([2.5, 2. , 1.5], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

Which gives the polynomial *p* in Chebyshev form. This works because $T_1(x) = x$ and substituting x for x doesn't change the original polynomial. However, all the multiplications and divisions will be done using Chebyshev series, hence the type of the result.

It is intended that all polynomial instances are immutable, therefore augmented operations (+=, −=, etc.) and any other functionality that would violate the immutablity of a polynomial instance are intentionally unimplemented.

Calculus

Polynomial instances can be integrated and differentiated.:

```
>>> from numpy.polynomial import Polynomial as P
>>> p = P([2, 6])
>>> p.integ()
Polynomial([0., 2., 3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> p.integ(2)
Polynomial([0., 0., 1., 1.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

The first example integrates *p* once, the second example integrates it twice. By default, the lower bound of the integration and the integration constant are 0, but both can be specified.:

```
>>> p.integ(lbnd=-1)
Polynomial([-1.,  2.,  3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> p.integ(lbnd=-1, k=1)
Polynomial([0., 2., 3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

In the first case the lower bound of the integration is set to -1 and the integration constant is 0. In the second the constant of integration is set to 1 as well. Differentiation is simpler since the only option is the number of times the polynomial is differentiated:

```
>>> p = P([1, 2, 3])
>>> p.deriv(1)
Polynomial([2., 6.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> p.deriv(2)
Polynomial([6.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
```

Other polynomial constructors

Constructing polynomials by specifying coefficients is just one way of obtaining a polynomial instance, they may also be created by specifying their roots, by conversion from other polynomial types, and by least squares fits. Fitting is discussed in its own section, the other methods are demonstrated below:

```
>>> from numpy.polynomial import Polynomial as P
>>> from numpy.polynomial import Chebyshev as T
>>> p = P.fromroots([1, 2, 3])
>>> p
Polynomial([-6., 11., -6.,  1.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> p.convert(kind=T)
Chebyshev([-9.  , 11.75, -3.  ,  0.25], domain=[-1.,  1.], window=[-1.,  1.], symbol=
↪'x')
```

The convert method can also convert domain and window:

```
>>> p.convert(kind=T, domain=[0, 1])
Chebyshev([-2.4375 ,  2.96875, -0.5625 ,  0.03125], domain=[0.,  1.], window=[-1.,  1.
↪], symbol='x')
>>> p.convert(kind=P, domain=[0, 1])
Polynomial([-1.875,  2.875, -1.125,  0.125], domain=[0.,  1.], window=[-1.,  1.],␣
↪symbol='x')
```

In numpy versions >= 1.7.0 the *basis* and *cast* class methods are also available. The cast method works like the convert method while the basis method returns the basis polynomial of given degree:

```
>>> P.basis(3)
Polynomial([0., 0., 0., 1.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> T.cast(p)
Chebyshev([-9.  , 11.75, -3. ,  0.25], domain=[-1.,  1.], window=[-1.,  1.], symbol='x
↪')
```

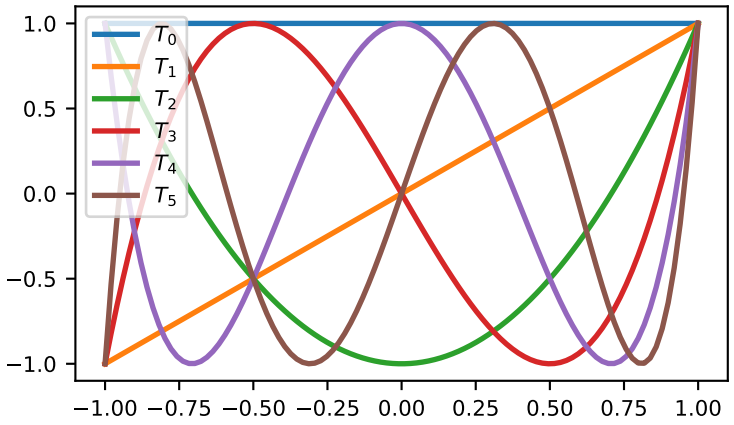
Conversions between types can be useful, but it is *not* recommended for routine use. The loss of numerical precision in passing from a Chebyshev series of degree 50 to a Polynomial series of the same degree can make the results of numerical evaluation essentially random.

Fitting

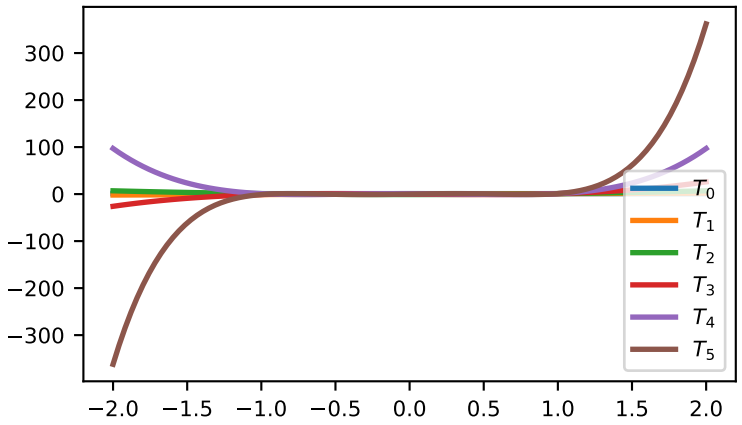
Fitting is the reason that the *domain* and *window* attributes are part of the convenience classes. To illustrate the problem, the values of the Chebyshev polynomials up to degree 5 are plotted below.

```
>>> import matplotlib.pyplot as plt
>>> from numpy.polynomial import Chebyshev as T
>>> x = np.linspace(-1, 1, 100)
>>> for i in range(6):
...     ax = plt.plot(x, T.basis(i)(x), lw=2, label=f"$T_{i}$")
...
>>> plt.legend(loc="upper left")
>>> plt.show()
```

In the range -1 <= *x* <= 1 they are nice, equiripple functions lying between +/- 1. The same plots over the range -2 <= *x* <= 2 look very different:



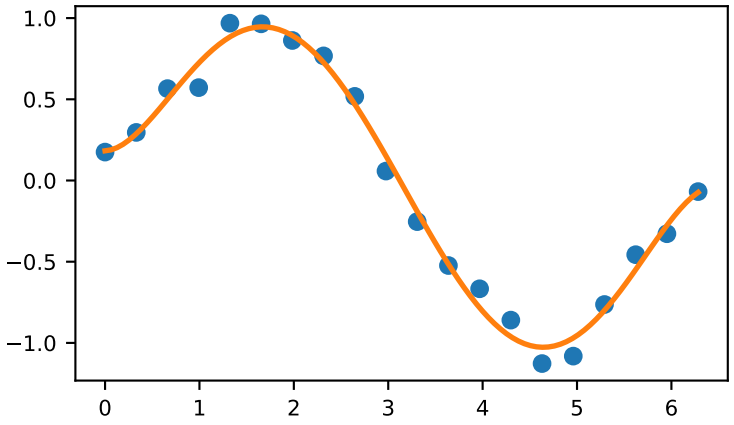

```
>>> import matplotlib.pyplot as plt
>>> from numpy.polynomial import Chebyshev as T
>>> x = np.linspace(-2, 2, 100)
>>> for i in range(6):
...     ax = plt.plot(x, T.basis(i)(x), lw=2, label=f"$T_{i}$")
...
>>> plt.legend(loc="lower right")
>>> plt.show()
```



As can be seen, the “good” parts have shrunk to insignificance. In using Chebyshev polynomials for fitting we want to use the region where *x* is between -1 and 1 and that is what the *window* specifies. However, it is unlikely that the data to be fit has all its data points in that interval, so we use *domain* to specify the interval where the data points lie. When the fit is done, the domain is first mapped to the window by a linear transformation and the usual least squares fit is done using the mapped data points. The window and domain of the fit are part of the returned series and are automatically used when computing values, derivatives, and such. If they aren’t specified in the call the fitting routine will use the default window

and the smallest domain that holds all the data points. This is illustrated below for a fit to a noisy sine curve.

```
>>> import numpy as np
>>> import matplotlib.pyplot as plt
>>> from numpy.polynomial import Chebyshev as T
>>> np.random.seed(11)
>>> x = np.linspace(0, 2*np.pi, 20)
>>> y = np.sin(x) + np.random.normal(scale=.1, size=x.shape)
>>> p = T.fit(x, y, 5)
>>> plt.plot(x, y, 'o')
>>> xx, yy = p.linspace()
>>> plt.plot(xx, yy, lw=2)
>>> p.domain
array([0.        , 6.28318531])
>>> p.window
array([-1.,  1.])
>>> plt.show()
```



Documentation pertaining to specific functions defined for each kind of polynomial individually can be found in the corresponding module documentation:

Power Series (`numpy.polynomial.polynomial`)

This module provides a number of objects (mostly functions) useful for dealing with polynomials, including a *Polynomial* class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with polynomial objects is in the docstring for its "parent" sub-package, *numpy.polynomial*).

Classes

Polynomial(coef[, domain, window, symbol])	A power series class.

class numpy.polynomial.polynomial.**Polynomial**(*coef*, *domain=None*, *window=None*, *symbol='x'*)

A power series class.

The Polynomial class provides the standard Python numerical methods '+', '-', '*', '//', '%', 'divmod', '**', and '()' as well as the attributes and methods listed below.

Parameters

coef
[array_like] Polynomial coefficients in order of increasing degree, i.e., `(1, 2, 3)` give `1 + 2*x + 3*x**2`.

domain
[(2,) array_like, optional] Domain to use. The interval `[domain[0], domain[1]]` is mapped to the interval `[window[0], window[1]]` by shifting and scaling. The default value is [-1., 1.].

window
[(2,) array_like, optional] Window, see `domain` for its use. The default value is [-1., 1.].

symbol
[str, optional] Symbol used to represent the independent variable in string representations of the polynomial expression, e.g. for printing. The symbol must be a valid Python identifier. Default value is 'x'.

New in version 1.24.

Attributes

basis_name
symbol

Methods

`__call__`(arg)	Call self as a function.
`basis`(deg[, domain, window, symbol])	Series basis polynomial of degree *deg*.
`cast`(series[, domain, window])	Convert series to series of this class.
`convert`([domain, kind, window])	Convert series to a different kind and/or domain and/or window.
`copy`()	Return a copy.
`cutdeg`(deg)	Truncate series to the given degree.
`degree`()	The degree of the series.
`deriv`([m])	Differentiate.
`fit`(x, y, deg[, domain, rcond, full, w, ...])	Least squares fit to data.
`fromroots`(roots[, domain, window, symbol])	Return series instance that has the specified roots.
`has_samecoef`(other)	Check if coefficients match.
`has_samedomain`(other)	Check if domains match.
`has_sametype`(other)	Check if types match.
`has_samewindow`(other)	Check if windows match.
`identity`([domain, window, symbol])	Identity function.
`integ`([m, k, lbnd])	Integrate.
`linspace`([n, domain])	Return x, y values at equally spaced points in domain.
`mapparms`()	Return the mapping parameters.
`roots`()	Return the roots of the series polynomial.
`trim`([tol])	Remove trailing coefficients
`truncate`(size)	Truncate series to length *size*.

method

polynomial.polynomial.Polynomial.**__call__**(*arg*)

Call self as a function.

method

classmethod polynomial.polynomial.Polynomial.**basis**(*deg*, *domain=None*, *window=None*, *symbol='x'*)

Series basis polynomial of degree *deg*.

Returns the series representing the basis polynomial of degree *deg*.

Parameters

deg
[int] Degree of the basis polynomial for the series. Must be >= 0.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series with the coefficient of the *deg* term set to one and all others zero.

method

classmethod polynomial.polynomial.Polynomial.**cast**(*series*, *domain=None*, *window=None*)

Convert series to series of this class.

The *series* is expected to be an instance of some polynomial series of one of the types supported by by the numpy.polynomial module, but could be some other class that supports the convert method.

Parameters

series
[series] The series instance to be converted.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series
[series] A series of the same kind as the calling class and equal to *series* when evaluated.

See also:

convert
similar instance method

method

polynomial.polynomial.Polynomial.**convert**(*domain=None*, *kind=None*, *window=None*)

Convert series to a different kind and/or domain and/or window.

Parameters

domain
[array_like, optional] The domain of the converted series. If the value is None, the default domain of *kind* is used.

kind
[class, optional] The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

window
[array_like, optional] The window of the converted series. If the value is None, the default window of *kind* is used.

Returns

new_series
[series] The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes

Conversion between domains and class types can result in numerically ill defined series.

method

polynomial.polynomial.Polynomial.**copy**()

Return a copy.

Returns

new_series
[series] Copy of self.

method

polynomial.polynomial.Polynomial.**cutdeg**(*deg*)

Truncate series to the given degree.

Reduce the degree of the series to *deg* by discarding the high order terms. If *deg* is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

deg
[non-negative int] The series is reduced to degree *deg* by discarding the high order terms. The value of *deg* must be a non-negative integer.

Returns

new_series
[series] New instance of series with reduced degree.

method

polynomial.polynomial.Polynomial.**degree**()

The degree of the series.

Returns

degree
[int] Degree of the series, one less than the number of coefficients.

Examples

Create a polynomial object for `1 + 7*x + 4*x**2`:

```
>>> poly = np.polynomial.Polynomial([1, 7, 4])
>>> print(poly)
1.0 + 7.0·x + 4.0·x²
>>> poly.degree()
2
```

Note that this method does not check for non-zero coefficients. You must trim the polynomial to remove any trailing zeroes:

```
>>> poly = np.polynomial.Polynomial([1, 7, 0])
>>> print(poly)
1.0 + 7.0·x + 0.0·x²
```

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```
>>> poly.degree()
2
>>> poly.trim().degree()
1
```

method

polynomial.polynomial.Polynomial.**deriv**(*m=1*)

Differentiate.

Return a series instance of that is the derivative of the current series.

Parameters

m
[non-negative int] Find the derivative of order *m*.

Returns

new_series
[series] A new series representing the derivative. The domain is the same as the domain of the differentiated series.

method

classmethod polynomial.polynomial.Polynomial.**fit**(*x*, *y*, *deg*, *domain=None*, *rcond=None*, *full=False*, *w=None*, *window=None*, *symbol='x'*)

Least squares fit to data.

Return a series instance that is the least squares fit to the data *y* sampled at *x*. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,)] y-coordinates of the M sample points `(x[i], y[i])`.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

domain
[{None, [beg, end], []}, optional] Domain to use for the returned series. If `None`, then a minimal domain that covers the points *x* is chosen. If `[]` the class domain is used. The default value was the class domain in NumPy 1.4 and `None` in later versions. The `[]` option was added in numpy 1.5.0.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is `len(x)*eps`, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (M,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

window
[{[beg, end]}, optional] Window to use for the returned series. The default value is the default class domain

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series that represents the least squares fit to the data and has the domain and window specified in the call. If the coefficients for the unscaled and unshifted basis polynomials are of interest, do `new_series.convert().coef`.

[resid, rank, sv, rcond]
[list] These values are only returned if `full == True`

- resid – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- sv – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *linalg.lstsq*.

method

classmethod polynomial.polynomial.Polynomial.**fromroots**(*roots*, *domain=[]*, *window=None*, *symbol='x'*)

Return series instance that has the specified roots.

Returns a series representing the product `(x - r[0])*(x - r[1])*...*(x - r[n-1])`, where `r` is a list of roots.

Parameters

roots
[array_like] List of roots.

domain
[{[], None, array_like}, optional] Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [] the domain is the class domain. The default is [].

window
[{None, array_like}, optional] Window for the returned series. If None the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series with the specified roots.

method

polynomial.polynomial.Polynomial.**has_samecoef**(*other*)

Check if coefficients match.

Parameters

other
[class instance] The other class must have the `coef` attribute.

Returns

bool
[boolean] True if the coefficients are the same, False otherwise.

method

polynomial.polynomial.Polynomial.**has_samedomain**(*other*)

Check if domains match.

Parameters

other
[class instance] The other class must have the `domain` attribute.

Returns

bool
[boolean] True if the domains are the same, False otherwise.

method

polynomial.polynomial.Polynomial.**has_sametype**(*other*)

Check if types match.

Parameters

other
[object] Class instance.

Returns

bool
[boolean] True if other is same class as self

method

polynomial.polynomial.Polynomial.**has_samewindow**(*other*)

Check if windows match.

Parameters

other
[class instance] The other class must have the `window` attribute.

Returns

bool
[boolean] True if the windows are the same, False otherwise.

method

classmethod polynomial.polynomial.Polynomial.**identity**(*domain=None*, *window=None*, *symbol='x'*)

Identity function.

If `p` is the returned series, then `p(x) == x` for all values of x.

Parameters

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series of representing the identity.

method

polynomial.polynomial.Polynomial.**integ**(*m=1*, *k=[]*, *lbnd=None*)

Integrate.

Return a series instance that is the definite integral of the current series.

Parameters

m
[non-negative int] The number of integrations to perform.

k
[array_like] Integration constants. The first constant is applied to the first integration, the second to the second, and so on. The list of values must less than or equal to *m* in length and any missing values are set to zero.

lbnd
[Scalar] The lower bound of the definite integral.

Returns

new_series
[series] A new series representing the integral. The domain is the same as the domain of the integrated series.

method

polynomial.polynomial.Polynomial.**linspace**(*n=100*, *domain=None*)

Return x, y values at equally spaced points in domain.

Returns the x, y values at *n* linearly spaced points across the domain. Here y is the value of the polynomial at the points x. By default the domain is the same as that of the series instance. This method is intended mostly as a plotting aid.

Parameters

n
[int, optional] Number of point pairs to return. The default value is 100.

domain
[{None, array_like}, optional] If not None, the specified domain is used instead of that of the calling instance. It should be of the form `[beg,end]`. The default is None which case the class domain is used.

Returns

x, y
[ndarray] x is equal to linspace(self.domain[0], self.domain[1], n) and y is the series evaluated at element of x.

method

`polynomial.polynomial.Polynomial.`**`mapparms`**`()`

Return the mapping parameters.

The returned values define a linear map `off + scl*x` that is applied to the input arguments before the series is evaluated. The map depends on the `domain` and `window`; if the current `domain` is equal to the `window` the resulting map is the identity. If the coefficients of the series instance are to be used by themselves outside this class, then the linear function must be substituted for the `x` in the standard representation of the base polynomials.

Returns

off, scl
[float or complex] The mapping function is defined by `off + scl*x`.

Notes

If the current domain is the interval `[l1, r1]` and the window is `[l2, r2]`, then the linear mapping function `L` is defined by the equations:

```
L(l1) = l2
L(r1) = r2
```

method

`polynomial.polynomial.Polynomial.`**`roots`**`()`

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decreases the further outside the `domain` they lie.

Returns

roots
[ndarray] Array containing the roots of the series.

method

`polynomial.polynomial.Polynomial.`**`trim`**`(`*`tol=0`*`)`

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than *tol* or the beginning of the series is reached. If all the coefficients would be removed the series is set to `[0]`. A new series instance is returned with the new coefficients. The current instance remains unchanged.

Parameters

tol
[non-negative number.] All trailing coefficients less than *tol* will be removed.

Returns

new_series
[series] New instance of series with trimmed coefficients.

method

polynomial.polynomial.Polynomial.**truncate**(*size*)

Truncate series to length *size*.

Reduce the series to length *size* by discarding the high degree terms. The value of *size* must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

size
[positive int] The series is reduced to length *size* by discarding the high degree terms. The value of *size* must be a positive integer.

Returns

new_series
[series] New instance of series with truncated coefficients.

Constants

polydomain	An array object represents a multidimensional, homogeneous array of fixed-size items.
polyzero	An array object represents a multidimensional, homogeneous array of fixed-size items.
polyone	An array object represents a multidimensional, homogeneous array of fixed-size items.
polyx	An array object represents a multidimensional, homogeneous array of fixed-size items.

polynomial.polynomial.**polydomain = array([-1., 1.])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.polynomial.`**`polyzero = array([0])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
: [tuple of ints] Shape of created array.

dtype
: [data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
: [object exposing buffer interface, optional] Used to fill the array with data.

offset
: [int, optional] Offset of array data in buffer.

strides
: [tuple of ints, optional] Strides of data in memory.

order
: [{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
: Construct an array.

zeros
: Create an array, each element of which is zero.

empty
: Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
: Create a data-type.

numpy.typing.NDArray
: An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

polynomial.polynomial.**polyone = array([1])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For

example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.polynomial.`**`polyx = array([0, 1])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *`array`*, *`zeros`* or *`empty`* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *`numpy`* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

`array`
Construct an array.

`zeros`
Create an array, each element of which is zero.

`empty`
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

`dtype`
Create a data-type.

`numpy.typing.NDArray`
An ndarray alias generic w.r.t. its *`dtype.type`*.

Notes

There are two modes of creating an array using `__new__`:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No `__init__` method is needed because the array is fully initialized after the `__new__` method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
: [ndarray] Transpose of the array.

data
: [buffer] The array's elements, in memory.

dtype
: [dtype object] Describes the format of the elements in the array.

flags
: [dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
: [numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
: [ndarray] Imaginary part of the array.

real
: [ndarray] Real part of the array.

size
: [int] Number of elements in the array.

itemsize
: [int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

Arithmetic

polyadd(c1, c2)	Add one polynomial to another.
polysub(c1, c2)	Subtract one polynomial from another.
polymulx(c)	Multiply a polynomial by x.
polymul(c1, c2)	Multiply one polynomial by another.
polydiv(c1, c2)	Divide one polynomial by another.
polypow(c, pow[, maxpower])	Raise a polynomial to a power.
polyval(x, c[, tensor])	Evaluate a polynomial at points x.
polyval2d(x, y, c)	Evaluate a 2-D polynomial at points (x, y).
polyval3d(x, y, z, c)	Evaluate a 3-D polynomial at points (x, y, z).
polygrid2d(x, y, c)	Evaluate a 2-D polynomial on the Cartesian product of x and y.
polygrid3d(x, y, z, c)	Evaluate a 3-D polynomial on the Cartesian product of x, y and z.

polynomial.polynomial.**polyadd**(*c1*, *c2*)

Add one polynomial to another.

Returns the sum of two polynomials *c1* + *c2*. The arguments are sequences of coefficients from lowest order term to highest, i.e., [1,2,3] represents the polynomial `1 + 2*x + 3*x**2`.

Parameters

c1, c2
[array_like] 1-D arrays of polynomial coefficients ordered from low to high.

Returns

out
[ndarray] The coefficient array representing their sum.

See also:

polysub, ***polymulx***, ***polymul***, ***polydiv***, ***polypow***

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c1 = (1, 2, 3)
>>> c2 = (3, 2, 1)
>>> sum = P.polyadd(c1,c2); sum
array([4.,  4.,  4.])
>>> P.polyval(2, sum)  # 4 + 4(2) + 4(2**2)
28.0
```

polynomial.polynomial.**polysub**(*c1*, *c2*)

Subtract one polynomial from another.

Returns the difference of two polynomials *c1* - *c2*. The arguments are sequences of coefficients from lowest order term to highest, i.e., [1,2,3] represents the polynomial `1 + 2*x + 3*x**2`.

Parameters

c1, c2
[array_like] 1-D arrays of polynomial coefficients ordered from low to high.

Returns

out
[ndarray] Of coefficients representing their difference.

See also:

polyadd, ***polymulx***, ***polymul***, ***polydiv***, ***polypow***

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c1 = (1, 2, 3)
>>> c2 = (3, 2, 1)
>>> P.polysub(c1,c2)
array([-2.,  0.,  2.])
>>> P.polysub(c2, c1)  # -P.polysub(c1,c2)
array([ 2.,  0., -2.])
```

polynomial.polynomial.**polymulx**(*c*)

Multiply a polynomial by x.

Multiply the polynomial *c* by x, where x is the independent variable.

Parameters

c
[array_like] 1-D array of polynomial coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the result of the multiplication.

See also:

polyadd, ***polysub***, ***polymul***, ***polydiv***, ***polypow***

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c = (1, 2, 3)
>>> P.polymulx(c)
array([0., 1., 2., 3.])
```

polynomial.polynomial.**polymul**(*c1*, *c2*)

Multiply one polynomial by another.

Returns the product of two polynomials *c1* * *c2*. The arguments are sequences of coefficients, from lowest order term to highest, e.g., [1,2,3] represents the polynomial `1 + 2*x + 3*x**2`.

Parameters

c1, c2
[array_like] 1-D arrays of coefficients representing a polynomial, relative to the "standard" basis, and ordered from lowest order term to highest.

Returns

out
[ndarray] Of the coefficients of their product.

See also:

polyadd, ***polysub***, ***polymulx***, ***polydiv***, ***polypow***

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c1 = (1, 2, 3)
>>> c2 = (3, 2, 1)
>>> P.polymul(c1, c2)
array([  3.,   8.,  14.,   8.,   3.])
```

polynomial.polynomial.**polydiv**(*c1*, *c2*)

Divide one polynomial by another.

Returns the quotient-with-remainder of two polynomials *c1* / *c2*. The arguments are sequences of coefficients, from lowest order term to highest, e.g., [1,2,3] represents `1 + 2*x + 3*x**2`.

Parameters

c1, c2
[array_like] 1-D arrays of polynomial coefficients ordered from low to high.

Returns

[quo, rem]
[ndarrays] Of coefficient series representing the quotient and remainder.

See also:

polyadd, ***polysub***, ***polymulx***, ***polymul***, ***polypow***

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c1 = (1, 2, 3)
>>> c2 = (3, 2, 1)
>>> P.polydiv(c1, c2)
(array([3.]), array([-8., -4.]))
>>> P.polydiv(c2, c1)
(array([ 0.33333333]), array([ 2.66666667,  1.33333333]))  # may vary
```

polynomial.polynomial.**polypow**(*c*, *pow*, *maxpower=None*)

Raise a polynomial to a power.

Returns the polynomial *c* raised to the power *pow*. The argument *c* is a sequence of coefficients ordered from low to high. i.e., [1,2,3] is the series `1 + 2*x + 3*x**2`.

Parameters

c
[array_like] 1-D array of array of series coefficients ordered from low to high degree.

pow
[integer] Power to which the series will be raised

maxpower
[integer, optional] Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

Returns

coef
[ndarray] Power series of power.

See also:

polyadd, ***polysub***, ***polymulx***, ***polymul***, ***polydiv***

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> P.polypow([1, 2, 3], 2)
array([ 1.,  4., 10., 12.,  9.])
```

polynomial.polynomial.**polyval**(*x*, *c*, *tensor=True*)

Evaluate a polynomial at points x.

If *c* is of length `n + 1`, this function returns the value

$$p(x) = c_0 + c_1 * x + ... + c_n * x^n$$

The parameter *x* is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either *x* or its elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array, then `p(x)` will have the same shape as *x*. If *c* is multidimensional, then the shape of the result depends on the value of *tensor*. If *tensor* is true the shape will be c.shape[1:] + x.shape. If *tensor* is false the shape will be c.shape[1:]. Note that scalars have shape (,).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

Parameters

x
: [array_like, compatible object] If *x* is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, *x* or its elements must support addition and multiplication with with themselves and with the elements of *c*.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree n are contained in c[n]. If *c* is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of *c*.

tensor
: [boolean, optional] If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of *x*. Scalars have dimension 0 for this action. The result is that every column of coefficients in *c* is evaluated for every element of *x*. If False, *x* is broadcast over the columns of *c* for the evaluation. This keyword is useful when *c* is multidimensional. The default value is True.

Returns

values
: [ndarray, compatible object] The shape of the returned array is described above.

See also:

polyval2d, ***polygrid2d***, ***polyval3d***, ***polygrid3d***

Notes

The evaluation uses Horner's method.

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.polynomial import polyval
>>> polyval(1, [1,2,3])
6.0
>>> a = np.arange(4).reshape(2,2)
>>> a
array([[0, 1],
       [2, 3]])
>>> polyval(a, [1, 2, 3])
array([[ 1.,   6.],
       [17.,  34.]])
>>> coef = np.arange(4).reshape(2, 2)  # multidimensional coefficients
>>> coef
array([[0, 1],
       [2, 3]])
>>> polyval([1, 2], coef, tensor=True)
array([[2.,  4.],
       [4.,  7.]])
>>> polyval([1, 2], coef, tensor=False)
array([2.,  7.])
```

polynomial.polynomial.**polyval2d**(*x*, *y*, *c*)

Evaluate a 2-D polynomial at points (x, y).

This function returns the value

$$p(x,y) = \sum_{i,j} c_{i,j} * x^i * y^j$$

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

Parameters

x, y
: [array_like, compatible objects] The two dimensional series is evaluated at the points `(x, y)`, where *x* and *y* must have the same shape. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points formed with pairs of corresponding values from *x* and *y*.

See also:

polyval, ***polygrid2d***, ***polyval3d***, ***polygrid3d***

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c = ((1, 2, 3), (4, 5, 6))
>>> P.polyval2d(1, 1, c)
21.0
```

polynomial.polynomial.**polyval3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D polynomial at points (x, y, z).

This function returns the values:

$$p(x,y,z) = \sum_{i,j,k} c_{i,j,k} * x^i * y^j * z^k$$

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape.

Parameters

x, y, z
: [array_like, compatible object] The three dimensional series is evaluated at the points `(x, y, z)`, where *x*, *y*, and *z* must have the same shape. If any of *x*, *y*, or *z* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j,k is contained in `c[i,j,k]`. If *c* has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the multidimensional polynomial on points formed with triples of corresponding values from *x*, *y*, and *z*.

See also:

polyval, ***polyval2d***, ***polygrid2d***, ***polygrid3d***

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c = ((1, 2, 3), (4, 5, 6), (7, 8, 9))
>>> P.polyval3d(1, 1, 1, c)
45.0
```

`polynomial.polynomial.`**`polygrid2d`**(*x*, *y*, *c*)

Evaluate a 2-D polynomial on the Cartesian product of x and y.

This function returns the values:

$$p(a,b) = \sum_{i,j} c_{i,j} * a^i * b^j$$

where the points `(a, b)` consist of all pairs formed by taking *a* from *x* and *b* from *y*. The resulting points form a grid with *x* in the first dimension and *y* in the second.

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape + y.shape.

Parameters

x, y
: [array_like, compatible objects] The two dimensional series is evaluated at the points in the Cartesian product of *x* and *y*. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points in the Cartesian product of x and y.

See also:

polyval, *polyval2d*, *polyval3d*, *polygrid3d*

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c = ((1, 2, 3), (4, 5, 6))
>>> P.polygrid2d([0, 1], [0, 1], c)
array([[ 1.,  6.],
       [ 5., 21.]])
```

polynomial.polynomial.**polygrid3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D polynomial on the Cartesian product of x, y and z.

This function returns the values:

$$p(a,b,c) = \sum_{i,j,k} c_{i,j,k} * a^i * b^j * c^k$$

where the points `(a, b, c)` consist of all triples formed by taking a from x, b from y, and c from z. The resulting points form a grid with x in the first dimension, y in the second, and z in the third.

The parameters x, y, and z are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either x, y, and z or their elements must support multiplication and addition both with themselves and with the elements of c.

If c has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape + y.shape + z.shape.

Parameters

x, y, z
: [array_like, compatible objects] The three dimensional series is evaluated at the points in the Cartesian product of x, y, and z. If x, y, or z is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in `c[i,j]`. If c has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points in the Cartesian product of x and y.

See also:

polyval, *polyval2d*, *polygrid2d*, *polyval3d*

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c = ((1, 2, 3), (4, 5, 6), (7, 8, 9))
>>> P.polygrid3d([0, 1], [0, 1], [0, 1], c)
array([[ 1., 13.],
       [ 6., 51.]])
```

Calculus

polyder(c[, m, scl, axis])	Differentiate a polynomial.
polyint(c[, m, k, lbnd, scl, axis])	Integrate a polynomial.

polynomial.polynomial.**polyder**(*c*, *m=1*, *scl=1*, *axis=0*)

Differentiate a polynomial.

Returns the polynomial coefficients *c* differentiated *m* times along *axis*. At each iteration the result is multiplied by *scl* (the scaling factor is for use in a linear change of variable). The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the polynomial `1 + 2*x + 3*x**2` while [[1,2],[1,2]] represents `1 + 1*x + 2*y + 2*x*y` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of polynomial coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Number of derivatives taken, must be non-negative. (Default: 1)

scl
: [scalar, optional] Each differentiation is multiplied by *scl*. The end result is multiplication by `scl**m`. This is for use in a linear change of variable. (Default: 1)

axis
: [int, optional] Axis over which the derivative is taken. (Default: 0).

Returns

der
: [ndarray] Polynomial coefficients of the derivative.

See also:

polyint

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c = (1, 2, 3, 4)
>>> P.polyder(c)  # (d/dx)(c)
array([  2.,   6.,  12.])
>>> P.polyder(c, 3)  # (d**3/dx**3)(c)
array([24.])
>>> P.polyder(c, scl=-1)  # (d/d(-x))(c)
array([ -2.,  -6., -12.])
>>> P.polyder(c, 2, -1)  # (d**2/d(-x)**2)(c)
array([  6.,  24.])
```

polynomial.polynomial.**polyint**(*c*, *m=1*, *k=[]*, *lbnd=0*, *scl=1*, *axis=0*)

Integrate a polynomial.

Returns the polynomial coefficients *c* integrated *m* times from *lbnd* along *axis*. At each iteration the resulting series is **multiplied** by *scl* and an integration constant, *k*, is added. The scaling factor is for use in a linear change of variable. ("Buyer beware": note that, depending on what one is doing, one may want *scl* to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument *c* is an array of coefficients, from low to high degree along each axis, e.g., [1,2,3] represents the polynomial `1 + 2*x + 3*x**2` while [[1,2],[1,2]] represents `1 + 1*x + 2*y + 2*x*y` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] 1-D array of polynomial coefficients, ordered from low to high.

m
: [int, optional] Order of integration, must be positive. (Default: 1)

k
: [{[], list, scalar}, optional] Integration constant(s). The value of the first integral at zero is the first value in the list, the value of the second integral at zero is the second value, etc. If `k == []` (the default), all constants are set to zero. If `m == 1`, a single scalar can be given instead of a list.

lbnd
: [scalar, optional] The lower bound of the integral. (Default: 0)

scl
: [scalar, optional] Following each integration the result is *multiplied* by *scl* before the integration constant is added. (Default: 1)

axis
: [int, optional] Axis over which the integral is taken. (Default: 0).

Returns

S
: [ndarray] Coefficient array of the integral.

Raises

ValueError
: If `m < 1`, `len(k) > m`, `np.ndim(lbnd) != 0`, or `np.ndim(scl) != 0`.

See also:

polyder

Notes

Note that the result of each integration is *multiplied* by *scl*. Why is this important to note? Say one is making a linear change of variable $u = ax + b$ in an integral relative to x. Then $dx = du/a$, so one will need to set *scl* equal to $1/a$ - perhaps not what one would have first thought.

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c = (1, 2, 3)
>>> P.polyint(c)  # should return array([0, 1, 1, 1])
array([0.,  1.,  1.,  1.])
>>> P.polyint(c, 3)  # should return array([0, 0, 0, 1/6, 1/12, 1/20])
 array([ 0.        ,  0.        ,  0.        ,  0.16666667,  0.08333333, # may␣
↪vary
         0.05      ])
>>> P.polyint(c, k=3)  # should return array([3, 1, 1, 1])
array([3.,  1.,  1.,  1.])
>>> P.polyint(c,lbnd=-2)  # should return array([6, 1, 1, 1])
array([6.,  1.,  1.,  1.])
>>> P.polyint(c,scl=-2)  # should return array([0, -2, -2, -2])
array([ 0., -2., -2., -2.])
```

Misc Functions

polyfromroots(roots)	Generate a monic polynomial with given roots.
polyroots(c)	Compute the roots of a polynomial.
polyvalfromroots(x, r[, tensor])	Evaluate a polynomial specified by its roots at points x.
polyvander(x, deg)	Vandermonde matrix of given degree.
polyvander2d(x, y, deg)	Pseudo-Vandermonde matrix of given degrees.
polyvander3d(x, y, z, deg)	Pseudo-Vandermonde matrix of given degrees.
polycompanion(c)	Return the companion matrix of c.
polyfit(x, y, deg[, rcond, full, w])	Least-squares fit of a polynomial to data.
polytrim(c[, tol])	Remove "small" "trailing" coefficients from a polynomial.
polyline(off, scl)	Returns an array representing a linear polynomial.

polynomial.polynomial.**polyfromroots**(*roots*)

Generate a monic polynomial with given roots.

Return the coefficients of the polynomial

$$p(x) = (x - r_0) * (x - r_1) * ... * (x - r_n),$$

where the r_n are the roots specified in *roots*. If a zero has multiplicity n, then it must appear in *roots* n times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then *roots* looks something like [2, 2, 2, 3, 3]. The roots can appear in any order.

If the returned coefficients are *c*, then

$$p(x) = c_0 + c_1 * x + ... + x^n$$

The coefficient of the last term is 1 for monic polynomials in this form.

Parameters

roots
[array_like] Sequence containing the roots.

Returns

out
[ndarray] 1-D array of the polynomial's coefficients If all the roots are real, then *out* is also real, otherwise it is complex. (see Examples below).

See also:

numpy.polynomial.chebyshev.chebfromroots
numpy.polynomial.legendre.legfromroots
numpy.polynomial.laguerre.lagfromroots
numpy.polynomial.hermite.hermfromroots
numpy.polynomial.hermite_e.hermefromroots

Notes

The coefficients are determined by multiplying together linear factors of the form `(x - r_i)`, i.e.

$$p(x) = (x - r_0)(x - r_1)...(x - r_n)$$

where `n == len(roots) - 1`; note that this implies that `1` is always returned for a_n.

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> P.polyfromroots((-1,0,1))  # x(x - 1)(x + 1) = x^3 - x
array([ 0., -1.,  0.,  1.])
>>> j = complex(0,1)
>>> P.polyfromroots((-j,j))  # complex returned, though values are real
array([1.+0.j,  0.+0.j,  1.+0.j])
```

polynomial.polynomial.**polyroots**(*c*)

Compute the roots of a polynomial.

Return the roots (a.k.a. "zeros") of the polynomial

$$p(x) = \sum_i c[i] * x^i.$$

Parameters

c
[1-D array_like] 1-D array of polynomial coefficients.

Returns

out
[ndarray] Array of the roots of the polynomial. If all the roots are real, then *out* is also real, otherwise it is complex.

See also:

numpy.polynomial.chebyshev.chebroots
numpy.polynomial.legendre.legroots
numpy.polynomial.laguerre.lagroots
numpy.polynomial.hermite.hermroots
numpy.polynomial.hermite_e.hermeroots

Notes

The root estimates are obtained as the eigenvalues of the companion matrix, Roots far from the origin of the complex plane may have large errors due to the numerical instability of the power series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton's method.

Examples

```
>>> import numpy.polynomial.polynomial as poly
>>> poly.polyroots(poly.polyfromroots((-1,0,1)))
array([-1.,  0.,  1.])
>>> poly.polyroots(poly.polyfromroots((-1,0,1))).dtype
dtype('float64')
>>> j = complex(0,1)
>>> poly.polyroots(poly.polyfromroots((-j,0,j)))
array([  0.00000000e+00+0.j,   0.00000000e+00+1.j,   2.77555756e-17-1.j])  # may␣
↪vary
```

polynomial.polynomial.**polyvalfromroots**(*x*, *r*, *tensor=True*)

Evaluate a polynomial specified by its roots at points x.

If *r* is of length `N`, this function returns the value

$$p(x) = \prod_{n=1}^{N} (x - r_n)$$

The parameter *x* is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either *x* or its elements must support multiplication and addition both with themselves and with the elements of *r*.

If *r* is a 1-D array, then `p(x)` will have the same shape as *x*. If *r* is multidimensional, then the shape of the result depends on the value of *tensor*. If *tensor* is `True` the shape will be r.shape[1:] + x.shape; that is, each polynomial is evaluated at every value of *x*. If *tensor* is `False`, the shape will be r.shape[1:]; that is, each polynomial is evaluated only for the corresponding broadcast value of *x*. Note that scalars have shape (,).

Parameters

x

[array_like, compatible object] If *x* is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, *x* or its elements must support addition and multiplication with with themselves and with the elements of *r*.

r

[array_like] Array of roots. If *r* is multidimensional the first index is the root index, while the remaining indices enumerate multiple polynomials. For instance, in the two dimensional case the roots of each polynomial may be thought of as stored in the columns of *r*.

tensor
: [boolean, optional] If True, the shape of the roots array is extended with ones on the right, one for each dimension of *x*. Scalars have dimension 0 for this action. The result is that every column of coefficients in *r* is evaluated for every element of *x*. If False, *x* is broadcast over the columns of *r* for the evaluation. This keyword is useful when *r* is multidimensional. The default value is True.

Returns

values
: [ndarray, compatible object] The shape of the returned array is described above.

See also:

polyroots*, *polyfromroots*, *polyval

Examples

```
>>> from numpy.polynomial.polynomial import polyvalfromroots
>>> polyvalfromroots(1, [1, 2, 3])
0.0
>>> a = np.arange(4).reshape(2, 2)
>>> a
array([[0, 1],
       [2, 3]])
>>> polyvalfromroots(a, [-1, 0, 1])
array([[-0.,   0.],
       [ 6.,  24.]])
>>> r = np.arange(-2, 2).reshape(2,2)  # multidimensional coefficients
>>> r # each column of r defines one polynomial
array([[-2, -1],
       [ 0,  1]])
>>> b = [-2, 1]
>>> polyvalfromroots(b, r, tensor=True)
array([[-0.,  3.],
       [ 3., 0.]])
>>> polyvalfromroots(b, r, tensor=False)
array([-0.,  0.])
```

polynomial.polynomial.**polyvander**(*x*, *deg*)

Vandermonde matrix of given degree.

Returns the Vandermonde matrix of degree *deg* and sample points *x*. The Vandermonde matrix is defined by

$$V[..., i] = x^i,$$

where `0 <= i <= deg`. The leading indices of *V* index the elements of *x* and the last index is the power of *x*.

If *c* is a 1-D array of coefficients of length `n + 1` and *V* is the matrix `V = polyvander(x, n)`, then `np.dot(V, c)` and `polyval(x, c)` are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of polynomials of the same degree and sample points.

Parameters

x
: [array_like] Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If *x* is scalar it is converted to a 1-D array.

deg
[int] Degree of the resulting matrix.

Returns

vander
[ndarray.] The Vandermonde matrix. The shape of the returned matrix is `x.shape + (deg + 1,)`, where the last index is the power of *x*. The dtype will be the same as the converted *x*.

See also:

polyvander2d*, *polyvander3d

Examples

The Vandermonde matrix of degree `deg = 5` and sample points `x = [-1, 2, 3]` contains the element-wise powers of *x* from 0 to 5 as its columns.

```
>>> from numpy.polynomial import polynomial as P
>>> x, deg = [-1, 2, 3], 5
>>> P.polyvander(x=x, deg=deg)
array([[  1.,  -1.,   1.,  -1.,   1.,  -1.],
       [  1.,   2.,   4.,   8.,  16.,  32.],
       [  1.,   3.,   9.,  27.,  81., 243.]])
```

`polynomial.polynomial.`**`polyvander2d`**(*x*, *y*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y)`. The pseudo-Vandermonde matrix is defined by

$$V[..., (deg[1] + 1) * i + j] = x^i * y^j,$$

where `0 <= i <= deg[0]` and `0 <= j <= deg[1]`. The leading indices of *V* index the points `(x, y)` and the last index encodes the powers of *x* and *y*.

If `V = polyvander2d(x, y, [xdeg, ydeg])`, then the columns of *V* correspond to the elements of a 2-D coefficient array *c* of shape (xdeg + 1, ydeg + 1) in the order

$$c_{00}, c_{01}, c_{02}..., c_{10}, c_{11}, c_{12}...$$

and `np.dot(V, c.flat)` and `polyval2d(x, y, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D polynomials of the same degrees and sample points.

Parameters

x, y
[array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
[list of ints] List of maximum degrees of the form [x_deg, y_deg].

Returns

vander2d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0] + 1) * (deg([1] + 1)$. The dtype will be the same as the converted *x* and *y*.

See also:

polyvander, *polyvander3d*, *polyval2d*, *polyval3d*

Examples

```
>>> import numpy as np
```

The 2-D pseudo-Vandermonde matrix of degree `[1, 2]` and sample points `x = [-1, 2]` and `y = [1, 3]` is as follows:

```
>>> from numpy.polynomial import polynomial as P
>>> x = np.array([-1, 2])
>>> y = np.array([1, 3])
>>> m, n = 1, 2
>>> deg = np.array([m, n])
>>> V = P.polyvander2d(x=x, y=y, deg=deg)
>>> V
array([[ 1.,  1.,  1., -1., -1., -1.],
       [ 1.,  3.,  9.,  2.,  6., 18.]])
```

We can verify the columns for any `0 <= i <= m` and `0 <= j <= n`:

```
>>> i, j = 0, 1
>>> V[:, (deg[1]+1)*i + j] == x**i * y**j
array([ True,  True])
```

The (1D) Vandermonde matrix of sample points `x` and degree `m` is a special case of the (2D) pseudo-Vandermonde matrix with `y` points all zero and degree `[m, 0]`.

```
>>> P.polyvander2d(x=x, y=0*x, deg=(m, 0)) == P.polyvander(x=x, deg=m)
array([[ True,  True],
       [ True,  True]])
```

polynomial.polynomial.**polyvander3d**(*x*, *y*, *z*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y, z)`. If *l*, *m*, *n* are the given degrees in *x*, *y*, *z*, then The pseudo-Vandermonde matrix is defined by

$$V[..., (m+1)(n+1)i + (n+1)j + k] = x^i * y^j * z^k,$$

where `0 <= i <= l`, `0 <= j <= m`, and `0 <= j <= n`. The leading indices of *V* index the points `(x, y, z)` and the last index encodes the powers of *x*, *y*, and *z*.

If `V = polyvander3d(x, y, z, [xdeg, ydeg, zdeg])`, then the columns of *V* correspond to the elements of a 3-D coefficient array *c* of shape (xdeg + 1, ydeg + 1, zdeg + 1) in the order

$$c_{000}, c_{001}, c_{002}, ..., c_{010}, c_{011}, c_{012}, ...$$

and `np.dot(V, c.flat)` and `polyval3d(x, y, z, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D polynomials of the same degrees and sample points.

Parameters

x, y, z
: [array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
: [list of ints] List of maximum degrees of the form [x_deg, y_deg, z_deg].

Returns

vander3d
: [ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg([1]+1)*(deg[2]+1)$. The dtype will be the same as the converted *x*, *y*, and *z*.

See also:

polyvander, ***polyvander3d***, ***polyval2d***, ***polyval3d***

Examples

```
>>> import numpy as np
>>> from numpy.polynomial import polynomial as P
>>> x = np.asarray([-1, 2, 1])
>>> y = np.asarray([1, -2, -3])
>>> z = np.asarray([2, 2, 5])
>>> l, m, n = [2, 2, 1]
>>> deg = [l, m, n]
>>> V = P.polyvander3d(x=x, y=y, z=z, deg=deg)
>>> V
array([[  1.,   2.,   1.,   2.,   1.,   2.,  -1.,  -2.,  -1.,
         -2.,  -1.,  -2.,   1.,   2.,   1.,   2.,   1.,   2.],
       [  1.,   2.,  -2.,  -4.,   4.,   8.,   2.,   4.,  -4.,
         -8.,   8.,  16.,   4.,   8.,  -8., -16.,  16.,  32.],
       [  1.,   5.,  -3., -15.,   9.,  45.,   1.,   5.,  -3.,
        -15.,   9.,  45.,   1.,   5.,  -3., -15.,   9.,  45.]])
```

We can verify the columns for any `0 <= i <= l`, `0 <= j <= m`, and `0 <= k <= n`

```
>>> i, j, k = 2, 1, 0
>>> V[:, (m+1)*(n+1)*i + (n+1)*j + k] == x**i * y**j * z**k
array([ True,  True,  True])
```

`polynomial.polynomial.`**`polycompanion`**`(c)`

Return the companion matrix of c.

The companion matrix for power series cannot be made symmetric by scaling the basis, so this function differs from those for the orthogonal polynomials.

Parameters

c
: [array_like] 1-D array of polynomial coefficients ordered from low to high degree.

Returns

mat
: [ndarray] Companion matrix of dimensions (deg, deg).

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> c = (1, 2, 3)
>>> P.polycompanion(c)
array([[ 0.        , -0.33333333],
       [ 1.        , -0.66666667]])
```

polynomial.polynomial.**polyfit**(*x*, *y*, *deg*, *rcond=None*, *full=False*, *w=None*)

Least-squares fit of a polynomial to data.

Return the coefficients of a polynomial of degree *deg* that is the least squares fit to the data values *y* given at points *x*. If *y* is 1-D the returned coefficients will also be 1-D. If *y* is 2-D multiple fits are done, one for each column of *y*, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

$$p(x) = c_0 + c_1 * x + ... + c_n * x^n,$$

where *n* is *deg*.

Parameters

x
: [array_like, shape (*M*,)] x-coordinates of the *M* sample (data) points `(x[i], y[i])`.

y
: [array_like, shape (*M*,) or (*M*, *K*)] y-coordinates of the sample points. Several sets of sample points sharing the same x-coordinates can be (independently) fit with one call to *polyfit* by passing in for *y* a 2-D array that contains one data set per column.

deg
: [int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

rcond
: [float, optional] Relative condition number of the fit. Singular values smaller than *rcond*, relative to the largest singular value, will be ignored. The default value is `len(x)*eps`, where *eps* is the relative precision of the platform's float type, about 2e-16 in most cases.

full
: [bool, optional] Switch determining the nature of the return value. When `False` (the default) just the coefficients are returned; when `True`, diagnostic information from the singular value decomposition (used to solve the fit's matrix equation) is also returned.

w
: [array_like, shape (*M*,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

Returns

coef
: [ndarray, shape (*deg* + 1,) or (*deg* + 1, *K*)] Polynomial coefficients ordered from low to high. If *y* was 2-D, the coefficients in column *k* of *coef* represent the polynomial fit to the data in *y*'s *k*-th column.

[residuals, rank, singular_values, rcond]
: [list] These values are only returned if `full == True`

- residuals – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- singular_values – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *numpy.linalg.lstsq*.

Raises

RankWarning
Raised if the matrix in the least-squares fit is rank deficient. The warning is only raised if `full == False`. The warnings can be turned off by:

```
>>> import warnings
>>> warnings.simplefilter('ignore', np.exceptions.RankWarning)
```

See also:

numpy.polynomial.chebyshev.chebfit
numpy.polynomial.legendre.legfit
numpy.polynomial.laguerre.lagfit
numpy.polynomial.hermite.hermfit
numpy.polynomial.hermite_e.hermefit
polyval
Evaluates a polynomial.

polyvander
Vandermonde matrix for powers.

numpy.linalg.lstsq
Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline
Computes spline fits.

Notes

The solution is the coefficients of the polynomial *p* that minimizes the sum of the weighted squared errors

$$E = \sum_j w_j^2 * |y_j - p(x_j)|^2,$$

where the w_j are the weights. This problem is solved by setting up the (typically) over-determined matrix equation:

$$V(x) * c = w * y,$$

where *V* is the weighted pseudo Vandermonde matrix of *x*, *c* are the coefficients to be solved for, *w* are the weights, and *y* are the observed values. This equation is then solved using the singular value decomposition of *V*.

If some of the singular values of *V* are so small that they are neglected (and *full* == `False`), a *RankWarning* will be raised. This means that the coefficient values may be poorly determined. Fitting to a lower order polynomial will usually get rid of the warning (but may not be what you want, of course; if you have independent reason(s) for choosing the degree which isn't working, you may have to: a) reconsider those reasons, and/or b) reconsider the quality of your data). The *rcond* parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Polynomial fits using double precision tend to "fail" at about (polynomial) degree 20. Fits using Chebyshev or Legendre series are generally better conditioned, but much can still depend on the distribution of the sample points and the smoothness of the data. If the quality of the fit is inadequate, splines may be a good alternative.

Examples

```
>>> import numpy as np
>>> from numpy.polynomial import polynomial as P
>>> x = np.linspace(-1,1,51)  # x "data": [-1, -0.96, ..., 0.96, 1]
>>> rng = np.random.default_rng()
>>> err = rng.normal(size=len(x))
>>> y = x**3 - x + err  # x^3 - x + Gaussian noise
>>> c, stats = P.polyfit(x,y,3,full=True)
>>> c # c[0], c[1] approx. -1, c[2] should be approx. 0, c[3] approx. 1
array([ 0.23111996, -1.02785049, -0.2241444 ,  1.08405657]) # may vary
>>> stats # note the large SSR, explaining the rather poor results
[array([48.312088]),                                         # may vary
 4,
 array([1.38446749, 1.32119158, 0.50443316, 0.28853036]),
 1.1324274851176597e-14]
```

Same thing without the added noise

```
>>> y = x**3 - x
>>> c, stats = P.polyfit(x,y,3,full=True)
>>> c # c[0], c[1] ~= -1, c[2] should be "very close to 0", c[3] ~= 1
array([-6.73496154e-17, -1.00000000e+00,  0.00000000e+00,  1.00000000e+00])
>>> stats # note the minuscule SSR
[array([8.79579319e-31]),
 np.int32(4),
 array([1.38446749, 1.32119158, 0.50443316, 0.28853036]),
 1.1324274851176597e-14]
```

`polynomial.polynomial.`**`polytrim`**(*c*, *tol=0*)

Remove "small" "trailing" coefficients from a polynomial.

"Small" means "small in absolute value" and is controlled by the parameter *tol*; "trailing" means highest order coefficient(s), e.g., in `[0, 1, 1, 0, 0]` (which represents `0 + x + x**2 + 0*x**3 + 0*x**4`) both the 3-rd and 4-th order coefficients would be "trimmed."

Parameters

c
: [array_like] 1-d array of coefficients, ordered from lowest order to highest.

tol
: [number, optional] Trailing (i.e., highest order) elements with absolute value less than or equal to *tol* (default value is zero) are removed.

Returns

trimmed
: [ndarray] 1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError
: If *tol* < 0

Examples

```
>>> from numpy.polynomial import polyutils as pu
>>> pu.trimcoef((0,0,3,0,5,0,0))
array([0.,  0.,  3.,  0.,  5.])
>>> pu.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([0.])
>>> i = complex(0,1) # works for complex
>>> pu.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([0.0003+0.j   , 0.001 -0.001j])
```

polynomial.polynomial.**polyline**(*off*, *scl*)

Returns an array representing a linear polynomial.

Parameters

off, scl
[scalars] The "y-intercept" and "slope" of the line, respectively.

Returns

y
[ndarray] This module's representation of the linear polynomial `off + scl*x`.

See also:

numpy.polynomial.chebyshev.chebline
numpy.polynomial.legendre.legline
numpy.polynomial.laguerre.lagline
numpy.polynomial.hermite.hermline
numpy.polynomial.hermite_e.hermeline

Examples

```
>>> from numpy.polynomial import polynomial as P
>>> P.polyline(1, -1)
array([ 1, -1])
>>> P.polyval(1, P.polyline(1, -1))  # should be 0
0.0
```

See Also

numpy.polynomial

Chebyshev Series (numpy.polynomial.chebyshev)

This module provides a number of objects (mostly functions) useful for dealing with Chebyshev series, including a *Chebyshev* class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its "parent" sub-package, *numpy.polynomial*).

Classes

Chebyshev(coef[, domain, window, symbol])	A Chebyshev series class.

class numpy.polynomial.chebyshev.**Chebyshev**(*coef*, *domain=None*, *window=None*, *symbol='x'*)

A Chebyshev series class.

The Chebyshev class provides the standard Python numerical methods '+', '-', '*', '//', '%', 'divmod', '**', and '()' as well as the attributes and methods listed below.

Parameters

coef
[array_like] Chebyshev coefficients in order of increasing degree, i.e., `(1, 2, 3)` gives `1*T_0(x) + 2*T_1(x) + 3*T_2(x)`.

domain
[(2,) array_like, optional] Domain to use. The interval `[domain[0], domain[1]]` is mapped to the interval `[window[0], window[1]]` by shifting and scaling. The default value is [-1., 1.].

window
[(2,) array_like, optional] Window, see `domain` for its use. The default value is [-1., 1.].

symbol
[str, optional] Symbol used to represent the independent variable in string representations of the polynomial expression, e.g. for printing. The symbol must be a valid Python identifier. Default value is 'x'.

New in version 1.24.

Attributes

symbol

Methods

`__call__`(arg)	Call self as a function.
`basis`(deg[, domain, window, symbol])	Series basis polynomial of degree *deg*.
`cast`(series[, domain, window])	Convert series to series of this class.
`convert`([domain, kind, window])	Convert series to a different kind and/or domain and/or window.
`copy`()	Return a copy.
`cutdeg`(deg)	Truncate series to the given degree.
`degree`()	The degree of the series.
`deriv`([m])	Differentiate.
`fit`(x, y, deg[, domain, rcond, full, w, ...])	Least squares fit to data.
`fromroots`(roots[, domain, window, symbol])	Return series instance that has the specified roots.
`has_samecoef`(other)	Check if coefficients match.
`has_samedomain`(other)	Check if domains match.
`has_sametype`(other)	Check if types match.
`has_samewindow`(other)	Check if windows match.
`identity`([domain, window, symbol])	Identity function.
`integ`([m, k, lbnd])	Integrate.
`interpolate`(func, deg[, domain, args])	Interpolate a function at the Chebyshev points of the first kind.
`linspace`([n, domain])	Return x, y values at equally spaced points in domain.
`mapparms`()	Return the mapping parameters.
`roots`()	Return the roots of the series polynomial.
`trim`([tol])	Remove trailing coefficients
`truncate`(size)	Truncate series to length *size*.

method

polynomial.chebyshev.Chebyshev.**__call__**(*arg*)

Call self as a function.

method

classmethod polynomial.chebyshev.Chebyshev.**basis**(*deg*, *domain=None*, *window=None*, *symbol='x'*)

Series basis polynomial of degree *deg*.

Returns the series representing the basis polynomial of degree *deg*.

Parameters

deg
[int] Degree of the basis polynomial for the series. Must be >= 0.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series with the coefficient of the *deg* term set to one and all others zero.

method

classmethod polynomial.chebyshev.Chebyshev.**cast**(*series*, *domain=None*, *window=None*)

Convert series to series of this class.

The *series* is expected to be an instance of some polynomial series of one of the types supported by by the numpy.polynomial module, but could be some other class that supports the convert method.

Parameters

series
[series] The series instance to be converted.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series
[series] A series of the same kind as the calling class and equal to *series* when evaluated.

See also:

convert
similar instance method

method

polynomial.chebyshev.Chebyshev.**convert**(*domain=None*, *kind=None*, *window=None*)

Convert series to a different kind and/or domain and/or window.

Parameters

domain
[array_like, optional] The domain of the converted series. If the value is None, the default domain of *kind* is used.

kind
[class, optional] The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

window
[array_like, optional] The window of the converted series. If the value is None, the default window of *kind* is used.

Returns

new_series
[series] The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes

Conversion between domains and class types can result in numerically ill defined series.

method

polynomial.chebyshev.Chebyshev.**copy**()

Return a copy.

Returns

new_series
[series] Copy of self.

method

polynomial.chebyshev.Chebyshev.**cutdeg**(*deg*)

Truncate series to the given degree.

Reduce the degree of the series to *deg* by discarding the high order terms. If *deg* is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

deg
[non-negative int] The series is reduced to degree *deg* by discarding the high order terms. The value of *deg* must be a non-negative integer.

Returns

new_series
[series] New instance of series with reduced degree.

method

polynomial.chebyshev.Chebyshev.**degree**()

The degree of the series.

Returns

degree
[int] Degree of the series, one less than the number of coefficients.

Examples

Create a polynomial object for `1 + 7*x + 4*x**2`:

```
>>> poly = np.polynomial.Polynomial([1, 7, 4])
>>> print(poly)
1.0 + 7.0·x + 4.0·x²
>>> poly.degree()
2
```

Note that this method does not check for non-zero coefficients. You must trim the polynomial to remove any trailing zeroes:

```
>>> poly = np.polynomial.Polynomial([1, 7, 0])
>>> print(poly)
1.0 + 7.0·x + 0.0·x²
```

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```
>>> poly.degree()
2
>>> poly.trim().degree()
1
```

method

polynomial.chebyshev.Chebyshev.**deriv**(*m=1*)

Differentiate.

Return a series instance of that is the derivative of the current series.

Parameters

m
[non-negative int] Find the derivative of order *m*.

Returns

new_series
[series] A new series representing the derivative. The domain is the same as the domain of the differentiated series.

method

classmethod polynomial.chebyshev.Chebyshev.**fit**(*x*, *y*, *deg*, *domain=None*, *rcond=None*, *full=False*, *w=None*, *window=None*, *symbol='x'*)

Least squares fit to data.

Return a series instance that is the least squares fit to the data *y* sampled at *x*. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,)] y-coordinates of the M sample points `(x[i], y[i])`.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

domain
[{None, [beg, end], []}, optional] Domain to use for the returned series. If `None`, then a minimal domain that covers the points *x* is chosen. If `[]` the class domain is used. The default value was the class domain in NumPy 1.4 and `None` in later versions. The `[]` option was added in numpy 1.5.0.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is `len(x)*eps`, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (M,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

window
[{[beg, end]}, optional] Window to use for the returned series. The default value is the default class domain

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series that represents the least squares fit to the data and has the domain and window specified in the call. If the coefficients for the unscaled and unshifted basis polynomials are of interest, do `new_series.convert().coef`.

[resid, rank, sv, rcond]
[list] These values are only returned if `full == True`

- resid – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- sv – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *linalg.lstsq*.

method

classmethod polynomial.chebyshev.Chebyshev.**fromroots**(*roots*, *domain=[]*, *window=None*, *symbol='x'*)

Return series instance that has the specified roots.

Returns a series representing the product `(x - r[0])*(x - r[1])*...*(x - r[n-1])`, where `r` is a list of roots.

Parameters

roots
[array_like] List of roots.

domain
[{[], None, array_like}, optional] Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [] the domain is the class domain. The default is [].

window
[{None, array_like}, optional] Window for the returned series. If None the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series with the specified roots.

method

polynomial.chebyshev.Chebyshev.**has_samecoef**(*other*)

Check if coefficients match.

Parameters

other
[class instance] The other class must have the `coef` attribute.

Returns

bool
[boolean] True if the coefficients are the same, False otherwise.

method

polynomial.chebyshev.Chebyshev.**has_samedomain**(*other*)

Check if domains match.

Parameters

other
[class instance] The other class must have the `domain` attribute.

Returns

bool
[boolean] True if the domains are the same, False otherwise.

method

polynomial.chebyshev.Chebyshev.**has_sametype**(*other*)

Check if types match.

Parameters

other
[object] Class instance.

Returns

bool
[boolean] True if other is same class as self

method

polynomial.chebyshev.Chebyshev.**has_samewindow**(*other*)

Check if windows match.

Parameters

other
[class instance] The other class must have the `window` attribute.

Returns

bool
[boolean] True if the windows are the same, False otherwise.

method

classmethod polynomial.chebyshev.Chebyshev.**identity**(*domain=None*, *window=None*, *symbol='x'*)

Identity function.

If `p` is the returned series, then `p(x) == x` for all values of x.

Parameters

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series of representing the identity.

method

polynomial.chebyshev.Chebyshev.**integ**(*m=1*, *k=[]*, *lbnd=None*)

Integrate.

Return a series instance that is the definite integral of the current series.

Parameters

m
[non-negative int] The number of integrations to perform.

k
[array_like] Integration constants. The first constant is applied to the first integration, the second to the second, and so on. The list of values must less than or equal to *m* in length and any missing values are set to zero.

lbnd
[Scalar] The lower bound of the definite integral.

Returns

new_series
[series] A new series representing the integral. The domain is the same as the domain of the integrated series.

method

classmethod polynomial.chebyshev.Chebyshev.**interpolate**(*func*, *deg*, *domain=None*, *args=()*)

Interpolate a function at the Chebyshev points of the first kind.

Returns the series that interpolates *func* at the Chebyshev points of the first kind scaled and shifted to the `domain`. The resulting series tends to a minmax approximation of *func* when the function is continuous in the domain.

Parameters

func
[function] The function to be interpolated. It must be a function of a single variable of the form `f(x, a, b, c...)`, where `a, b, c...` are extra arguments passed in the *args* parameter.

deg
[int] Degree of the interpolating polynomial.

domain
[{None, [beg, end]}, optional] Domain over which *func* is interpolated. The default is None, in which case the domain is [-1, 1].

args
[tuple, optional] Extra arguments to be used in the function call. Default is no extra arguments.

Returns

polynomial
[Chebyshev instance] Interpolating Chebyshev instance.

Notes

See *numpy.polynomial.chebinterpolate* for more details.

method

`polynomial.chebyshev.Chebyshev.`**`linspace`**(*n=100*, *domain=None*)

Return x, y values at equally spaced points in domain.

Returns the x, y values at *n* linearly spaced points across the domain. Here y is the value of the polynomial at the points x. By default the domain is the same as that of the series instance. This method is intended mostly as a plotting aid.

Parameters

n
[int, optional] Number of point pairs to return. The default value is 100.

domain
[{None, array_like}, optional] If not None, the specified domain is used instead of that of the calling instance. It should be of the form `[beg,end]`. The default is None which case the class domain is used.

Returns

x, y
[ndarray] x is equal to linspace(self.domain[0], self.domain[1], n) and y is the series evaluated at element of x.

method

`polynomial.chebyshev.Chebyshev.`**`mapparms`**()

Return the mapping parameters.

The returned values define a linear map `off + scl*x` that is applied to the input arguments before the series is evaluated. The map depends on the `domain` and `window`; if the current `domain` is equal to the `window` the resulting map is the identity. If the coefficients of the series instance are to be used by themselves outside this class, then the linear function must be substituted for the `x` in the standard representation of the base polynomials.

Returns

off, scl
[float or complex] The mapping function is defined by `off + scl*x`.

Notes

If the current domain is the interval `[l1, r1]` and the window is `[l2, r2]`, then the linear mapping function `L` is defined by the equations:

```
L(l1) = l2
L(r1) = r2
```

method

`polynomial.chebyshev.Chebyshev.`**`roots`**`()`

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decreases the further outside the `domain` they lie.

Returns

roots
[ndarray] Array containing the roots of the series.

method

`polynomial.chebyshev.Chebyshev.`**`trim`**`(`*`tol=0`*`)`

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than *tol* or the beginning of the series is reached. If all the coefficients would be removed the series is set to `[0]`. A new series instance is returned with the new coefficients. The current instance remains unchanged.

Parameters

tol
[non-negative number.] All trailing coefficients less than *tol* will be removed.

Returns

new_series
[series] New instance of series with trimmed coefficients.

method

`polynomial.chebyshev.Chebyshev.`**`truncate`**`(`*`size`*`)`

Truncate series to length *size*.

Reduce the series to length *size* by discarding the high degree terms. The value of *size* must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

size
[positive int] The series is reduced to length *size* by discarding the high degree terms. The value of *size* must be a positive integer.

Returns

new_series
[series] New instance of series with truncated coefficients.

Constants

chebdomain	An array object represents a multidimensional, homogeneous array of fixed-size items.
chebzero	An array object represents a multidimensional, homogeneous array of fixed-size items.
chebone	An array object represents a multidimensional, homogeneous array of fixed-size items.
chebx	An array object represents a multidimensional, homogeneous array of fixed-size items.

polynomial.chebyshev.**chebdomain = array([-1., 1.])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.chebyshev.`**`chebzero = array([0])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.chebyshev.`**`chebone = array([1])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.chebyshev.`**`chebx = array([0, 1])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

Arithmetic

chebadd(c1, c2)	Add one Chebyshev series to another.
chebsub(c1, c2)	Subtract one Chebyshev series from another.
chebmulx(c)	Multiply a Chebyshev series by x.
chebmul(c1, c2)	Multiply one Chebyshev series by another.
chebdiv(c1, c2)	Divide one Chebyshev series by another.
chebpow(c, pow[, maxpower])	Raise a Chebyshev series to a power.
chebval(x, c[, tensor])	Evaluate a Chebyshev series at points x.
chebval2d(x, y, c)	Evaluate a 2-D Chebyshev series at points (x, y).
chebval3d(x, y, z, c)	Evaluate a 3-D Chebyshev series at points (x, y, z).
chebgrid2d(x, y, c)	Evaluate a 2-D Chebyshev series on the Cartesian product of x and y.
chebgrid3d(x, y, z, c)	Evaluate a 3-D Chebyshev series on the Cartesian product of x, y, and z.

polynomial.chebyshev.**chebadd**(*c1*, *c2*)

Add one Chebyshev series to another.

Returns the sum of two Chebyshev series *c1* + *c2*. The arguments are sequences of coefficients ordered from lowest order term to highest, i.e., [1,2,3] represents the series `T_0 + 2*T_1 + 3*T_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Chebyshev series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the Chebyshev series of their sum.

See also:

chebsub, ***chebmulx***, ***chebmul***, ***chebdiv***, ***chebpow***

Notes

Unlike multiplication, division, etc., the sum of two Chebyshev series is a Chebyshev series (without having to "reproject" the result onto the basis set) so addition, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial import chebyshev as C
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> C.chebadd(c1,c2)
array([4., 4., 4.])
```

polynomial.chebyshev.**chebsub**(*c1*, *c2*)

Subtract one Chebyshev series from another.

Returns the difference of two Chebyshev series *c1* - *c2*. The sequences of coefficients are from lowest order term to highest, i.e., [1,2,3] represents the series `T_0 + 2*T_1 + 3*T_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Chebyshev series coefficients ordered from low to high.

Returns

out
[ndarray] Of Chebyshev series coefficients representing their difference.

See also:

chebadd, ***chebmulx***, ***chebmul***, ***chebdiv***, ***chebpow***

Notes

Unlike multiplication, division, etc., the difference of two Chebyshev series is a Chebyshev series (without having to "reproject" the result onto the basis set) so subtraction, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial import chebyshev as C
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> C.chebsub(c1,c2)
array([-2.,  0.,  2.])
>>> C.chebsub(c2,c1) # -C.chebsub(c1,c2)
array([ 2.,  0., -2.])
```

polynomial.chebyshev.**chebmulx**(*c*)

Multiply a Chebyshev series by x.

Multiply the polynomial *c* by x, where x is the independent variable.

Parameters

c
[array_like] 1-D array of Chebyshev series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the result of the multiplication.

See also:

chebadd, ***chebsub***, ***chebmul***, ***chebdiv***, ***chebpow***

Examples

```
>>> from numpy.polynomial import chebyshev as C
>>> C.chebmulx([1,2,3])
array([1. , 2.5, 1. , 1.5])
```

polynomial.chebyshev.**chebmul**(*c1*, *c2*)

Multiply one Chebyshev series by another.

Returns the product of two Chebyshev series *c1* * *c2*. The arguments are sequences of coefficients, from lowest order "term" to highest, e.g., [1,2,3] represents the series `T_0 + 2*T_1 + 3*T_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Chebyshev series coefficients ordered from low to high.

Returns

out
[ndarray] Of Chebyshev series coefficients representing their product.

See also:

chebadd, ***chebsub***, ***chebmulx***, ***chebdiv***, ***chebpow***

Notes

In general, the (polynomial) product of two C-series results in terms that are not in the Chebyshev polynomial basis set. Thus, to express the product as a C-series, it is typically necessary to "reproject" the product onto said basis set, which typically produces "unintuitive live" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial import chebyshev as C
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> C.chebmul(c1,c2) # multiplication requires "reprojection"
array([  6.5,  12. ,  12. ,   4. ,   1.5])
```

polynomial.chebyshev.**chebdiv**(*c1*, *c2*)

Divide one Chebyshev series by another.

Returns the quotient-with-remainder of two Chebyshev series *c1* / *c2*. The arguments are sequences of coefficients from lowest order "term" to highest, e.g., [1,2,3] represents the series `T_0 + 2*T_1 + 3*T_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Chebyshev series coefficients ordered from low to high.

Returns

[quo, rem]
[ndarrays] Of Chebyshev series coefficients representing the quotient and remainder.

See also:

chebadd, *chebsub*, *chebmulx*, *chebmul*, *chebpow*

Notes

In general, the (polynomial) division of one C-series by another results in quotient and remainder terms that are not in the Chebyshev polynomial basis set. Thus, to express these results as C-series, it is typically necessary to "reproject" the results onto said basis set, which typically produces "unintuitive" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial import chebyshev as C
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> C.chebdiv(c1,c2) # quotient "intuitive," remainder not
(array([3.]), array([-8., -4.]))
>>> c2 = (0,1,2,3)
>>> C.chebdiv(c2,c1) # neither "intuitive"
(array([0., 2.]), array([-2., -4.]))
```

polynomial.chebyshev.**chebpow**(*c*, *pow*, *maxpower=16*)

Raise a Chebyshev series to a power.

Returns the Chebyshev series *c* raised to the power *pow*. The argument *c* is a sequence of coefficients ordered from low to high. i.e., [1,2,3] is the series `T_0 + 2*T_1 + 3*T_2`.

Parameters

c
[array_like] 1-D array of Chebyshev series coefficients ordered from low to high.

pow
[integer] Power to which the series will be raised

maxpower
[integer, optional] Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

Returns

coef
[ndarray] Chebyshev series of power.

See also:

chebadd, *chebsub*, *chebmulx*, *chebmul*, *chebdiv*

Examples

```
>>> from numpy.polynomial import chebyshev as C
>>> C.chebpow([1, 2, 3, 4], 2)
array([15.5, 22. , 16. , ..., 12.5, 12. ,  8. ])
```

polynomial.chebyshev.**chebval**(*x*, *c*, *tensor=True*)

Evaluate a Chebyshev series at points x.

If *c* is of length *n + 1*, this function returns the value:

$$p(x) = c_0 * T_0(x) + c_1 * T_1(x) + ... + c_n * T_n(x)$$

The parameter *x* is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either *x* or its elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array, then `p(x)` will have the same shape as *x*. If *c* is multidimensional, then the shape of the result depends on the value of *tensor*. If *tensor* is true the shape will be c.shape[1:] + x.shape. If *tensor* is false the shape will be c.shape[1:]. Note that scalars have shape (,).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

Parameters

x
: [array_like, compatible object] If *x* is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, *x* or its elements must support addition and multiplication with themselves and with the elements of *c*.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree n are contained in c[n]. If *c* is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of *c*.

tensor
: [boolean, optional] If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of *x*. Scalars have dimension 0 for this action. The result is that every column of coefficients in *c* is evaluated for every element of *x*. If False, *x* is broadcast over the columns of *c* for the evaluation. This keyword is useful when *c* is multidimensional. The default value is True.

Returns

values
: [ndarray, algebra_like] The shape of the return value is described above.

See also:

chebval2d, ***chebgrid2d***, ***chebval3d***, ***chebgrid3d***

Notes

The evaluation uses Clenshaw recursion, aka synthetic division.

polynomial.chebyshev.**chebval2d**(*x*, *y*, *c*)

Evaluate a 2-D Chebyshev series at points (x, y).

This function returns the values:

$$p(x,y) = \sum_{i,j} c_{i,j} * T_i(x) * T_j(y)$$

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

Parameters

x, y
: [array_like, compatible objects] The two dimensional series is evaluated at the points `(x, y)`, where *x* and *y* must have the same shape. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in `c[i,j]`. If *c* has dimension greater than 2 the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional Chebyshev series at points formed from pairs of corresponding values from *x* and *y*.

See also:

chebval, ***chebgrid2d***, ***chebval3d***, ***chebgrid3d***

polynomial.chebyshev.**chebval3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D Chebyshev series at points (x, y, z).

This function returns the values:

$$p(x,y,z) = \sum_{i,j,k} c_{i,j,k} * T_i(x) * T_j(y) * T_k(z)$$

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape.

Parameters

x, y, z
: [array_like, compatible object] The three dimensional series is evaluated at the points `(x, y, z)`, where *x*, *y*, and *z* must have the same shape. If any of *x*, *y*, or *z* is a list or tuple, it is first

converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c

[array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j,k is contained in `c[i,j,k]`. If *c* has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns

values

[ndarray, compatible object] The values of the multidimensional polynomial on points formed with triples of corresponding values from *x*, *y*, and *z*.

See also:

chebval, ***chebval2d***, ***chebgrid2d***, ***chebgrid3d***

`polynomial.chebyshev.`**`chebgrid2d`**(*x*, *y*, *c*)

Evaluate a 2-D Chebyshev series on the Cartesian product of x and y.

This function returns the values:

$$p(a,b) = \sum_{i,j} c_{i,j} * T_i(a) * T_j(b),$$

where the points *(a, b)* consist of all pairs formed by taking *a* from *x* and *b* from *y*. The resulting points form a grid with *x* in the first dimension and *y* in the second.

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape + y.shape.

Parameters

x, y

[array_like, compatible objects] The two dimensional series is evaluated at the points in the Cartesian product of *x* and *y*. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c

[array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values

[ndarray, compatible object] The values of the two dimensional Chebyshev series at points in the Cartesian product of *x* and *y*.

See also:

chebval, ***chebval2d***, ***chebval3d***, ***chebgrid3d***

polynomial.chebyshev.**chebgrid3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D Chebyshev series on the Cartesian product of x, y, and z.

This function returns the values:

$$p(a,b,c) = \sum_{i,j,k} c_{i,j,k} * T_i(a) * T_j(b) * T_k(c)$$

where the points `(a, b, c)` consist of all triples formed by taking *a* from *x*, *b* from *y*, and *c* from *z*. The resulting points form a grid with *x* in the first dimension, *y* in the second, and *z* in the third.

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape + y.shape + z.shape.

Parameters

x, y, z
: [array_like, compatible objects] The three dimensional series is evaluated at the points in the Cartesian product of *x*, *y*, and *z*. If *x*, *y*, or *z* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points in the Cartesian product of *x* and *y*.

See also:

chebval, ***chebval2d***, ***chebgrid2d***, ***chebval3d***

Calculus

chebder(c[, m, scl, axis])	Differentiate a Chebyshev series.
chebint(c[, m, k, lbnd, scl, axis])	Integrate a Chebyshev series.

polynomial.chebyshev.**chebder**(*c*, *m=1*, *scl=1*, *axis=0*)

Differentiate a Chebyshev series.

Returns the Chebyshev series coefficients *c* differentiated *m* times along *axis*. At each iteration the result is multiplied by *scl* (the scaling factor is for use in a linear change of variable). The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series `1*T_0 + 2*T_1 + 3*T_2` while [[1,2],[1,2]] represents `1*T_0(x)*T_0(y) + 1*T_1(x)*T_0(y) + 2*T_0(x)*T_1(y) + 2*T_1(x)*T_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of Chebyshev series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Number of derivatives taken, must be non-negative. (Default: 1)

scl
: [scalar, optional] Each differentiation is multiplied by *scl*. The end result is multiplication by `scl**m`. This is for use in a linear change of variable. (Default: 1)

axis
: [int, optional] Axis over which the derivative is taken. (Default: 0).

Returns

der
: [ndarray] Chebyshev series of the derivative.

See also:

chebint

Notes

In general, the result of differentiating a C-series needs to be "reprojected" onto the C-series basis set. Thus, typically, the result of this function is "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial import chebyshev as C
>>> c = (1,2,3,4)
>>> C.chebder(c)
array([14., 12., 24.])
>>> C.chebder(c,3)
array([96.])
>>> C.chebder(c,scl=-1)
array([-14., -12., -24.])
>>> C.chebder(c,2,-1)
array([12.,  96.])
```

`polynomial.chebyshev.`**`chebint`**(*c*, *m=1*, *k=[]*, *lbnd=0*, *scl=1*, *axis=0*)

Integrate a Chebyshev series.

Returns the Chebyshev series coefficients *c* integrated *m* times from *lbnd* along *axis*. At each iteration the resulting series is **multiplied** by *scl* and an integration constant, *k*, is added. The scaling factor is for use in a linear change of variable. ("Buyer beware": note that, depending on what one is doing, one may want *scl* to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series `T_0 + 2*T_1 + 3*T_2` while [[1,2],[1,2]] represents `1*T_0(x)*T_0(y) + 1*T_1(x)*T_0(y) + 2*T_0(x)*T_1(y) + 2*T_1(x)*T_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of Chebyshev series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Order of integration, must be positive. (Default: 1)

k
: [{[], list, scalar}, optional] Integration constant(s). The value of the first integral at zero is the first value in the list, the value of the second integral at zero is the second value, etc. If `k == []` (the default), all constants are set to zero. If `m == 1`, a single scalar can be given instead of a list.

lbnd
: [scalar, optional] The lower bound of the integral. (Default: 0)

scl
: [scalar, optional] Following each integration the result is *multiplied* by *scl* before the integration constant is added. (Default: 1)

axis
: [int, optional] Axis over which the integral is taken. (Default: 0).

Returns

S
: [ndarray] C-series coefficients of the integral.

Raises

ValueError
: If `m < 1`, `len(k) > m`, `np.ndim(lbnd) != 0`, or `np.ndim(scl) != 0`.

See also:

chebder

Notes

Note that the result of each integration is *multiplied* by *scl*. Why is this important to note? Say one is making a linear change of variable $u = ax + b$ in an integral relative to x. Then $dx = du/a$, so one will need to set *scl* equal to $1/a$- perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be "reprojected" onto the C-series basis set. Thus, typically, the result of this function is "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial import chebyshev as C
>>> c = (1,2,3)
>>> C.chebint(c)
array([ 0.5, -0.5,  0.5,  0.5])
>>> C.chebint(c,3)
array([ 0.03125   , -0.1875    ,  0.04166667, -0.05208333,  0.01041667, # may vary
    0.00625   ])
>>> C.chebint(c, k=3)
array([ 3.5, -0.5,  0.5,  0.5])
>>> C.chebint(c,lbnd=-2)
array([ 8.5, -0.5,  0.5,  0.5])
>>> C.chebint(c,scl=-2)
array([-1.,  1., -1., -1.])
```

Misc Functions

chebfromroots(roots)	Generate a Chebyshev series with given roots.
chebroots(c)	Compute the roots of a Chebyshev series.
chebvander(x, deg)	Pseudo-Vandermonde matrix of given degree.
chebvander2d(x, y, deg)	Pseudo-Vandermonde matrix of given degrees.
chebvander3d(x, y, z, deg)	Pseudo-Vandermonde matrix of given degrees.
chebgauss(deg)	Gauss-Chebyshev quadrature.
chebweight(x)	The weight function of the Chebyshev polynomials.
chebcompanion(c)	Return the scaled companion matrix of c.
chebfit(x, y, deg[, rcond, full, w])	Least squares fit of Chebyshev series to data.
chebpts1(npts)	Chebyshev points of the first kind.
chebpts2(npts)	Chebyshev points of the second kind.
chebtrim(c[, tol])	Remove "small" "trailing" coefficients from a polynomial.
chebline(off, scl)	Chebyshev series whose graph is a straight line.
cheb2poly(c)	Convert a Chebyshev series to a polynomial.
poly2cheb(pol)	Convert a polynomial to a Chebyshev series.
chebinterpolate(func, deg[, args])	Interpolate a function at the Chebyshev points of the first kind.

polynomial.chebyshev.**chebfromroots**(*roots*)

Generate a Chebyshev series with given roots.

The function returns the coefficients of the polynomial

$$p(x) = (x - r_0) * (x - r_1) * ... * (x - r_n),$$

in Chebyshev form, where the r_n are the roots specified in *roots*. If a zero has multiplicity n, then it must appear in *roots* n times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then *roots* looks something like [2, 2, 2, 3, 3]. The roots can appear in any order.

If the returned coefficients are *c*, then

$$p(x) = c_0 + c_1 * T_1(x) + ... + c_n * T_n(x)$$

The coefficient of the last term is not generally 1 for monic polynomials in Chebyshev form.

Parameters

roots
[array_like] Sequence containing the roots.

Returns

out
[ndarray] 1-D array of coefficients. If all roots are real then *out* is a real array, if some of the roots are complex, then *out* is complex even if all the coefficients in the result are real (see Examples below).

See also:

numpy.polynomial.polynomial.polyfromroots
numpy.polynomial.legendre.legfromroots
numpy.polynomial.laguerre.lagfromroots
numpy.polynomial.hermite.hermfromroots
numpy.polynomial.hermite_e.hermefromroots

Examples

```
>>> import numpy.polynomial.chebyshev as C
>>> C.chebfromroots((-1,0,1)) # x^3 - x relative to the standard basis
array([ 0.  , -0.25,  0.  ,  0.25])
>>> j = complex(0,1)
>>> C.chebfromroots((-j,j)) # x^2 + 1 relative to the standard basis
array([1.5+0.j, 0. +0.j, 0.5+0.j])
```

polynomial.chebyshev.**chebroots**(*c*)

Compute the roots of a Chebyshev series.

Return the roots (a.k.a. "zeros") of the polynomial

$$p(x) = \sum_i c[i] * T_i(x).$$

Parameters

c
[1-D array_like] 1-D array of coefficients.

Returns

out
[ndarray] Array of the roots of the series. If all the roots are real, then *out* is also real, otherwise it is complex.

See also:

numpy.polynomial.polynomial.polyroots
numpy.polynomial.legendre.legroots
numpy.polynomial.laguerre.lagroots
numpy.polynomial.hermite.hermroots
numpy.polynomial.hermite_e.hermeroots

Notes

The root estimates are obtained as the eigenvalues of the companion matrix, Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton's method.

The Chebyshev series basis polynomials aren't powers of *x* so the results of this function may seem unintuitive.

Examples

```
>>> import numpy.polynomial.chebyshev as cheb
>>> cheb.chebroots((-1, 1,-1, 1)) # T3 - T2 + T1 - T0 has real roots
array([ -5.00000000e-01,   2.60860684e-17,   1.00000000e+00]) # may vary
```

polynomial.chebyshev.**chebvander**(*x*, *deg*)

Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree *deg* and sample points *x*. The pseudo-Vandermonde matrix is defined by

$$V[..., i] = T_i(x),$$

where `0 <= i <= deg`. The leading indices of *V* index the elements of *x* and the last index is the degree of the Chebyshev polynomial.

If *c* is a 1-D array of coefficients of length `n + 1` and *V* is the matrix `V = chebvander(x, n)`, then `np.dot(V, c)` and `chebval(x, c)` are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of Chebyshev series of the same degree and sample points.

Parameters

x
[array_like] Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If *x* is scalar it is converted to a 1-D array.

deg
[int] Degree of the resulting matrix.

Returns

vander
[ndarray] The pseudo Vandermonde matrix. The shape of the returned matrix is `x.shape + (deg + 1,)`, where The last index is the degree of the corresponding Chebyshev polynomial. The dtype will be the same as the converted *x*.

`polynomial.chebyshev.`**`chebvander2d`**(*x*, *y*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y)`. The pseudo-Vandermonde matrix is defined by

$$V[..., (deg[1] + 1) * i + j] = T_i(x) * T_j(y),$$

where `0 <= i <= deg[0]` and `0 <= j <= deg[1]`. The leading indices of *V* index the points `(x, y)` and the last index encodes the degrees of the Chebyshev polynomials.

If `V = chebvander2d(x, y, [xdeg, ydeg])`, then the columns of *V* correspond to the elements of a 2-D coefficient array *c* of shape (xdeg + 1, ydeg + 1) in the order

$$c_{00}, c_{01}, c_{02}..., c_{10}, c_{11}, c_{12}...$$

and `np.dot(V, c.flat)` and `chebval2d(x, y, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D Chebyshev series of the same degrees and sample points.

Parameters

x, y
[array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
[list of ints] List of maximum degrees of the form [x_deg, y_deg].

Returns

vander2d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)$. The dtype will be the same as the converted *x* and *y*.

See also:

chebvander, ***chebvander3d***, ***chebval2d***, ***chebval3d***

`polynomial.chebyshev.`**`chebvander3d`**(*x*, *y*, *z*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y, z)`. If *l*, *m*, *n* are the given degrees in *x*, *y*, *z*, then The pseudo-Vandermonde matrix is defined by

$$V[..., (m+1)(n+1)i + (n+1)j + k] = T_i(x) * T_j(y) * T_k(z),$$

where `0 <= i <= l`, `0 <= j <= m`, and `0 <= j <= n`. The leading indices of *V* index the points `(x, y, z)` and the last index encodes the degrees of the Chebyshev polynomials.

If `V = chebvander3d(x, y, z, [xdeg, ydeg, zdeg])`, then the columns of *V* correspond to the elements of a 3-D coefficient array *c* of shape (xdeg + 1, ydeg + 1, zdeg + 1) in the order

$$c_{000}, c_{001}, c_{002}, ..., c_{010}, c_{011}, c_{012}, ...$$

and `np.dot(V, c.flat)` and `chebval3d(x, y, z, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D Chebyshev series of the same degrees and sample points.

Parameters

x, y, z
[array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
[list of ints] List of maximum degrees of the form [x_deg, y_deg, z_deg].

Returns

vander3d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)*(deg[2]+1)$. The dtype will be the same as the converted *x*, *y*, and *z*.

See also:

chebvander, ***chebvander3d***, ***chebval2d***, ***chebval3d***

`polynomial.chebyshev.`**`chebgauss`**(*deg*)

Gauss-Chebyshev quadrature.

Computes the sample points and weights for Gauss-Chebyshev quadrature. These sample points and weights will correctly integrate polynomials of degree $2 * deg - 1$ or less over the interval $[-1, 1]$ with the weight function $f(x) = 1/\sqrt{1-x^2}$.

Parameters

deg
[int] Number of sample points and weights. It must be >= 1.

Returns

x
[ndarray] 1-D ndarray containing the sample points.

y
[ndarray] 1-D ndarray containing the weights.

Notes

The results have only been tested up to degree 100, higher degrees may be problematic. For Gauss-Chebyshev there are closed form solutions for the sample points and weights. If n = *deg*, then

$$x_i = \cos(\pi(2i - 1)/(2n))$$

$$w_i = \pi/n$$

polynomial.chebyshev.**chebweight**(*x*)

The weight function of the Chebyshev polynomials.

The weight function is $1/\sqrt{1 - x^2}$ and the interval of integration is $[-1, 1]$. The Chebyshev polynomials are orthogonal, but not normalized, with respect to this weight function.

Parameters

x
[array_like] Values at which the weight function will be computed.

Returns

w
[ndarray] The weight function at *x*.

polynomial.chebyshev.**chebcompanion**(*c*)

Return the scaled companion matrix of c.

The basis polynomials are scaled so that the companion matrix is symmetric when *c* is a Chebyshev basis polynomial. This provides better eigenvalue estimates than the unscaled case and for basis polynomials the eigenvalues are guaranteed to be real if *numpy.linalg.eigvalsh* is used to obtain them.

Parameters

c
[array_like] 1-D array of Chebyshev series coefficients ordered from low to high degree.

Returns

mat
[ndarray] Scaled companion matrix of dimensions (deg, deg).

polynomial.chebyshev.**chebfit**(*x*, *y*, *deg*, *rcond=None*, *full=False*, *w=None*)

Least squares fit of Chebyshev series to data.

Return the coefficients of a Chebyshev series of degree *deg* that is the least squares fit to the data values *y* given at points *x*. If *y* is 1-D the returned coefficients will also be 1-D. If *y* is 2-D multiple fits are done, one for each column of *y*, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

$$p(x) = c_0 + c_1 * T_1(x) + ... + c_n * T_n(x),$$

where *n* is *deg*.

Parameters

x
: [array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
: [array_like, shape (M,) or (M, K)] y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg
: [int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer, all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

rcond
: [float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is `len(x)*eps`, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
: [bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
: [array_like, shape (*M*,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

Returns

coef
: [ndarray, shape (M,) or (M, K)] Chebyshev coefficients ordered from low to high. If *y* was 2-D, the coefficients for the data in column k of *y* are in column *k*.

[residuals, rank, singular_values, rcond]
: [list] These values are only returned if `full == True`

  - residuals – sum of squared residuals of the least squares fit
  - rank – the numerical rank of the scaled Vandermonde matrix
  - singular_values – singular values of the scaled Vandermonde matrix
  - rcond – value of *rcond*.

  For more details, see *numpy.linalg.lstsq*.

Warns

RankWarning
: The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if `full == False`. The warnings can be turned off by

```
>>> import warnings
>>> warnings.simplefilter('ignore', np.exceptions.RankWarning)
```

See also:

numpy.polynomial.polynomial.polyfit
numpy.polynomial.legendre.legfit
numpy.polynomial.laguerre.lagfit
numpy.polynomial.hermite.hermfit
numpy.polynomial.hermite_e.hermefit
chebval
Evaluates a Chebyshev series.

chebvander
Vandermonde matrix of Chebyshev series.

chebweight
Chebyshev weight function.

numpy.linalg.lstsq
Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline
Computes spline fits.

Notes

The solution is the coefficients of the Chebyshev series *p* that minimizes the sum of the weighted squared errors

$$E = \sum_j w_j^2 * |y_j - p(x_j)|^2,$$

where w_j are the weights. This problem is solved by setting up as the (typically) overdetermined matrix equation

$$V(x) * c = w * y,$$

where *V* is the weighted pseudo Vandermonde matrix of *x*, *c* are the coefficients to be solved for, *w* are the weights, and *y* are the observed values. This equation is then solved using the singular value decomposition of *V*.

If some of the singular values of *V* are so small that they are neglected, then a *RankWarning* will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The *rcond* parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using Chebyshev series are usually better conditioned than fits using power series, but much can depend on the distribution of the sample points and the smoothness of the data. If the quality of the fit is inadequate splines may be a good alternative.

References

[1]

polynomial.chebyshev.**chebpts1**(*npts*)
Chebyshev points of the first kind.

The Chebyshev points of the first kind are the points `cos(x)`, where `x = [pi*(k + .5)/npts for k in range(npts)]`.

Parameters

npts
[int] Number of sample points desired.

Returns

pts
[ndarray] The Chebyshev points of the first kind.

See also:

chebpts2

polynomial.chebyshev.**chebpts2**(*npts*)

Chebyshev points of the second kind.

The Chebyshev points of the second kind are the points `cos(x)`, where `x = [pi*k/(npts - 1) for k in range(npts)]` sorted in ascending order.

Parameters

npts
[int] Number of sample points desired.

Returns

pts
[ndarray] The Chebyshev points of the second kind.

polynomial.chebyshev.**chebtrim**(*c*, *tol=0*)

Remove "small" "trailing" coefficients from a polynomial.

"Small" means "small in absolute value" and is controlled by the parameter *tol*; "trailing" means highest order coefficient(s), e.g., in `[0, 1, 1, 0, 0]` (which represents `0 + x + x**2 + 0*x**3 + 0*x**4`) both the 3-rd and 4-th order coefficients would be "trimmed."

Parameters

c
[array_like] 1-d array of coefficients, ordered from lowest order to highest.

tol
[number, optional] Trailing (i.e., highest order) elements with absolute value less than or equal to *tol* (default value is zero) are removed.

Returns

trimmed
[ndarray] 1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError
If *tol* < 0

Examples

```
>>> from numpy.polynomial import polyutils as pu
>>> pu.trimcoef((0,0,3,0,5,0,0))
array([0.,  0.,  3.,  0.,  5.])
>>> pu.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([0.])
>>> i = complex(0,1) # works for complex
>>> pu.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([0.0003+0.j   , 0.001 -0.001j])
```

polynomial.chebyshev.**chebline**(*off*, *scl*)

Chebyshev series whose graph is a straight line.

Parameters

off, scl
[scalars] The specified line is given by `off + scl*x`.

Returns

y
[ndarray] This module's representation of the Chebyshev series for `off + scl*x`.

See also:

numpy.polynomial.polynomial.polyline
numpy.polynomial.legendre.legline
numpy.polynomial.laguerre.lagline
numpy.polynomial.hermite.hermline
numpy.polynomial.hermite_e.hermeline

Examples

```
>>> import numpy.polynomial.chebyshev as C
>>> C.chebline(3,2)
array([3, 2])
>>> C.chebval(-3, C.chebline(3,2)) # should be -3
-3.0
```

polynomial.chebyshev.**cheb2poly**(*c*)

Convert a Chebyshev series to a polynomial.

Convert an array representing the coefficients of a Chebyshev series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest to highest degree.

Parameters

c
[array_like] 1-D array containing the Chebyshev series coefficients, ordered from lowest order term to highest.

Returns

pol
[ndarray] 1-D array containing the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest order term to highest.

See also:

poly2cheb

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> from numpy import polynomial as P
>>> c = P.Chebyshev(range(4))
>>> c
Chebyshev([0., 1., 2., 3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> p = c.convert(kind=P.Polynomial)
>>> p
Polynomial([-2., -8.,  4., 12.], domain=[-1.,  1.], window=[-1.,  1.], ...
>>> P.chebyshev.cheb2poly(range(4))
array([-2.,  -8.,   4.,  12.])
```

polynomial.chebyshev.**poly2cheb**(*pol*)

Convert a polynomial to a Chebyshev series.

Convert an array representing the coefficients of a polynomial (relative to the "standard" basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Chebyshev series, ordered from lowest to highest degree.

Parameters

pol
[array_like] 1-D array containing the polynomial coefficients

Returns

c
[ndarray] 1-D array containing the coefficients of the equivalent Chebyshev series.

See also:

cheb2poly

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> from numpy import polynomial as P
>>> p = P.Polynomial(range(4))
>>> p
Polynomial([0., 1., 2., 3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> c = p.convert(kind=P.Chebyshev)
>>> c
Chebyshev([1.  , 3.25, 1.  , 0.75], domain=[-1.,  1.], window=[-1., ...
>>> P.chebyshev.poly2cheb(range(4))
array([1.  , 3.25, 1.  , 0.75])
```

polynomial.chebyshev.**chebinterpolate**(*func*, *deg*, *args=()*)

Interpolate a function at the Chebyshev points of the first kind.

Returns the Chebyshev series that interpolates *func* at the Chebyshev points of the first kind in the interval [-1, 1]. The interpolating series tends to a minmax approximation to *func* with increasing *deg* if the function is continuous in the interval.

Parameters

func
[function] The function to be approximated. It must be a function of a single variable of the form `f(x, a, b, c...)`, where `a, b, c...` are extra arguments passed in the *args* parameter.

deg
[int] Degree of the interpolating polynomial

args
[tuple, optional] Extra arguments to be used in the function call. Default is no extra arguments.

Returns

coef
[ndarray, shape (deg + 1,)] Chebyshev coefficients of the interpolating series ordered from low to high.

Notes

The Chebyshev polynomials used in the interpolation are orthogonal when sampled at the Chebyshev points of the first kind. If it is desired to constrain some of the coefficients they can simply be set to the desired value after the interpolation, no new interpolation or fit is needed. This is especially useful if it is known apriori that some of coefficients are zero. For instance, if the function is even then the coefficients of the terms of odd degree in the result can be set to zero.

Examples

```
>>> import numpy.polynomial.chebyshev as C
>>> C.chebinterpolate(lambda x: np.tanh(x) + 0.5, 8)
array([  5.00000000e-01,   8.11675684e-01,  -9.86864911e-17,
        -5.42457905e-02,  -2.71387850e-16,   4.51658839e-03,
         2.46716228e-17,  -3.79694221e-04,  -3.26899002e-16])
```

See also

numpy.polynomial

Notes

The implementations of multiplication, division, integration, and differentiation use the algebraic identities [1]:

$$T_n(x) = \frac{z^n + z^{-n}}{2}$$
$$z\frac{dx}{dz} = \frac{z - z^{-1}}{2}.$$

where

$$x = \frac{z + z^{-1}}{2}.$$

These identities allow a Chebyshev series to be expressed as a finite, symmetric Laurent series. In this module, this sort of Laurent series is referred to as a "z-series."

References

Hermite Series, "Physicists" (`numpy.polynomial.hermite`)

This module provides a number of objects (mostly functions) useful for dealing with Hermite series, including a *Hermite* class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its "parent" sub-package, *numpy.polynomial*).

Classes

Hermite(coef[, domain, window, symbol])	An Hermite series class.

class numpy.polynomial.hermite.**Hermite**(*coef*, *domain=None*, *window=None*, *symbol='x'*)

An Hermite series class.

The Hermite class provides the standard Python numerical methods '+', '-', '*', '//', '%', 'divmod', '**', and '()' as well as the attributes and methods listed below.

Parameters

coef
: [array_like] Hermite coefficients in order of increasing degree, i.e, `(1, 2, 3)` gives `1*H_0(x) + 2*H_1(x) + 3*H_2(x)`.

domain
: [(2,) array_like, optional] Domain to use. The interval `[domain[0], domain[1]]` is mapped to the interval `[window[0], window[1]]` by shifting and scaling. The default value is [-1., 1.].

window
: [(2,) array_like, optional] Window, see `domain` for its use. The default value is [-1., 1.].

symbol
: [str, optional] Symbol used to represent the independent variable in string representations of the polynomial expression, e.g. for printing. The symbol must be a valid Python identifier. Default value is 'x'.

New in version 1.24.

Attributes

symbol

Methods

`__call__`(arg)	Call self as a function.
`basis`(deg[, domain, window, symbol])	Series basis polynomial of degree *deg*.
`cast`(series[, domain, window])	Convert series to series of this class.
`convert`([domain, kind, window])	Convert series to a different kind and/or domain and/or window.
`copy`()	Return a copy.
`cutdeg`(deg)	Truncate series to the given degree.
`degree`()	The degree of the series.
`deriv`([m])	Differentiate.
`fit`(x, y, deg[, domain, rcond, full, w, ...])	Least squares fit to data.
`fromroots`(roots[, domain, window, symbol])	Return series instance that has the specified roots.
`has_samecoef`(other)	Check if coefficients match.
`has_samedomain`(other)	Check if domains match.
`has_sametype`(other)	Check if types match.
`has_samewindow`(other)	Check if windows match.
`identity`([domain, window, symbol])	Identity function.
`integ`([m, k, lbnd])	Integrate.
`linspace`([n, domain])	Return x, y values at equally spaced points in domain.
`mapparms`()	Return the mapping parameters.
`roots`()	Return the roots of the series polynomial.
`trim`([tol])	Remove trailing coefficients
`truncate`(size)	Truncate series to length *size*.

method

polynomial.hermite.Hermite.**__call__**(*arg*)

Call self as a function.

method

classmethod polynomial.hermite.Hermite.**basis**(*deg*, *domain=None*, *window=None*, *symbol='x'*)

Series basis polynomial of degree *deg*.

Returns the series representing the basis polynomial of degree *deg*.

Parameters

deg
[int] Degree of the basis polynomial for the series. Must be >= 0.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series with the coefficient of the *deg* term set to one and all others zero.

method

classmethod polynomial.hermite.Hermite.**cast**(*series*, *domain=None*, *window=None*)

Convert series to series of this class.

The *series* is expected to be an instance of some polynomial series of one of the types supported by by the numpy.polynomial module, but could be some other class that supports the convert method.

Parameters

series
[series] The series instance to be converted.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series
[series] A series of the same kind as the calling class and equal to *series* when evaluated.

See also:

convert
similar instance method

method

polynomial.hermite.Hermite.**convert**(*domain=None*, *kind=None*, *window=None*)

Convert series to a different kind and/or domain and/or window.

Parameters

domain
[array_like, optional] The domain of the converted series. If the value is None, the default domain of *kind* is used.

kind
[class, optional] The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

window
[array_like, optional] The window of the converted series. If the value is None, the default window of *kind* is used.

Returns

new_series
[series] The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes

Conversion between domains and class types can result in numerically ill defined series.

method

`polynomial.hermite.Hermite.`**`copy`**`()`

Return a copy.

Returns

new_series
[series] Copy of self.

method

`polynomial.hermite.Hermite.`**`cutdeg`**`(`*deg*`)`

Truncate series to the given degree.

Reduce the degree of the series to *deg* by discarding the high order terms. If *deg* is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

deg
[non-negative int] The series is reduced to degree *deg* by discarding the high order terms. The value of *deg* must be a non-negative integer.

Returns

new_series
[series] New instance of series with reduced degree.

method

`polynomial.hermite.Hermite.`**`degree`**`()`

The degree of the series.

Returns

degree
[int] Degree of the series, one less than the number of coefficients.

Examples

Create a polynomial object for `1 + 7*x + 4*x**2`:

```
>>> poly = np.polynomial.Polynomial([1, 7, 4])
>>> print(poly)
1.0 + 7.0·x + 4.0·x²
>>> poly.degree()
2
```

Note that this method does not check for non-zero coefficients. You must trim the polynomial to remove any trailing zeroes:

```
>>> poly = np.polynomial.Polynomial([1, 7, 0])
>>> print(poly)
1.0 + 7.0·x + 0.0·x²
>>> poly.degree()
2
>>> poly.trim().degree()
1
```

method

polynomial.hermite.Hermite.**deriv**(*m=1*)

Differentiate.

Return a series instance of that is the derivative of the current series.

Parameters

m
[non-negative int] Find the derivative of order *m*.

Returns

new_series
[series] A new series representing the derivative. The domain is the same as the domain of the differentiated series.

method

classmethod polynomial.hermite.Hermite.**fit**(*x*, *y*, *deg*, *domain=None*, *rcond=None*, *full=False*, *w=None*, *window=None*, *symbol='x'*)

Least squares fit to data.

Return a series instance that is the least squares fit to the data *y* sampled at *x*. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,)] y-coordinates of the M sample points `(x[i], y[i])`.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

domain
[{None, [beg, end], []}, optional] Domain to use for the returned series. If `None`, then a minimal domain that covers the points *x* is chosen. If `[]` the class domain is used. The default value was the class domain in NumPy 1.4 and `None` in later versions. The `[]` option was added in numpy 1.5.0.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is `len(x)*eps`, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (M,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

window
[{[beg, end]}, optional] Window to use for the returned series. The default value is the default class domain

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series that represents the least squares fit to the data and has the domain and window specified in the call. If the coefficients for the unscaled and unshifted basis polynomials are of interest, do `new_series.convert().coef`.

[resid, rank, sv, rcond]
[list] These values are only returned if `full == True`

- resid – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- sv – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *linalg.lstsq*.

method

classmethod polynomial.hermite.Hermite.**fromroots**(*roots*, *domain=[]*, *window=None*, *symbol='x'*)

Return series instance that has the specified roots.

Returns a series representing the product `(x - r[0])*(x - r[1])*...*(x - r[n-1])`, where `r` is a list of roots.

Parameters

roots
[array_like] List of roots.

domain
[{[], None, array_like}, optional] Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [] the domain is the class domain. The default is [].

window
[{None, array_like}, optional] Window for the returned series. If None the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series with the specified roots.

method

polynomial.hermite.Hermite.**has_samecoef**(*other*)

Check if coefficients match.

Parameters

other
[class instance] The other class must have the `coef` attribute.

Returns

bool
[boolean] True if the coefficients are the same, False otherwise.

method

polynomial.hermite.Hermite.**has_samedomain**(*other*)

Check if domains match.

Parameters

other
[class instance] The other class must have the `domain` attribute.

Returns

bool
[boolean] True if the domains are the same, False otherwise.

method

polynomial.hermite.Hermite.**has_sametype**(*other*)

Check if types match.

Parameters

other
[object] Class instance.

Returns

bool
[boolean] True if other is same class as self

method

polynomial.hermite.Hermite.**has_samewindow**(*other*)

Check if windows match.

Parameters

other
[class instance] The other class must have the `window` attribute.

Returns

bool
[boolean] True if the windows are the same, False otherwise.

method

classmethod polynomial.hermite.Hermite.**identity**(*domain=None*, *window=None*, *symbol='x'*)

Identity function.

If `p` is the returned series, then `p(x) == x` for all values of x.

Parameters

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series of representing the identity.

method

polynomial.hermite.Hermite.**integ**(*m=1*, *k=[]*, *lbnd=None*)

Integrate.

Return a series instance that is the definite integral of the current series.

Parameters

m
[non-negative int] The number of integrations to perform.

k
[array_like] Integration constants. The first constant is applied to the first integration, the second to the second, and so on. The list of values must less than or equal to *m* in length and any missing values are set to zero.

lbnd
[Scalar] The lower bound of the definite integral.

Returns

new_series
[series] A new series representing the integral. The domain is the same as the domain of the integrated series.

method

polynomial.hermite.Hermite.**linspace**(*n=100*, *domain=None*)

Return x, y values at equally spaced points in domain.

Returns the x, y values at *n* linearly spaced points across the domain. Here y is the value of the polynomial at the points x. By default the domain is the same as that of the series instance. This method is intended mostly as a plotting aid.

Parameters

n
[int, optional] Number of point pairs to return. The default value is 100.

domain
[{None, array_like}, optional] If not None, the specified domain is used instead of that of the calling instance. It should be of the form `[beg,end]`. The default is None which case the class domain is used.

Returns

x, y
[ndarray] x is equal to linspace(self.domain[0], self.domain[1], n) and y is the series evaluated at element of x.

method

`polynomial.hermite.Hermite.`**`mapparms`**`()`

Return the mapping parameters.

The returned values define a linear map `off + scl*x` that is applied to the input arguments before the series is evaluated. The map depends on the `domain` and `window`; if the current `domain` is equal to the `window` the resulting map is the identity. If the coefficients of the series instance are to be used by themselves outside this class, then the linear function must be substituted for the `x` in the standard representation of the base polynomials.

Returns

off, scl
[float or complex] The mapping function is defined by `off + scl*x`.

Notes

If the current domain is the interval `[l1, r1]` and the window is `[l2, r2]`, then the linear mapping function `L` is defined by the equations:

```
L(l1) = l2
L(r1) = r2
```

method

`polynomial.hermite.Hermite.`**`roots`**`()`

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decreases the further outside the `domain` they lie.

Returns

roots
[ndarray] Array containing the roots of the series.

method

`polynomial.hermite.Hermite.`**`trim`**`(`*`tol=0`*`)`

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than *tol* or the beginning of the series is reached. If all the coefficients would be removed the series is set to `[0]`. A new series instance is returned with the new coefficients. The current instance remains unchanged.

Parameters

tol
[non-negative number.] All trailing coefficients less than *tol* will be removed.

Returns

new_series
[series] New instance of series with trimmed coefficients.

method

polynomial.hermite.Hermite.**truncate**(*size*)

Truncate series to length *size*.

Reduce the series to length *size* by discarding the high degree terms. The value of *size* must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

size
[positive int] The series is reduced to length *size* by discarding the high degree terms. The value of *size* must be a positive integer.

Returns

new_series
[series] New instance of series with truncated coefficients.

Constants

hermdomain	An array object represents a multidimensional, homogeneous array of fixed-size items.
hermzero	An array object represents a multidimensional, homogeneous array of fixed-size items.
hermone	An array object represents a multidimensional, homogeneous array of fixed-size items.
hermx	An array object represents a multidimensional, homogeneous array of fixed-size items.

polynomial.hermite.**hermdomain = array([-1., 1.])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.hermite.`**`hermzero = array([0])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
: [tuple of ints] Shape of created array.

dtype
: [data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
: [object exposing buffer interface, optional] Used to fill the array with data.

offset
: [int, optional] Offset of array data in buffer.

strides
: [tuple of ints, optional] Strides of data in memory.

order
: [{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
: Construct an array.

zeros
: Create an array, each element of which is zero.

empty
: Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
: Create a data-type.

numpy.typing.NDArray
: An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using `__new__`:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No `__init__` method is needed because the array is fully initialized after the `__new__` method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

polynomial.hermite.**hermone = array([1])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For

example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.hermite.`**`hermx = array([0. , 0.5])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using `__new__`:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No `__init__` method is needed because the array is fully initialized after the `__new__` method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
: [ndarray] Transpose of the array.

data
: [buffer] The array's elements, in memory.

dtype
: [dtype object] Describes the format of the elements in the array.

flags
: [dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
: [numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
: [ndarray] Imaginary part of the array.

real
: [ndarray] Real part of the array.

size
: [int] Number of elements in the array.

itemsize
: [int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

Arithmetic

hermadd(c1, c2)	Add one Hermite series to another.
hermsub(c1, c2)	Subtract one Hermite series from another.
hermmulx(c)	Multiply a Hermite series by x.
hermmul(c1, c2)	Multiply one Hermite series by another.
hermdiv(c1, c2)	Divide one Hermite series by another.
hermpow(c, pow[, maxpower])	Raise a Hermite series to a power.
hermval(x, c[, tensor])	Evaluate an Hermite series at points x.
hermval2d(x, y, c)	Evaluate a 2-D Hermite series at points (x, y).
hermval3d(x, y, z, c)	Evaluate a 3-D Hermite series at points (x, y, z).
hermgrid2d(x, y, c)	Evaluate a 2-D Hermite series on the Cartesian product of x and y.
hermgrid3d(x, y, z, c)	Evaluate a 3-D Hermite series on the Cartesian product of x, y, and z.

polynomial.hermite.**hermadd**(*c1*, *c2*)

Add one Hermite series to another.

Returns the sum of two Hermite series *c1* + *c2*. The arguments are sequences of coefficients ordered from lowest order term to highest, i.e., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Hermite series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the Hermite series of their sum.

See also:

hermsub*, *hermmulx*, *hermmul*, *hermdiv*, *hermpow

Notes

Unlike multiplication, division, etc., the sum of two Hermite series is a Hermite series (without having to "reproject" the result onto the basis set) so addition, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial.hermite import hermadd
>>> hermadd([1, 2, 3], [1, 2, 3, 4])
array([2., 4., 6., 4.])
```

polynomial.hermite.**hermsub**(*c1*, *c2*)

Subtract one Hermite series from another.

Returns the difference of two Hermite series *c1* - *c2*. The sequences of coefficients are from lowest order term to highest, i.e., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Hermite series coefficients ordered from low to high.

Returns

out
[ndarray] Of Hermite series coefficients representing their difference.

See also:

hermadd*, *hermmulx*, *hermmul*, *hermdiv*, *hermpow

Notes

Unlike multiplication, division, etc., the difference of two Hermite series is a Hermite series (without having to "reproject" the result onto the basis set) so subtraction, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial.hermite import hermsub
>>> hermsub([1, 2, 3, 4], [1, 2, 3])
array([0.,  0.,  0.,  4.])
```

polynomial.hermite.**hermmulx**(*c*)

Multiply a Hermite series by x.

Multiply the Hermite series *c* by x, where x is the independent variable.

Parameters

c
[array_like] 1-D array of Hermite series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the result of the multiplication.

See also:

hermadd*, *hermsub*, *hermmul*, *hermdiv*, *hermpow

Notes

The multiplication uses the recursion relationship for Hermite polynomials in the form

$$xP_i(x) = (P_{i+1}(x)/2 + i * P_{i-1}(x))$$

Examples

```
>>> from numpy.polynomial.hermite import hermmulx
>>> hermmulx([1, 2, 3])
array([2. , 6.5, 1. , 1.5])
```

polynomial.hermite.**hermmul**(*c1*, *c2*)

Multiply one Hermite series by another.

Returns the product of two Hermite series *c1* * *c2*. The arguments are sequences of coefficients, from lowest order "term" to highest, e.g., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
: [array_like] 1-D arrays of Hermite series coefficients ordered from low to high.

Returns

out
: [ndarray] Of Hermite series coefficients representing their product.

See also:

hermadd*, *hermsub*, *hermmulx*, *hermdiv*, *hermpow

Notes

In general, the (polynomial) product of two C-series results in terms that are not in the Hermite polynomial basis set. Thus, to express the product as a Hermite series, it is necessary to "reproject" the product onto said basis set, which may produce "unintuitive" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial.hermite import hermmul
>>> hermmul([1, 2, 3], [0, 1, 2])
array([52.,  29.,  52.,   7.,   6.])
```

polynomial.hermite.**hermdiv**(*c1*, *c2*)

Divide one Hermite series by another.

Returns the quotient-with-remainder of two Hermite series *c1* / *c2*. The arguments are sequences of coefficients from lowest order "term" to highest, e.g., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Hermite series coefficients ordered from low to high.

Returns

[quo, rem]
[ndarrays] Of Hermite series coefficients representing the quotient and remainder.

See also:

hermadd, ***hermsub***, ***hermmulx***, ***hermmul***, ***hermpow***

Notes

In general, the (polynomial) division of one Hermite series by another results in quotient and remainder terms that are not in the Hermite polynomial basis set. Thus, to express these results as a Hermite series, it is necessary to "reproject" the results onto the Hermite basis set, which may produce "unintuitive" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial.hermite import hermdiv
>>> hermdiv([ 52.,  29.,  52.,   7.,   6.], [0, 1, 2])
(array([1., 2., 3.]), array([0.]))
>>> hermdiv([ 54.,  31.,  52.,   7.,   6.], [0, 1, 2])
(array([1., 2., 3.]), array([2., 2.]))
>>> hermdiv([ 53.,  30.,  52.,   7.,   6.], [0, 1, 2])
(array([1., 2., 3.]), array([1., 1.]))
```

polynomial.hermite.**hermpow**(*c*, *pow*, *maxpower=16*)

Raise a Hermite series to a power.

Returns the Hermite series *c* raised to the power *pow*. The argument *c* is a sequence of coefficients ordered from low to high. i.e., [1,2,3] is the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c
[array_like] 1-D array of Hermite series coefficients ordered from low to high.

pow
[integer] Power to which the series will be raised

maxpower
[integer, optional] Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

Returns

coef
[ndarray] Hermite series of power.

See also:

hermadd, ***hermsub***, ***hermmulx***, ***hermmul***, ***hermdiv***

Examples

```
>>> from numpy.polynomial.hermite import hermpow
>>> hermpow([1, 2, 3], 2)
array([81.,  52.,  82.,  12.,   9.])
```

polynomial.hermite.**hermval**(*x*, *c*, *tensor=True*)

Evaluate an Hermite series at points x.

If *c* is of length `n + 1`, this function returns the value:

$$p(x) = c_0 * H_0(x) + c_1 * H_1(x) + ... + c_n * H_n(x)$$

The parameter *x* is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either *x* or its elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array, then `p(x)` will have the same shape as *x*. If *c* is multidimensional, then the shape of the result depends on the value of *tensor*. If *tensor* is true the shape will be c.shape[1:] + x.shape. If *tensor* is false the shape will be c.shape[1:]. Note that scalars have shape (,).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

Parameters

x
: [array_like, compatible object] If *x* is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, *x* or its elements must support addition and multiplication with themselves and with the elements of *c*.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree n are contained in c[n]. If *c* is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of *c*.

tensor
: [boolean, optional] If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of *x*. Scalars have dimension 0 for this action. The result is that every column of coefficients in *c* is evaluated for every element of *x*. If False, *x* is broadcast over the columns of *c* for the evaluation. This keyword is useful when *c* is multidimensional. The default value is True.

Returns

values
: [ndarray, algebra_like] The shape of the return value is described above.

See also:

hermval2d, ***hermgrid2d***, ***hermval3d***, ***hermgrid3d***

Notes

The evaluation uses Clenshaw recursion, aka synthetic division.

Examples

```
>>> from numpy.polynomial.hermite import hermval
>>> coef = [1,2,3]
>>> hermval(1, coef)
11.0
>>> hermval([[1,2],[3,4]], coef)
array([[ 11.,   51.],
       [115.,  203.]])
```

polynomial.hermite.**hermval2d**(*x*, *y*, *c*)

Evaluate a 2-D Hermite series at points (x, y).

This function returns the values:

$$p(x,y) = \sum_{i,j} c_{i,j} * H_i(x) * H_j(y)$$

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

Parameters

x, y
: [array_like, compatible objects] The two dimensional series is evaluated at the points `(x, y)`, where *x* and *y* must have the same shape. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points formed with pairs of corresponding values from *x* and *y*.

See also:

hermval, ***hermgrid2d***, ***hermval3d***, ***hermgrid3d***

Examples

```
>>> from numpy.polynomial.hermite import hermval2d
>>> x = [1, 2]
>>> y = [4, 5]
>>> c = [[1, 2, 3], [4, 5, 6]]
>>> hermval2d(x, y, c)
array([1035., 2883.])
```

polynomial.hermite.**hermval3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D Hermite series at points (x, y, z).

This function returns the values:

$$p(x,y,z) = \sum_{i,j,k} c_{i,j,k} * H_i(x) * H_j(y) * H_k(z)$$

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape.

Parameters

x, y, z
: [array_like, compatible object] The three dimensional series is evaluated at the points `(x, y, z)`, where *x*, *y*, and *z* must have the same shape. If any of *x*, *y*, or *z* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j,k is contained in `c[i,j,k]`. If *c* has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the multidimensional polynomial on points formed with triples of corresponding values from *x*, *y*, and *z*.

See also:

hermval, ***hermval2d***, ***hermgrid2d***, ***hermgrid3d***

Examples

```
>>> from numpy.polynomial.hermite import hermval3d
>>> x = [1, 2]
>>> y = [4, 5]
>>> z = [6, 7]
>>> c = [[[1, 2, 3], [4, 5, 6]], [[7, 8, 9], [10, 11, 12]]]
>>> hermval3d(x, y, z, c)
array([ 40077., 120131.])
```

polynomial.hermite.**hermgrid2d**(*x*, *y*, *c*)

Evaluate a 2-D Hermite series on the Cartesian product of x and y.

This function returns the values:

$$p(a,b) = \sum_{i,j} c_{i,j} * H_i(a) * H_j(b)$$

where the points `(a, b)` consist of all pairs formed by taking *a* from *x* and *b* from *y*. The resulting points form a grid with *x* in the first dimension and *y* in the second.

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

Parameters

x, y
: [array_like, compatible objects] The two dimensional series is evaluated at the points in the Cartesian product of *x* and *y*. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points in the Cartesian product of *x* and *y*.

See also:

hermval*, *hermval2d*, *hermval3d*, *hermgrid3d

Examples

```
>>> from numpy.polynomial.hermite import hermgrid2d
>>> x = [1, 2, 3]
>>> y = [4, 5]
>>> c = [[1, 2, 3], [4, 5, 6]]
>>> hermgrid2d(x, y, c)
array([[1035., 1599.],
       [1867., 2883.],
       [2699., 4167.]])
```

polynomial.hermite.**hermgrid3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D Hermite series on the Cartesian product of x, y, and z.

This function returns the values:

$$p(a,b,c) = \sum_{i,j,k} c_{i,j,k} * H_i(a) * H_j(b) * H_k(c)$$

where the points `(a, b, c)` consist of all triples formed by taking *a* from *x*, *b* from *y*, and *c* from *z*. The resulting points form a grid with *x* in the first dimension, *y* in the second, and *z* in the third.

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape + y.shape + z.shape.

Parameters

x, y, z
: [array_like, compatible objects] The three dimensional series is evaluated at the points in the Cartesian product of *x*, *y*, and *z*. If *x*, *y*, or *z* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points in the Cartesian product of *x* and *y*.

See also:

hermval, ***hermval2d***, ***hermgrid2d***, ***hermval3d***

Examples

```
>>> from numpy.polynomial.hermite import hermgrid3d
>>> x = [1, 2]
>>> y = [4, 5]
>>> z = [6, 7]
>>> c = [[[1, 2, 3], [4, 5, 6]], [[7, 8, 9], [10, 11, 12]]]
>>> hermgrid3d(x, y, z, c)
array([[[ 40077.,  54117.],
        [ 49293.,  66561.]],
       [[ 72375.,  97719.],
        [ 88975., 120131.]]])
```

Calculus

hermder(c[, m, scl, axis])	Differentiate a Hermite series.
hermint(c[, m, k, lbnd, scl, axis])	Integrate a Hermite series.

`polynomial.hermite.`**`hermder`**(*c*, *m=1*, *scl=1*, *axis=0*)

Differentiate a Hermite series.

Returns the Hermite series coefficients *c* differentiated *m* times along *axis*. At each iteration the result is multiplied by *scl* (the scaling factor is for use in a linear change of variable). The argument *c* is an array of coefficients from low

to high degree along each axis, e.g., [1,2,3] represents the series `1*H_0 + 2*H_1 + 3*H_2` while [[1,2],[1,2]] represents `1*H_0(x)*H_0(y) + 1*H_1(x)*H_0(y) + 2*H_0(x)*H_1(y) + 2*H_1(x)*H_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of Hermite series coefficients. If *c* is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Number of derivatives taken, must be non-negative. (Default: 1)

scl
: [scalar, optional] Each differentiation is multiplied by *scl*. The end result is multiplication by `scl**m`. This is for use in a linear change of variable. (Default: 1)

axis
: [int, optional] Axis over which the derivative is taken. (Default: 0).

Returns

der
: [ndarray] Hermite series of the derivative.

See also:

hermint

Notes

In general, the result of differentiating a Hermite series does not resemble the same operation on a power series. Thus the result of this function may be "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial.hermite import hermder
>>> hermder([ 1. ,  0.5,  0.5,  0.5])
array([1., 2., 3.])
>>> hermder([-0.5,  1./2.,  1./8.,  1./12.,  1./16.], m=2)
array([1., 2., 3.])
```

`polynomial.hermite.`**`hermint`**(*c*, *m=1*, *k=[]*, *lbnd=0*, *scl=1*, *axis=0*)

Integrate a Hermite series.

Returns the Hermite series coefficients *c* integrated *m* times from *lbnd* along *axis*. At each iteration the resulting series is **multiplied** by *scl* and an integration constant, *k*, is added. The scaling factor is for use in a linear change of variable. ("Buyer beware": note that, depending on what one is doing, one may want *scl* to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series `H_0 + 2*H_1 + 3*H_2` while [[1,2],[1,2]] represents `1*H_0(x)*H_0(y) + 1*H_1(x)*H_0(y) + 2*H_0(x)*H_1(y) + 2*H_1(x)*H_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of Hermite series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Order of integration, must be positive. (Default: 1)

k
: [{[], list, scalar}, optional] Integration constant(s). The value of the first integral at `lbnd` is the first value in the list, the value of the second integral at `lbnd` is the second value, etc. If `k == []` (the default), all constants are set to zero. If `m == 1`, a single scalar can be given instead of a list.

lbnd
: [scalar, optional] The lower bound of the integral. (Default: 0)

scl
: [scalar, optional] Following each integration the result is *multiplied* by *scl* before the integration constant is added. (Default: 1)

axis
: [int, optional] Axis over which the integral is taken. (Default: 0).

Returns

S
: [ndarray] Hermite series coefficients of the integral.

Raises

ValueError
: If `m < 0`, `len(k) > m`, `np.ndim(lbnd) != 0`, or `np.ndim(scl) != 0`.

See also:

hermder

Notes

Note that the result of each integration is *multiplied* by *scl*. Why is this important to note? Say one is making a linear change of variable $u = ax + b$ in an integral relative to x. Then $dx = du/a$, so one will need to set *scl* equal to $1/a$ - perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be "reprojected" onto the C-series basis set. Thus, typically, the result of this function is "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial.hermite import hermint
>>> hermint([1,2,3]) # integrate once, value 0 at 0.
array([1. , 0.5, 0.5, 0.5])
>>> hermint([1,2,3], m=2) # integrate twice, value & deriv 0 at 0
array([-0.5       ,  0.5       ,  0.125     ,  0.08333333,  0.0625    ]) # may␣
↪vary
>>> hermint([1,2,3], k=1) # integrate once, value 1 at 0.
array([2. , 0.5, 0.5, 0.5])
>>> hermint([1,2,3], lbnd=-1) # integrate once, value 0 at -1
array([-2. ,  0.5,  0.5,  0.5])
>>> hermint([1,2,3], m=2, k=[1,2], lbnd=-1)
array([ 1.66666667, -0.5       ,  0.125     ,  0.08333333,  0.0625    ]) # may␣
↪vary
```

Misc Functions

hermfromroots(roots)	Generate a Hermite series with given roots.
hermroots(c)	Compute the roots of a Hermite series.
hermvander(x, deg)	Pseudo-Vandermonde matrix of given degree.
hermvander2d(x, y, deg)	Pseudo-Vandermonde matrix of given degrees.
hermvander3d(x, y, z, deg)	Pseudo-Vandermonde matrix of given degrees.
hermgauss(deg)	Gauss-Hermite quadrature.
hermweight(x)	Weight function of the Hermite polynomials.
hermcompanion(c)	Return the scaled companion matrix of c.
hermfit(x, y, deg[, rcond, full, w])	Least squares fit of Hermite series to data.
hermtrim(c[, tol])	Remove "small" "trailing" coefficients from a polynomial.
hermline(off, scl)	Hermite series whose graph is a straight line.
herm2poly(c)	Convert a Hermite series to a polynomial.
poly2herm(pol)	Convert a polynomial to a Hermite series.

polynomial.hermite.**hermfromroots**(*roots*)

Generate a Hermite series with given roots.

The function returns the coefficients of the polynomial

$$p(x) = (x - r_0) * (x - r_1) * ... * (x - r_n),$$

in Hermite form, where the r_n are the roots specified in *roots*. If a zero has multiplicity n, then it must appear in *roots* n times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then *roots* looks something like [2, 2, 2, 3, 3]. The roots can appear in any order.

If the returned coefficients are *c*, then

$$p(x) = c_0 + c_1 * H_1(x) + ... + c_n * H_n(x)$$

The coefficient of the last term is not generally 1 for monic polynomials in Hermite form.

Parameters

roots
[array_like] Sequence containing the roots.

Returns

out
[ndarray] 1-D array of coefficients. If all roots are real then *out* is a real array, if some of the roots are complex, then *out* is complex even if all the coefficients in the result are real (see Examples below).

See also:

numpy.polynomial.polynomial.polyfromroots
numpy.polynomial.legendre.legfromroots
numpy.polynomial.laguerre.lagfromroots
numpy.polynomial.chebyshev.chebfromroots
numpy.polynomial.hermite_e.hermefromroots

Examples

```
>>> from numpy.polynomial.hermite import hermfromroots, hermval
>>> coef = hermfromroots((-1, 0, 1))
>>> hermval((-1, 0, 1), coef)
array([0.,  0.,  0.])
>>> coef = hermfromroots((-1j, 1j))
>>> hermval((-1j, 1j), coef)
array([0.+0.j, 0.+0.j])
```

polynomial.hermite.**hermroots**(*c*)

Compute the roots of a Hermite series.

Return the roots (a.k.a. "zeros") of the polynomial

$$p(x) = \sum_i c[i] * H_i(x).$$

Parameters

c
[1-D array_like] 1-D array of coefficients.

Returns

out
[ndarray] Array of the roots of the series. If all the roots are real, then *out* is also real, otherwise it is complex.

See also:

numpy.polynomial.polynomial.polyroots
numpy.polynomial.legendre.legroots
numpy.polynomial.laguerre.lagroots
numpy.polynomial.chebyshev.chebroots
numpy.polynomial.hermite_e.hermeroots

Notes

The root estimates are obtained as the eigenvalues of the companion matrix, Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton's method.

The Hermite series basis polynomials aren't powers of x so the results of this function may seem unintuitive.

Examples

```
>>> from numpy.polynomial.hermite import hermroots, hermfromroots
>>> coef = hermfromroots([-1, 0, 1])
>>> coef
array([0.   ,  0.25 ,  0.   ,  0.125])
>>> hermroots(coef)
array([-1.00000000e+00, -1.38777878e-17,  1.00000000e+00])
```

polynomial.hermite.**hermvander**(*x*, *deg*)

Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree *deg* and sample points *x*. The pseudo-Vandermonde matrix is defined by

$$V[..., i] = H_i(x),$$

where `0 <= i <= deg`. The leading indices of *V* index the elements of *x* and the last index is the degree of the Hermite polynomial.

If *c* is a 1-D array of coefficients of length `n + 1` and *V* is the array `V = hermvander(x, n)`, then `np.dot(V, c)` and `hermval(x, c)` are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of Hermite series of the same degree and sample points.

Parameters

x
: [array_like] Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If *x* is scalar it is converted to a 1-D array.

deg
: [int] Degree of the resulting matrix.

Returns

vander
: [ndarray] The pseudo-Vandermonde matrix. The shape of the returned matrix is `x.shape + (deg + 1,)`, where The last index is the degree of the corresponding Hermite polynomial. The dtype will be the same as the converted *x*.

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.hermite import hermvander
>>> x = np.array([-1, 0, 1])
>>> hermvander(x, 3)
array([[ 1., -2.,  2.,  4.],
       [ 1.,  0., -2., -0.],
       [ 1.,  2.,  2., -4.]])
```

polynomial.hermite.**hermvander2d**(*x*, *y*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y)`. The pseudo-Vandermonde matrix is defined by

$$V[..., (deg[1] + 1) * i + j] = H_i(x) * H_j(y),$$

where `0 <= i <= deg[0]` and `0 <= j <= deg[1]`. The leading indices of *V* index the points `(x, y)` and the last index encodes the degrees of the Hermite polynomials.

If `V = hermvander2d(x, y, [xdeg, ydeg])`, then the columns of *V* correspond to the elements of a 2-D coefficient array *c* of shape (xdeg + 1, ydeg + 1) in the order

$$c_{00}, c_{01}, c_{02} ..., c_{10}, c_{11}, c_{12} ...$$

and `np.dot(V, c.flat)` and `hermval2d(x, y, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D Hermite series of the same degrees and sample points.

Parameters

x, y
[array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
[list of ints] List of maximum degrees of the form [x_deg, y_deg].

Returns

vander2d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)$. The dtype will be the same as the converted *x* and *y*.

See also:

hermvander, ***hermvander3d***, ***hermval2d***, ***hermval3d***

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.hermite import hermvander2d
>>> x = np.array([-1, 0, 1])
>>> y = np.array([-1, 0, 1])
>>> hermvander2d(x, y, [2, 2])
array([[ 1., -2.,  2., -2.,  4., -4.,  2., -4.,  4.],
       [ 1.,  0., -2.,  0.,  0., -0., -2., -0.,  4.],
       [ 1.,  2.,  2.,  2.,  4.,  4.,  2.,  4.,  4.]])
```

`polynomial.hermite.`**hermvander3d**(*x*, *y*, *z*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y, z)`. If *l*, *m*, *n* are the given degrees in *x*, *y*, *z*, then The pseudo-Vandermonde matrix is defined by

$$V[..., (m+1)(n+1)i + (n+1)j + k] = H_i(x) * H_j(y) * H_k(z),$$

where `0 <= i <= l`, `0 <= j <= m`, and `0 <= j <= n`. The leading indices of *V* index the points `(x, y, z)` and the last index encodes the degrees of the Hermite polynomials.

If `V = hermvander3d(x, y, z, [xdeg, ydeg, zdeg])`, then the columns of *V* correspond to the elements of a 3-D coefficient array *c* of shape (xdeg + 1, ydeg + 1, zdeg + 1) in the order

$$c_{000}, c_{001}, c_{002}, ..., c_{010}, c_{011}, c_{012}, ...$$

and `np.dot(V, c.flat)` and `hermval3d(x, y, z, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D Hermite series of the same degrees and sample points.

Parameters

x, y, z
[array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
[list of ints] List of maximum degrees of the form [x_deg, y_deg, z_deg].

Returns

vander3d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)*(deg[2]+1)$. The dtype will be the same as the converted x, y, and z.

See also:

hermvander, ***hermvander3d***, ***hermval2d***, ***hermval3d***

Examples

```
>>> from numpy.polynomial.hermite import hermvander3d
>>> x = np.array([-1, 0, 1])
>>> y = np.array([-1, 0, 1])
>>> z = np.array([-1, 0, 1])
>>> hermvander3d(x, y, z, [0, 1, 2])
array([[ 1., -2.,  2., -2.,  4., -4.],
       [ 1.,  0., -2.,  0.,  0., -0.],
       [ 1.,  2.,  2.,  2.,  4.,  4.]])
```

`polynomial.hermite.`**`hermgauss`**(*deg*)

Gauss-Hermite quadrature.

Computes the sample points and weights for Gauss-Hermite quadrature. These sample points and weights will correctly integrate polynomials of degree $2*deg-1$ or less over the interval $[-\inf, \inf]$ with the weight function $f(x) = \exp(-x^2)$.

Parameters

deg
[int] Number of sample points and weights. It must be >= 1.

Returns

x
[ndarray] 1-D ndarray containing the sample points.

y
[ndarray] 1-D ndarray containing the weights.

Notes

The results have only been tested up to degree 100, higher degrees may be problematic. The weights are determined by using the fact that

$$w_k = c/(H'_n(x_k) * H_{n-1}(x_k))$$

where c is a constant independent of k and x_k is the k'th root of H_n, and then scaling the results to get the right value when integrating 1.

Examples

```
>>> from numpy.polynomial.hermite import hermgauss
>>> hermgauss(2)
(array([-0.70710678,  0.70710678]), array([0.88622693, 0.88622693]))
```

polynomial.hermite.**hermweight**(*x*)

Weight function of the Hermite polynomials.

The weight function is $\exp(-x^2)$ and the interval of integration is $[-\inf, \inf]$. the Hermite polynomials are orthogonal, but not normalized, with respect to this weight function.

Parameters

x
[array_like] Values at which the weight function will be computed.

Returns

w
[ndarray] The weight function at *x*.

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.hermite import hermweight
>>> x = np.arange(-2, 2)
>>> hermweight(x)
array([0.01831564, 0.36787944, 1.        , 0.36787944])
```

polynomial.hermite.**hermcompanion**(*c*)

Return the scaled companion matrix of c.

The basis polynomials are scaled so that the companion matrix is symmetric when *c* is an Hermite basis polynomial. This provides better eigenvalue estimates than the unscaled case and for basis polynomials the eigenvalues are guaranteed to be real if *numpy.linalg.eigvalsh* is used to obtain them.

Parameters

c
[array_like] 1-D array of Hermite series coefficients ordered from low to high degree.

Returns

mat
[ndarray] Scaled companion matrix of dimensions (deg, deg).

Examples

```
>>> from numpy.polynomial.hermite import hermcompanion
>>> hermcompanion([1, 0, 1])
array([[0.        , 0.35355339],
       [0.70710678, 0.        ]])
```

polynomial.hermite.**hermfit**(*x*, *y*, *deg*, *rcond=None*, *full=False*, *w=None*)

Least squares fit of Hermite series to data.

Return the coefficients of a Hermite series of degree *deg* that is the least squares fit to the data values *y* given at points *x*. If *y* is 1-D the returned coefficients will also be 1-D. If *y* is 2-D multiple fits are done, one for each column of *y*, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

$$p(x) = c_0 + c_1 * H_1(x) + ... + c_n * H_n(x),$$

where *n* is *deg*.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,) or (M, K)] y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (*M*,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

Returns

coef
[ndarray, shape (M,) or (M, K)] Hermite coefficients ordered from low to high. If *y* was 2-D, the coefficients for the data in column k of *y* are in column *k*.

[residuals, rank, singular_values, rcond]
[list] These values are only returned if `full == True`

- residuals – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- singular_values – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *numpy.linalg.lstsq*.

Warns

RankWarning
The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if `full == False`. The warnings can be turned off by

```
>>> import warnings
>>> warnings.simplefilter('ignore', np.exceptions.RankWarning)
```

See also:

numpy.polynomial.chebyshev.chebfit
numpy.polynomial.legendre.legfit
numpy.polynomial.laguerre.lagfit
numpy.polynomial.polynomial.polyfit
numpy.polynomial.hermite_e.hermefit
hermval
Evaluates a Hermite series.

hermvander
Vandermonde matrix of Hermite series.

hermweight
Hermite weight function

numpy.linalg.lstsq
Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline
Computes spline fits.

Notes

The solution is the coefficients of the Hermite series *p* that minimizes the sum of the weighted squared errors

$$E = \sum_j w_j^2 * |y_j - p(x_j)|^2,$$

where the w_j are the weights. This problem is solved by setting up the (typically) overdetermined matrix equation

$$V(x) * c = w * y,$$

where *V* is the weighted pseudo Vandermonde matrix of *x*, *c* are the coefficients to be solved for, *w* are the weights, *y* are the observed values. This equation is then solved using the singular value decomposition of *V*.

If some of the singular values of *V* are so small that they are neglected, then a *RankWarning* will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The *rcond* parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using Hermite series are probably most useful when the data can be approximated by `sqrt(w(x)) * p(x)`, where `w(x)` is the Hermite weight. In that case the weight `sqrt(w(x[i]))` should be used together with data values `y[i]/sqrt(w(x[i]))`. The weight function is available as *hermweight*.

References

[1]

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.hermite import hermfit, hermval
>>> x = np.linspace(-10, 10)
>>> rng = np.random.default_rng()
>>> err = rng.normal(scale=1./10, size=len(x))
>>> y = hermval(x, [1, 2, 3]) + err
>>> hermfit(x, y, 2)
array([1.02294967, 2.00016403, 2.99994614]) # may vary
```

polynomial.hermite.**hermtrim**(*c*, *tol=0*)

Remove "small" "trailing" coefficients from a polynomial.

"Small" means "small in absolute value" and is controlled by the parameter *tol*; "trailing" means highest order coefficient(s), e.g., in `[0, 1, 1, 0, 0]` (which represents `0 + x + x**2 + 0*x**3 + 0*x**4`) both the 3-rd and 4-th order coefficients would be "trimmed."

Parameters

c
: [array_like] 1-d array of coefficients, ordered from lowest order to highest.

tol
: [number, optional] Trailing (i.e., highest order) elements with absolute value less than or equal to *tol* (default value is zero) are removed.

Returns

trimmed
: [ndarray] 1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError
: If *tol* < 0

Examples

```
>>> from numpy.polynomial import polyutils as pu
>>> pu.trimcoef((0,0,3,0,5,0,0))
array([0.,  0.,  3.,  0.,  5.])
>>> pu.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([0.])
>>> i = complex(0,1) # works for complex
>>> pu.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([0.0003+0.j   , 0.001 -0.001j])
```

polynomial.hermite.**hermline**(*off*, *scl*)

Hermite series whose graph is a straight line.

Parameters

off, scl
[scalars] The specified line is given by `off + scl*x`.

Returns

y
[ndarray] This module's representation of the Hermite series for `off + scl*x`.

See also:

numpy.polynomial.polynomial.polyline
numpy.polynomial.chebyshev.chebline
numpy.polynomial.legendre.legline
numpy.polynomial.laguerre.lagline
numpy.polynomial.hermite_e.hermeline

Examples

```
>>> from numpy.polynomial.hermite import hermline, hermval
>>> hermval(0,hermline(3, 2))
3.0
>>> hermval(1,hermline(3, 2))
5.0
```

polynomial.hermite.**herm2poly**(*c*)

Convert a Hermite series to a polynomial.

Convert an array representing the coefficients of a Hermite series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest to highest degree.

Parameters

c
[array_like] 1-D array containing the Hermite series coefficients, ordered from lowest order term to highest.

Returns

pol
[ndarray] 1-D array containing the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest order term to highest.

See also:

poly2herm

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> from numpy.polynomial.hermite import herm2poly
>>> herm2poly([ 1.   ,  2.75 ,  0.5  ,  0.375])
array([0., 1., 2., 3.])
```

polynomial.hermite.**poly2herm**(*pol*)

Convert a polynomial to a Hermite series.

Convert an array representing the coefficients of a polynomial (relative to the "standard" basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Hermite series, ordered from lowest to highest degree.

Parameters

pol
[array_like] 1-D array containing the polynomial coefficients

Returns

c
[ndarray] 1-D array containing the coefficients of the equivalent Hermite series.

See also:

herm2poly

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> from numpy.polynomial.hermite import poly2herm
>>> poly2herm(np.arange(4))
array([1.   ,  2.75 ,  0.5  ,  0.375])
```

See also

numpy.polynomial

HermiteE Series, "Probabilists" (`numpy.polynomial.hermite_e`)

This module provides a number of objects (mostly functions) useful for dealing with Hermite_e series, including a *HermiteE* class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its "parent" sub-package, *numpy.polynomial*).

Classes

HermiteE(coef[, domain, window, symbol])	An HermiteE series class.

class numpy.polynomial.hermite_e.**HermiteE**(*coef*, *domain=None*, *window=None*, *symbol='x'*)

An HermiteE series class.

The HermiteE class provides the standard Python numerical methods '+', '-', '*', '//', '%', 'divmod', '**', and '()' as well as the attributes and methods listed below.

Parameters

coef
: [array_like] HermiteE coefficients in order of increasing degree, i.e, `(1, 2, 3)` gives `1*He_0(x) + 2*He_1(X) + 3*He_2(x)`.

domain
: [(2,) array_like, optional] Domain to use. The interval `[domain[0], domain[1]]` is mapped to the interval `[window[0], window[1]]` by shifting and scaling. The default value is [-1., 1.].

window
: [(2,) array_like, optional] Window, see `domain` for its use. The default value is [-1., 1.].

symbol
: [str, optional] Symbol used to represent the independent variable in string representations of the polynomial expression, e.g. for printing. The symbol must be a valid Python identifier. Default value is 'x'.

  New in version 1.24.

Attributes

symbol

Methods

`__call__`(arg)	Call self as a function.
`basis`(deg[, domain, window, symbol])	Series basis polynomial of degree *deg*.
`cast`(series[, domain, window])	Convert series to series of this class.
`convert`([domain, kind, window])	Convert series to a different kind and/or domain and/or window.
`copy`()	Return a copy.
`cutdeg`(deg)	Truncate series to the given degree.
`degree`()	The degree of the series.
`deriv`([m])	Differentiate.
`fit`(x, y, deg[, domain, rcond, full, w, ...])	Least squares fit to data.
`fromroots`(roots[, domain, window, symbol])	Return series instance that has the specified roots.
`has_samecoef`(other)	Check if coefficients match.
`has_samedomain`(other)	Check if domains match.
`has_sametype`(other)	Check if types match.
`has_samewindow`(other)	Check if windows match.
`identity`([domain, window, symbol])	Identity function.
`integ`([m, k, lbnd])	Integrate.
`linspace`([n, domain])	Return x, y values at equally spaced points in domain.
`mapparms`()	Return the mapping parameters.
`roots`()	Return the roots of the series polynomial.
`trim`([tol])	Remove trailing coefficients
`truncate`(size)	Truncate series to length *size*.

method

polynomial.hermite_e.HermiteE.**__call__**(*arg*)

Call self as a function.

method

classmethod polynomial.hermite_e.HermiteE.**basis**(*deg*, *domain=None*, *window=None*, *symbol='x'*)

Series basis polynomial of degree *deg*.

Returns the series representing the basis polynomial of degree *deg*.

Parameters

deg
[int] Degree of the basis polynomial for the series. Must be >= 0.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series with the coefficient of the *deg* term set to one and all others zero.

method

classmethod polynomial.hermite_e.HermiteE.**cast**(*series*, *domain=None*, *window=None*)

Convert series to series of this class.

The *series* is expected to be an instance of some polynomial series of one of the types supported by by the numpy.polynomial module, but could be some other class that supports the convert method.

Parameters

series
[series] The series instance to be converted.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series
[series] A series of the same kind as the calling class and equal to *series* when evaluated.

See also:

convert
similar instance method

method

polynomial.hermite_e.HermiteE.**convert**(*domain=None*, *kind=None*, *window=None*)

Convert series to a different kind and/or domain and/or window.

Parameters

domain
[array_like, optional] The domain of the converted series. If the value is None, the default domain of *kind* is used.

kind
[class, optional] The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

window
[array_like, optional] The window of the converted series. If the value is None, the default window of *kind* is used.

Returns

new_series
[series] The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes

Conversion between domains and class types can result in numerically ill defined series.

method

polynomial.hermite_e.HermiteE.**copy**()

Return a copy.

Returns

new_series
[series] Copy of self.

method

polynomial.hermite_e.HermiteE.**cutdeg**(*deg*)

Truncate series to the given degree.

Reduce the degree of the series to *deg* by discarding the high order terms. If *deg* is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

deg
[non-negative int] The series is reduced to degree *deg* by discarding the high order terms. The value of *deg* must be a non-negative integer.

Returns

new_series
[series] New instance of series with reduced degree.

method

polynomial.hermite_e.HermiteE.**degree**()

The degree of the series.

Returns

degree
[int] Degree of the series, one less than the number of coefficients.

Examples

Create a polynomial object for `1 + 7*x + 4*x**2`:

```
>>> poly = np.polynomial.Polynomial([1, 7, 4])
>>> print(poly)
1.0 + 7.0·x + 4.0·x²
>>> poly.degree()
2
```

Note that this method does not check for non-zero coefficients. You must trim the polynomial to remove any trailing zeroes:

```
>>> poly = np.polynomial.Polynomial([1, 7, 0])
>>> print(poly)
1.0 + 7.0·x + 0.0·x²
```

(continues on next page)

(continued from previous page)

```
>>> poly.degree()
2
>>> poly.trim().degree()
1
```

method

polynomial.hermite_e.HermiteE.**deriv**(*m=1*)

Differentiate.

Return a series instance of that is the derivative of the current series.

Parameters

m
[non-negative int] Find the derivative of order *m*.

Returns

new_series
[series] A new series representing the derivative. The domain is the same as the domain of the differentiated series.

method

classmethod polynomial.hermite_e.HermiteE.**fit**(*x*, *y*, *deg*, *domain=None*, *rcond=None*, *full=False*, *w=None*, *window=None*, *symbol='x'*)

Least squares fit to data.

Return a series instance that is the least squares fit to the data *y* sampled at *x*. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,)] y-coordinates of the M sample points `(x[i], y[i])`.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

domain
[{None, [beg, end], []}, optional] Domain to use for the returned series. If `None`, then a minimal domain that covers the points *x* is chosen. If `[]` the class domain is used. The default value was the class domain in NumPy 1.4 and `None` in later versions. The `[]` option was added in numpy 1.5.0.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is `len(x)*eps`, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (M,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

window
[{[beg, end]}, optional] Window to use for the returned series. The default value is the default class domain

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series that represents the least squares fit to the data and has the domain and window specified in the call. If the coefficients for the unscaled and unshifted basis polynomials are of interest, do `new_series.convert().coef`.

[resid, rank, sv, rcond]
[list] These values are only returned if `full == True`

- resid – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- sv – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *linalg.lstsq*.

method

classmethod polynomial.hermite_e.HermiteE.**fromroots**(*roots*, *domain=[]*, *window=None*, *symbol='x'*)

Return series instance that has the specified roots.

Returns a series representing the product `(x - r[0])*(x - r[1])*...*(x - r[n-1])`, where `r` is a list of roots.

Parameters

roots
[array_like] List of roots.

domain
[{[], None, array_like}, optional] Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [] the domain is the class domain. The default is [].

window
[{None, array_like}, optional] Window for the returned series. If None the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series with the specified roots.

method

polynomial.hermite_e.HermiteE.**has_samecoef**(*other*)

Check if coefficients match.

Parameters

other
[class instance] The other class must have the `coef` attribute.

Returns

bool
[boolean] True if the coefficients are the same, False otherwise.

method

polynomial.hermite_e.HermiteE.**has_samedomain**(*other*)

Check if domains match.

Parameters

other
[class instance] The other class must have the `domain` attribute.

Returns

bool
[boolean] True if the domains are the same, False otherwise.

method

polynomial.hermite_e.HermiteE.**has_sametype**(*other*)

Check if types match.

Parameters

other
[object] Class instance.

Returns

bool
[boolean] True if other is same class as self

method

polynomial.hermite_e.HermiteE.**has_samewindow**(*other*)

Check if windows match.

Parameters

other
[class instance] The other class must have the `window` attribute.

Returns

bool
[boolean] True if the windows are the same, False otherwise.

method

classmethod polynomial.hermite_e.HermiteE.**identity**(*domain=None*, *window=None*, *symbol='x'*)

Identity function.

If `p` is the returned series, then `p(x) == x` for all values of x.

Parameters

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series of representing the identity.

method

polynomial.hermite_e.HermiteE.**integ**(*m=1*, *k=[]*, *lbnd=None*)

Integrate.

Return a series instance that is the definite integral of the current series.

Parameters

m
[non-negative int] The number of integrations to perform.

k
[array_like] Integration constants. The first constant is applied to the first integration, the second to the second, and so on. The list of values must less than or equal to *m* in length and any missing values are set to zero.

lbnd
[Scalar] The lower bound of the definite integral.

Returns

new_series
[series] A new series representing the integral. The domain is the same as the domain of the integrated series.

method

polynomial.hermite_e.HermiteE.**linspace**(*n=100*, *domain=None*)

Return x, y values at equally spaced points in domain.

Returns the x, y values at *n* linearly spaced points across the domain. Here y is the value of the polynomial at the points x. By default the domain is the same as that of the series instance. This method is intended mostly as a plotting aid.

Parameters

n
[int, optional] Number of point pairs to return. The default value is 100.

domain
[{None, array_like}, optional] If not None, the specified domain is used instead of that of the calling instance. It should be of the form `[beg,end]`. The default is None which case the class domain is used.

Returns

x, y
[ndarray] x is equal to linspace(self.domain[0], self.domain[1], n) and y is the series evaluated at element of x.

method

`polynomial.hermite_e.HermiteE.`**`mapparms`**`()`

Return the mapping parameters.

The returned values define a linear map `off + scl*x` that is applied to the input arguments before the series is evaluated. The map depends on the `domain` and `window`; if the current `domain` is equal to the `window` the resulting map is the identity. If the coefficients of the series instance are to be used by themselves outside this class, then the linear function must be substituted for the `x` in the standard representation of the base polynomials.

Returns

off, scl
[float or complex] The mapping function is defined by `off + scl*x`.

Notes

If the current domain is the interval `[l1, r1]` and the window is `[l2, r2]`, then the linear mapping function `L` is defined by the equations:

```
L(l1) = l2
L(r1) = r2
```

method

`polynomial.hermite_e.HermiteE.`**`roots`**`()`

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decreases the further outside the `domain` they lie.

Returns

roots
[ndarray] Array containing the roots of the series.

method

`polynomial.hermite_e.HermiteE.`**`trim`**`(`*`tol=0`*`)`

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than *tol* or the beginning of the series is reached. If all the coefficients would be removed the series is set to `[0]`. A new series instance is returned with the new coefficients. The current instance remains unchanged.

Parameters

tol
[non-negative number.] All trailing coefficients less than *tol* will be removed.

Returns

new_series
[series] New instance of series with trimmed coefficients.

method

polynomial.hermite_e.HermiteE.**truncate**(*size*)

Truncate series to length *size*.

Reduce the series to length *size* by discarding the high degree terms. The value of *size* must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

size
[positive int] The series is reduced to length *size* by discarding the high degree terms. The value of *size* must be a positive integer.

Returns

new_series
[series] New instance of series with truncated coefficients.

Constants

hermedomain	An array object represents a multidimensional, homogeneous array of fixed-size items.
hermezero	An array object represents a multidimensional, homogeneous array of fixed-size items.
hermeone	An array object represents a multidimensional, homogeneous array of fixed-size items.
hermex	An array object represents a multidimensional, homogeneous array of fixed-size items.

polynomial.hermite_e.**hermedomain = array([-1., 1.])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.hermite_e.`**`hermezero = array([0])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
: [tuple of ints] Shape of created array.

dtype
: [data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
: [object exposing buffer interface, optional] Used to fill the array with data.

offset
: [int, optional] Offset of array data in buffer.

strides
: [tuple of ints, optional] Strides of data in memory.

order
: [{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
: Construct an array.

zeros
: Create an array, each element of which is zero.

empty
: Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
: Create a data-type.

numpy.typing.NDArray
: An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using `__new__`:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No `__init__` method is needed because the array is fully initialized after the `__new__` method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

polynomial.hermite_e.**hermeone = array([1])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
: [tuple of ints] Shape of created array.

dtype
: [data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
: [object exposing buffer interface, optional] Used to fill the array with data.

offset
: [int, optional] Offset of array data in buffer.

strides
: [tuple of ints, optional] Strides of data in memory.

order
: [{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
: Construct an array.

zeros
: Create an array, each element of which is zero.

empty
: Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
: Create a data-type.

numpy.typing.NDArray
: An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For

example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.hermite_e.`**`hermex = array([0, 1])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using `__new__`:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No `__init__` method is needed because the array is fully initialized after the `__new__` method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
: [ndarray] Transpose of the array.

data
: [buffer] The array's elements, in memory.

dtype
: [dtype object] Describes the format of the elements in the array.

flags
: [dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
: [numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
: [ndarray] Imaginary part of the array.

real
: [ndarray] Real part of the array.

size
: [int] Number of elements in the array.

itemsize
: [int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

Arithmetic

hermeadd(c1, c2)	Add one Hermite series to another.
hermesub(c1, c2)	Subtract one Hermite series from another.
hermemulx(c)	Multiply a Hermite series by x.
hermemul(c1, c2)	Multiply one Hermite series by another.
hermediv(c1, c2)	Divide one Hermite series by another.
hermepow(c, pow[, maxpower])	Raise a Hermite series to a power.
hermeval(x, c[, tensor])	Evaluate an HermiteE series at points x.
hermeval2d(x, y, c)	Evaluate a 2-D HermiteE series at points (x, y).
hermeval3d(x, y, z, c)	Evaluate a 3-D Hermite_e series at points (x, y, z).
hermegrid2d(x, y, c)	Evaluate a 2-D HermiteE series on the Cartesian product of x and y.
hermegrid3d(x, y, z, c)	Evaluate a 3-D HermiteE series on the Cartesian product of x, y, and z.

polynomial.hermite_e.**hermeadd**(*c1*, *c2*)

Add one Hermite series to another.

Returns the sum of two Hermite series *c1* + *c2*. The arguments are sequences of coefficients ordered from lowest order term to highest, i.e., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Hermite series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the Hermite series of their sum.

See also:

hermesub, ***hermemulx***, ***hermemul***, ***hermediv***, ***hermepow***

Notes

Unlike multiplication, division, etc., the sum of two Hermite series is a Hermite series (without having to "reproject" the result onto the basis set) so addition, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial.hermite_e import hermeadd
>>> hermeadd([1, 2, 3], [1, 2, 3, 4])
array([2.,  4.,  6.,  4.])
```

polynomial.hermite_e.**hermesub**(*c1*, *c2*)

Subtract one Hermite series from another.

Returns the difference of two Hermite series *c1* - *c2*. The sequences of coefficients are from lowest order term to highest, i.e., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Hermite series coefficients ordered from low to high.

Returns

out
[ndarray] Of Hermite series coefficients representing their difference.

See also:

hermeadd*, *hermemulx*, *hermemul*, *hermediv*, *hermepow

Notes

Unlike multiplication, division, etc., the difference of two Hermite series is a Hermite series (without having to "reproject" the result onto the basis set) so subtraction, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial.hermite_e import hermesub
>>> hermesub([1, 2, 3, 4], [1, 2, 3])
array([0., 0., 0., 4.])
```

polynomial.hermite_e.**hermemulx**(*c*)

Multiply a Hermite series by x.

Multiply the Hermite series *c* by x, where x is the independent variable.

Parameters

c
[array_like] 1-D array of Hermite series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the result of the multiplication.

See also:

hermeadd*, *hermesub*, *hermemul*, *hermediv*, *hermepow

Notes

The multiplication uses the recursion relationship for Hermite polynomials in the form

$$xP_i(x) = (P_{i+1}(x) + iP_{i-1}(x)))$$

Examples

```
>>> from numpy.polynomial.hermite_e import hermemulx
>>> hermemulx([1, 2, 3])
array([2.,  7.,  2.,  3.])
```

polynomial.hermite_e.**hermemul**(*c1*, *c2*)

Multiply one Hermite series by another.

Returns the product of two Hermite series *c1* * *c2*. The arguments are sequences of coefficients, from lowest order "term" to highest, e.g., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
: [array_like] 1-D arrays of Hermite series coefficients ordered from low to high.

Returns

out
: [ndarray] Of Hermite series coefficients representing their product.

See also:

hermeadd*, *hermesub*, *hermemulx*, *hermediv*, *hermepow

Notes

In general, the (polynomial) product of two C-series results in terms that are not in the Hermite polynomial basis set. Thus, to express the product as a Hermite series, it is necessary to "reproject" the product onto said basis set, which may produce "unintuitive" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial.hermite_e import hermemul
>>> hermemul([1, 2, 3], [0, 1, 2])
array([14.,  15.,  28.,   7.,   6.])
```

polynomial.hermite_e.**hermediv**(*c1*, *c2*)

Divide one Hermite series by another.

Returns the quotient-with-remainder of two Hermite series *c1* / *c2*. The arguments are sequences of coefficients from lowest order "term" to highest, e.g., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Hermite series coefficients ordered from low to high.

Returns

[quo, rem]
[ndarrays] Of Hermite series coefficients representing the quotient and remainder.

See also:

hermeadd*, *hermesub*, *hermemulx*, *hermemul*, *hermepow

Notes

In general, the (polynomial) division of one Hermite series by another results in quotient and remainder terms that are not in the Hermite polynomial basis set. Thus, to express these results as a Hermite series, it is necessary to "reproject" the results onto the Hermite basis set, which may produce "unintuitive" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial.hermite_e import hermediv
>>> hermediv([ 14.,  15.,  28.,   7.,   6.], [0, 1, 2])
(array([1., 2., 3.]), array([0.]))
>>> hermediv([ 15.,  17.,  28.,   7.,   6.], [0, 1, 2])
(array([1., 2., 3.]), array([1., 2.]))
```

polynomial.hermite_e.**hermepow**(*c*, *pow*, *maxpower=16*)

Raise a Hermite series to a power.

Returns the Hermite series *c* raised to the power *pow*. The argument *c* is a sequence of coefficients ordered from low to high. i.e., [1,2,3] is the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c
[array_like] 1-D array of Hermite series coefficients ordered from low to high.

pow
[integer] Power to which the series will be raised

maxpower
[integer, optional] Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

Returns

coef
[ndarray] Hermite series of power.

See also:

hermeadd*, *hermesub*, *hermemulx*, *hermemul*, *hermediv

Examples

```
>>> from numpy.polynomial.hermite_e import hermepow
>>> hermepow([1, 2, 3], 2)
array([23.,  28.,  46.,  12.,   9.])
```

polynomial.hermite_e.**hermeval**(*x*, *c*, *tensor=True*)

Evaluate an HermiteE series at points x.

If *c* is of length `n + 1`, this function returns the value:

$$p(x) = c_0 * He_0(x) + c_1 * He_1(x) + ... + c_n * He_n(x)$$

The parameter *x* is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either *x* or its elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array, then `p(x)` will have the same shape as *x*. If *c* is multidimensional, then the shape of the result depends on the value of *tensor*. If *tensor* is true the shape will be c.shape[1:] + x.shape. If *tensor* is false the shape will be c.shape[1:]. Note that scalars have shape (,).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

Parameters

x
: [array_like, compatible object] If *x* is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, *x* or its elements must support addition and multiplication with with themselves and with the elements of *c*.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree n are contained in c[n]. If *c* is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of *c*.

tensor
: [boolean, optional] If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of *x*. Scalars have dimension 0 for this action. The result is that every column of coefficients in *c* is evaluated for every element of *x*. If False, *x* is broadcast over the columns of *c* for the evaluation. This keyword is useful when *c* is multidimensional. The default value is True.

Returns

values
: [ndarray, algebra_like] The shape of the return value is described above.

See also:

hermeval2d, ***hermegrid2d***, ***hermeval3d***, ***hermegrid3d***

Notes

The evaluation uses Clenshaw recursion, aka synthetic division.

Examples

```
>>> from numpy.polynomial.hermite_e import hermeval
>>> coef = [1,2,3]
>>> hermeval(1, coef)
3.0
>>> hermeval([[1,2],[3,4]], coef)
array([[ 3., 14.],
       [31., 54.]])
```

polynomial.hermite_e.**hermeval2d**(*x*, *y*, *c*)

Evaluate a 2-D HermiteE series at points (x, y).

This function returns the values:

$$p(x,y) = \sum_{i,j} c_{i,j} * He_i(x) * He_j(y)$$

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

Parameters

x, y
: [array_like, compatible objects] The two dimensional series is evaluated at the points `(x, y)`, where *x* and *y* must have the same shape. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points formed with pairs of corresponding values from *x* and *y*.

See also:

hermeval*, *hermegrid2d*, *hermeval3d*, *hermegrid3d

polynomial.hermite_e.**hermeval3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D Hermite_e series at points (x, y, z).

This function returns the values:

$$p(x,y,z) = \sum_{i,j,k} c_{i,j,k} * He_i(x) * He_j(y) * He_k(z)$$

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape.

Parameters

x, y, z
[array_like, compatible object] The three dimensional series is evaluated at the points *(x, y, z)*, where *x*, *y*, and *z* must have the same shape. If any of *x*, *y*, or *z* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c
[array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j,k is contained in `c[i,j,k]`. If *c* has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns

values
[ndarray, compatible object] The values of the multidimensional polynomial on points formed with triples of corresponding values from *x*, *y*, and *z*.

See also:

hermeval*, *hermeval2d*, *hermegrid2d*, *hermegrid3d

`polynomial.hermite_e.`**`hermegrid2d`**(*x*, *y*, *c*)

Evaluate a 2-D HermiteE series on the Cartesian product of x and y.

This function returns the values:

$$p(a,b) = \sum_{i,j} c_{i,j} * H_i(a) * H_j(b)$$

where the points `(a, b)` consist of all pairs formed by taking *a* from *x* and *b* from *y*. The resulting points form a grid with *x* in the first dimension and *y* in the second.

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

Parameters

x, y
[array_like, compatible objects] The two dimensional series is evaluated at the points in the Cartesian product of *x* and *y*. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
[array_like] Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points in the Cartesian product of *x* and *y*.

See also:

hermeval*, *hermeval2d*, *hermeval3d*, *hermegrid3d

`polynomial.hermite_e.`**`hermegrid3d`**(*x*, *y*, *z*, *c*)

Evaluate a 3-D HermiteE series on the Cartesian product of x, y, and z.

This function returns the values:

$$p(a,b,c) = \sum_{i,j,k} c_{i,j,k} * He_i(a) * He_j(b) * He_k(c)$$

where the points `(a, b, c)` consist of all triples formed by taking *a* from *x*, *b* from *y*, and *c* from *z*. The resulting points form a grid with *x* in the first dimension, *y* in the second, and *z* in the third.

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape + y.shape + z.shape.

Parameters

x, y, z
: [array_like, compatible objects] The three dimensional series is evaluated at the points in the Cartesian product of *x*, *y*, and *z*. If *x*, *y*, or *z* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points in the Cartesian product of *x* and *y*.

See also:

hermeval*, *hermeval2d*, *hermegrid2d*, *hermeval3d

Calculus

hermeder(c[, m, scl, axis])	Differentiate a Hermite_e series.
hermeint(c[, m, k, lbnd, scl, axis])	Integrate a Hermite_e series.

polynomial.hermite_e.**hermeder**(*c*, *m=1*, *scl=1*, *axis=0*)

Differentiate a Hermite_e series.

Returns the series coefficients *c* differentiated *m* times along *axis*. At each iteration the result is multiplied by *scl* (the scaling factor is for use in a linear change of variable). The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series `1*He_0 + 2*He_1 + 3*He_2` while [[1,2],[1,2]] represents `1*He_0(x)*He_0(y) + 1*He_1(x)*He_0(y) + 2*He_0(x)*He_1(y) + 2*He_1(x)*He_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of Hermite_e series coefficients. If *c* is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Number of derivatives taken, must be non-negative. (Default: 1)

scl
: [scalar, optional] Each differentiation is multiplied by *scl*. The end result is multiplication by `scl**m`. This is for use in a linear change of variable. (Default: 1)

axis
: [int, optional] Axis over which the derivative is taken. (Default: 0).

Returns

der
: [ndarray] Hermite series of the derivative.

See also:

hermeint

Notes

In general, the result of differentiating a Hermite series does not resemble the same operation on a power series. Thus the result of this function may be "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial.hermite_e import hermeder
>>> hermeder([ 1.,  1.,  1.,  1.])
array([1.,  2.,  3.])
>>> hermeder([-0.25,  1.,  1./2.,  1./3.,  1./4 ], m=2)
array([1.,  2.,  3.])
```

polynomial.hermite_e.**hermeint**(*c*, *m=1*, *k=[]*, *lbnd=0*, *scl=1*, *axis=0*)

Integrate a Hermite_e series.

Returns the Hermite_e series coefficients *c* integrated *m* times from *lbnd* along *axis*. At each iteration the resulting series is **multiplied** by *scl* and an integration constant, *k*, is added. The scaling factor is for use in a linear change of variable. ("Buyer beware": note that, depending on what one is doing, one may want *scl* to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series `H_0 + 2*H_1 + 3*H_2` while [[1,2],[1,2]] represents `1*H_0(x)*H_0(y) + 1*H_1(x)*H_0(y) + 2*H_0(x)*H_1(y) + 2*H_1(x)*H_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
[array_like] Array of Hermite_e series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
[int, optional] Order of integration, must be positive. (Default: 1)

k
[{[], list, scalar}, optional] Integration constant(s). The value of the first integral at `lbnd` is the first value in the list, the value of the second integral at `lbnd` is the second value, etc. If `k == []` (the default), all constants are set to zero. If `m == 1`, a single scalar can be given instead of a list.

lbnd
[scalar, optional] The lower bound of the integral. (Default: 0)

scl
[scalar, optional] Following each integration the result is *multiplied* by *scl* before the integration constant is added. (Default: 1)

axis
[int, optional] Axis over which the integral is taken. (Default: 0).

Returns

S
[ndarray] Hermite_e series coefficients of the integral.

Raises

ValueError
If `m < 0`, `len(k) > m`, `np.ndim(lbnd) != 0`, or `np.ndim(scl) != 0`.

See also:

hermeder

Notes

Note that the result of each integration is *multiplied* by *scl*. Why is this important to note? Say one is making a linear change of variable $u = ax + b$ in an integral relative to x. Then $dx = du/a$, so one will need to set *scl* equal to $1/a$ - perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be "reprojected" onto the C-series basis set. Thus, typically, the result of this function is "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial.hermite_e import hermeint
>>> hermeint([1, 2, 3]) # integrate once, value 0 at 0.
array([1., 1., 1., 1.])
>>> hermeint([1, 2, 3], m=2) # integrate twice, value & deriv 0 at 0
array([-0.25      ,  1.        ,  0.5       ,  0.33333333,  0.25      ]) # may␣
↪vary
>>> hermeint([1, 2, 3], k=1) # integrate once, value 1 at 0.
array([2., 1., 1., 1.])
```

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```
>>> hermeint([1, 2, 3], lbnd=-1) # integrate once, value 0 at -1
array([-1.,  1.,  1.,  1.])
>>> hermeint([1, 2, 3], m=2, k=[1, 2], lbnd=-1)
array([ 1.83333333,  0.        ,  0.5       ,  0.33333333,  0.25      ]) # may␣
↪vary
```

Misc Functions

hermefromroots(roots)	Generate a HermiteE series with given roots.
hermeroots(c)	Compute the roots of a HermiteE series.
hermevander(x, deg)	Pseudo-Vandermonde matrix of given degree.
hermevander2d(x, y, deg)	Pseudo-Vandermonde matrix of given degrees.
hermevander3d(x, y, z, deg)	Pseudo-Vandermonde matrix of given degrees.
hermegauss(deg)	Gauss-HermiteE quadrature.
hermeweight(x)	Weight function of the Hermite_e polynomials.
hermecompanion(c)	Return the scaled companion matrix of c.
hermefit(x, y, deg[, rcond, full, w])	Least squares fit of Hermite series to data.
hermetrim(c[, tol])	Remove "small" "trailing" coefficients from a polynomial.
hermeline(off, scl)	Hermite series whose graph is a straight line.
herme2poly(c)	Convert a Hermite series to a polynomial.
poly2herme(pol)	Convert a polynomial to a Hermite series.

polynomial.hermite_e.**hermefromroots**(*roots*)

Generate a HermiteE series with given roots.

The function returns the coefficients of the polynomial

$$p(x) = (x - r_0) * (x - r_1) * ... * (x - r_n),$$

in HermiteE form, where the r_n are the roots specified in *roots*. If a zero has multiplicity n, then it must appear in *roots* n times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then *roots* looks something like [2, 2, 2, 3, 3]. The roots can appear in any order.

If the returned coefficients are *c*, then

$$p(x) = c_0 + c_1 * He_1(x) + ... + c_n * He_n(x)$$

The coefficient of the last term is not generally 1 for monic polynomials in HermiteE form.

Parameters

roots
[array_like] Sequence containing the roots.

Returns

out
[ndarray] 1-D array of coefficients. If all roots are real then *out* is a real array, if some of the roots are complex, then *out* is complex even if all the coefficients in the result are real (see Examples below).

See also:

numpy.polynomial.polynomial.polyfromroots
numpy.polynomial.legendre.legfromroots
numpy.polynomial.laguerre.lagfromroots
numpy.polynomial.hermite.hermfromroots
numpy.polynomial.chebyshev.chebfromroots

Examples

```
>>> from numpy.polynomial.hermite_e import hermefromroots, hermeval
>>> coef = hermefromroots((-1, 0, 1))
>>> hermeval((-1, 0, 1), coef)
array([0., 0., 0.])
>>> coef = hermefromroots((-1j, 1j))
>>> hermeval((-1j, 1j), coef)
array([0.+0.j, 0.+0.j])
```

polynomial.hermite_e.**hermeroots**(*c*)

Compute the roots of a HermiteE series.

Return the roots (a.k.a. "zeros") of the polynomial

$$p(x) = \sum_i c[i] * He_i(x).$$

Parameters

c
[1-D array_like] 1-D array of coefficients.

Returns

out
[ndarray] Array of the roots of the series. If all the roots are real, then *out* is also real, otherwise it is complex.

See also:

numpy.polynomial.polynomial.polyroots
numpy.polynomial.legendre.legroots
numpy.polynomial.laguerre.lagroots
numpy.polynomial.hermite.hermroots
numpy.polynomial.chebyshev.chebroots

Notes

The root estimates are obtained as the eigenvalues of the companion matrix, Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton's method.

The HermiteE series basis polynomials aren't powers of x so the results of this function may seem unintuitive.

Examples

```
>>> from numpy.polynomial.hermite_e import hermeroots, hermefromroots
>>> coef = hermefromroots([-1, 0, 1])
>>> coef
array([0., 2., 0., 1.])
>>> hermeroots(coef)
array([-1.,  0.,  1.]) # may vary
```

polynomial.hermite_e.**hermevander**(*x*, *deg*)

Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree *deg* and sample points *x*. The pseudo-Vandermonde matrix is defined by

$$V[..., i] = He_i(x),$$

where `0 <= i <= deg`. The leading indices of *V* index the elements of *x* and the last index is the degree of the HermiteE polynomial.

If *c* is a 1-D array of coefficients of length `n + 1` and *V* is the array `V = hermevander(x, n)`, then `np.dot(V, c)` and `hermeval(x, c)` are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of HermiteE series of the same degree and sample points.

Parameters

x
: [array_like] Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If *x* is scalar it is converted to a 1-D array.

deg
: [int] Degree of the resulting matrix.

Returns

vander
: [ndarray] The pseudo-Vandermonde matrix. The shape of the returned matrix is `x.shape + (deg + 1,)`, where The last index is the degree of the corresponding HermiteE polynomial. The dtype will be the same as the converted *x*.

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.hermite_e import hermevander
>>> x = np.array([-1, 0, 1])
>>> hermevander(x, 3)
array([[ 1., -1.,  0.,  2.],
       [ 1.,  0., -1., -0.],
       [ 1.,  1.,  0., -2.]])
```

polynomial.hermite_e.**hermevander2d**(*x*, *y*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y)`. The pseudo-Vandermonde matrix is defined by

$$V[..., (deg[1] + 1) * i + j] = He_i(x) * He_j(y),$$

where `0 <= i <= deg[0]` and `0 <= j <= deg[1]`. The leading indices of *V* index the points `(x, y)` and the last index encodes the degrees of the HermiteE polynomials.

If `V = hermevander2d(x, y, [xdeg, ydeg])`, then the columns of *V* correspond to the elements of a 2-D coefficient array *c* of shape (xdeg + 1, ydeg + 1) in the order

$$c_{00}, c_{01}, c_{02} ..., c_{10}, c_{11}, c_{12} ...$$

and `np.dot(V, c.flat)` and `hermeval2d(x, y, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D HermiteE series of the same degrees and sample points.

Parameters

x, y
: [array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
: [list of ints] List of maximum degrees of the form [x_deg, y_deg].

Returns

vander2d
: [ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)$. The dtype will be the same as the converted *x* and *y*.

See also:

hermevander*, *hermevander3d*, *hermeval2d*, *hermeval3d

`polynomial.hermite_e.`**`hermevander3d`**(*x*, *y*, *z*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y, z)`. If *l*, *m*, *n* are the given degrees in *x*, *y*, *z*, then Hehe pseudo-Vandermonde matrix is defined by

$$V[..., (m+1)(n+1)i + (n+1)j + k] = He_i(x) * He_j(y) * He_k(z),$$

where `0 <= i <= l`, `0 <= j <= m`, and `0 <= j <= n`. The leading indices of *V* index the points `(x, y, z)` and the last index encodes the degrees of the HermiteE polynomials.

If `V = hermevander3d(x, y, z, [xdeg, ydeg, zdeg])`, then the columns of *V* correspond to the elements of a 3-D coefficient array *c* of shape (xdeg + 1, ydeg + 1, zdeg + 1) in the order

$$c_{000}, c_{001}, c_{002}, ..., c_{010}, c_{011}, c_{012}, ...$$

and `np.dot(V, c.flat)` and `hermeval3d(x, y, z, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D HermiteE series of the same degrees and sample points.

Parameters

x, y, z
: [array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
: [list of ints] List of maximum degrees of the form [x_deg, y_deg, z_deg].

Returns

vander3d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)*(deg[2]+1)$. The dtype will be the same as the converted x, y, and z.

See also:

hermevander, ***hermevander3d***, ***hermeval2d***, ***hermeval3d***

`polynomial.hermite_e.`**hermegauss**(*deg*)

Gauss-HermiteE quadrature.

Computes the sample points and weights for Gauss-HermiteE quadrature. These sample points and weights will correctly integrate polynomials of degree $2*deg-1$ or less over the interval $[-\inf, \inf]$ with the weight function $f(x) = \exp(-x^2/2)$.

Parameters

deg
[int] Number of sample points and weights. It must be >= 1.

Returns

x
[ndarray] 1-D ndarray containing the sample points.

y
[ndarray] 1-D ndarray containing the weights.

Notes

The results have only been tested up to degree 100, higher degrees may be problematic. The weights are determined by using the fact that

$$w_k = c/(He'_n(x_k) * He_{n-1}(x_k))$$

where c is a constant independent of k and x_k is the k'th root of He_n, and then scaling the results to get the right value when integrating 1.

`polynomial.hermite_e.`**hermeweight**(*x*)

Weight function of the Hermite_e polynomials.

The weight function is $\exp(-x^2/2)$ and the interval of integration is $[-\inf, \inf]$. the HermiteE polynomials are orthogonal, but not normalized, with respect to this weight function.

Parameters

x
[array_like] Values at which the weight function will be computed.

Returns

w
[ndarray] The weight function at x.

polynomial.hermite_e.**hermecompanion**(*c*)

Return the scaled companion matrix of c.

The basis polynomials are scaled so that the companion matrix is symmetric when *c* is an HermiteE basis polynomial. This provides better eigenvalue estimates than the unscaled case and for basis polynomials the eigenvalues are guaranteed to be real if *numpy.linalg.eigvalsh* is used to obtain them.

Parameters

c
[array_like] 1-D array of HermiteE series coefficients ordered from low to high degree.

Returns

mat
[ndarray] Scaled companion matrix of dimensions (deg, deg).

polynomial.hermite_e.**hermefit**(*x*, *y*, *deg*, *rcond=None*, *full=False*, *w=None*)

Least squares fit of Hermite series to data.

Return the coefficients of a HermiteE series of degree *deg* that is the least squares fit to the data values *y* given at points *x*. If *y* is 1-D the returned coefficients will also be 1-D. If *y* is 2-D multiple fits are done, one for each column of *y*, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

$$p(x) = c_0 + c_1 * He_1(x) + ... + c_n * He_n(x),$$

where *n* is *deg*.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,) or (M, K)] y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (*M*,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

Returns

coef
: [ndarray, shape (M,) or (M, K)] Hermite coefficients ordered from low to high. If *y* was 2-D, the coefficients for the data in column k of *y* are in column *k*.

[residuals, rank, singular_values, rcond]
: [list] These values are only returned if `full == True`

- residuals – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- singular_values – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *numpy.linalg.lstsq*.

Warns

RankWarning
: The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if `full = False`. The warnings can be turned off by

```
>>> import warnings
>>> warnings.simplefilter('ignore', np.exceptions.RankWarning)
```

See also:

numpy.polynomial.chebyshev.chebfit
numpy.polynomial.legendre.legfit
numpy.polynomial.polynomial.polyfit
numpy.polynomial.hermite.hermfit
numpy.polynomial.laguerre.lagfit
hermeval
: Evaluates a Hermite series.

hermevander
: pseudo Vandermonde matrix of Hermite series.

hermeweight
: HermiteE weight function.

numpy.linalg.lstsq
: Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline
: Computes spline fits.

Notes

The solution is the coefficients of the HermiteE series *p* that minimizes the sum of the weighted squared errors

$$E = \sum_j w_j^2 * |y_j - p(x_j)|^2,$$

where the w_j are the weights. This problem is solved by setting up the (typically) overdetermined matrix equation

$$V(x) * c = w * y,$$

where *V* is the pseudo Vandermonde matrix of *x*, the elements of *c* are the coefficients to be solved for, and the elements of *y* are the observed values. This equation is then solved using the singular value decomposition of *V*.

If some of the singular values of V are so small that they are neglected, then a *RankWarning* will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The *rcond* parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using HermiteE series are probably most useful when the data can be approximated by `sqrt(w(x)) * p(x)`, where `w(x)` is the HermiteE weight. In that case the weight `sqrt(w(x[i]))` should be used together with data values `y[i]/sqrt(w(x[i]))`. The weight function is available as *hermeweight*.

References

[1]

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.hermite_e import hermefit, hermeval
>>> x = np.linspace(-10, 10)
>>> rng = np.random.default_rng()
>>> err = rng.normal(scale=1./10, size=len(x))
>>> y = hermeval(x, [1, 2, 3]) + err
>>> hermefit(x, y, 2)
array([1.02284196, 2.00032805, 2.99978457]) # may vary
```

polynomial.hermite_e.**hermetrim**(*c*, *tol=0*)

Remove "small" "trailing" coefficients from a polynomial.

"Small" means "small in absolute value" and is controlled by the parameter *tol*; "trailing" means highest order coefficient(s), e.g., in `[0, 1, 1, 0, 0]` (which represents `0 + x + x**2 + 0*x**3 + 0*x**4`) both the 3-rd and 4-th order coefficients would be "trimmed."

Parameters

c
[array_like] 1-d array of coefficients, ordered from lowest order to highest.

tol
[number, optional] Trailing (i.e., highest order) elements with absolute value less than or equal to *tol* (default value is zero) are removed.

Returns

trimmed
[ndarray] 1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError
If *tol* < 0

Examples

```
>>> from numpy.polynomial import polyutils as pu
>>> pu.trimcoef((0,0,3,0,5,0,0))
array([0.,  0.,  3.,  0.,  5.])
>>> pu.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([0.])
>>> i = complex(0,1) # works for complex
>>> pu.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([0.0003+0.j    , 0.001 -0.001j])
```

polynomial.hermite_e.**hermeline**(*off*, *scl*)

Hermite series whose graph is a straight line.

Parameters

off, scl
: [scalars] The specified line is given by `off + scl*x`.

Returns

y
: [ndarray] This module's representation of the Hermite series for `off + scl*x`.

See also:

numpy.polynomial.polynomial.polyline
numpy.polynomial.chebyshev.chebline
numpy.polynomial.legendre.legline
numpy.polynomial.laguerre.lagline
numpy.polynomial.hermite.hermline

Examples

```
>>> from numpy.polynomial.hermite_e import hermeline
>>> from numpy.polynomial.hermite_e import hermeline, hermeval
>>> hermeval(0,hermeline(3, 2))
3.0
>>> hermeval(1,hermeline(3, 2))
5.0
```

polynomial.hermite_e.**herme2poly**(*c*)

Convert a Hermite series to a polynomial.

Convert an array representing the coefficients of a Hermite series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest to highest degree.

Parameters

c
: [array_like] 1-D array containing the Hermite series coefficients, ordered from lowest order term to highest.

Returns

pol
[ndarray] 1-D array containing the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest order term to highest.

See also:

poly2herme

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> from numpy.polynomial.hermite_e import herme2poly
>>> herme2poly([  2.,  10.,   2.,   3.])
array([0.,  1.,  2.,  3.])
```

polynomial.hermite_e.**poly2herme**(*pol*)

Convert a polynomial to a Hermite series.

Convert an array representing the coefficients of a polynomial (relative to the "standard" basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Hermite series, ordered from lowest to highest degree.

Parameters

pol
[array_like] 1-D array containing the polynomial coefficients

Returns

c
[ndarray] 1-D array containing the coefficients of the equivalent Hermite series.

See also:

herme2poly

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.hermite_e import poly2herme
>>> poly2herme(np.arange(4))
array([  2.,  10.,   2.,   3.])
```

See also

numpy.polynomial

Laguerre Series (`numpy.polynomial.laguerre`)

This module provides a number of objects (mostly functions) useful for dealing with Laguerre series, including a *Laguerre* class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its "parent" sub-package, *numpy.polynomial*).

Classes

Laguerre(coef[, domain, window, symbol])	A Laguerre series class.

class numpy.polynomial.laguerre.**Laguerre**(*coef*, *domain=None*, *window=None*, *symbol='x'*)

A Laguerre series class.

The Laguerre class provides the standard Python numerical methods '+', '-', '*', '//', '%', 'divmod', '**', and '()' as well as the attributes and methods listed below.

Parameters

coef
[array_like] Laguerre coefficients in order of increasing degree, i.e, `(1, 2, 3)` gives `1*L_0(x) + 2*L_1(X) + 3*L_2(x)`.

domain
[(2,) array_like, optional] Domain to use. The interval `[domain[0], domain[1]]` is mapped to the interval `[window[0], window[1]]` by shifting and scaling. The default value is [0., 1.].

window
[(2,) array_like, optional] Window, see `domain` for its use. The default value is [0., 1.].

symbol
[str, optional] Symbol used to represent the independent variable in string representations of the polynomial expression, e.g. for printing. The symbol must be a valid Python identifier. Default value is 'x'.

New in version 1.24.

Attributes

symbol

Methods

`__call__`(arg)	Call self as a function.
`basis`(deg[, domain, window, symbol])	Series basis polynomial of degree *deg*.
`cast`(series[, domain, window])	Convert series to series of this class.
`convert`([domain, kind, window])	Convert series to a different kind and/or domain and/or window.
`copy`()	Return a copy.
`cutdeg`(deg)	Truncate series to the given degree.
`degree`()	The degree of the series.
`deriv`([m])	Differentiate.
`fit`(x, y, deg[, domain, rcond, full, w, ...])	Least squares fit to data.
`fromroots`(roots[, domain, window, symbol])	Return series instance that has the specified roots.
`has_samecoef`(other)	Check if coefficients match.
`has_samedomain`(other)	Check if domains match.
`has_sametype`(other)	Check if types match.
`has_samewindow`(other)	Check if windows match.
`identity`([domain, window, symbol])	Identity function.
`integ`([m, k, lbnd])	Integrate.
`linspace`([n, domain])	Return x, y values at equally spaced points in domain.
`mapparms`()	Return the mapping parameters.
`roots`()	Return the roots of the series polynomial.
`trim`([tol])	Remove trailing coefficients
`truncate`(size)	Truncate series to length *size*.

method

polynomial.laguerre.Laguerre.**__call__**(*arg*)

Call self as a function.

method

classmethod polynomial.laguerre.Laguerre.**basis**(*deg*, *domain=None*, *window=None*, *symbol='x'*)

Series basis polynomial of degree *deg*.

Returns the series representing the basis polynomial of degree *deg*.

Parameters

deg
[int] Degree of the basis polynomial for the series. Must be >= 0.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series with the coefficient of the *deg* term set to one and all others zero.

method

classmethod polynomial.laguerre.Laguerre.**cast**(*series*, *domain=None*, *window=None*)

Convert series to series of this class.

The *series* is expected to be an instance of some polynomial series of one of the types supported by by the numpy.polynomial module, but could be some other class that supports the convert method.

Parameters

series
[series] The series instance to be converted.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series
[series] A series of the same kind as the calling class and equal to *series* when evaluated.

See also:

convert
similar instance method

method

polynomial.laguerre.Laguerre.**convert**(*domain=None*, *kind=None*, *window=None*)

Convert series to a different kind and/or domain and/or window.

Parameters

domain
[array_like, optional] The domain of the converted series. If the value is None, the default domain of *kind* is used.

kind
[class, optional] The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

window
[array_like, optional] The window of the converted series. If the value is None, the default window of *kind* is used.

Returns

new_series
[series] The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes

Conversion between domains and class types can result in numerically ill defined series.

method

polynomial.laguerre.Laguerre.**copy**()

Return a copy.

Returns

new_series
[series] Copy of self.

method

polynomial.laguerre.Laguerre.**cutdeg**(*deg*)

Truncate series to the given degree.

Reduce the degree of the series to *deg* by discarding the high order terms. If *deg* is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

deg
[non-negative int] The series is reduced to degree *deg* by discarding the high order terms. The value of *deg* must be a non-negative integer.

Returns

new_series
[series] New instance of series with reduced degree.

method

polynomial.laguerre.Laguerre.**degree**()

The degree of the series.

Returns

degree
[int] Degree of the series, one less than the number of coefficients.

Examples

Create a polynomial object for `1 + 7*x + 4*x**2`:

```
>>> poly = np.polynomial.Polynomial([1, 7, 4])
>>> print(poly)
1.0 + 7.0·x + 4.0·x²
>>> poly.degree()
2
```

Note that this method does not check for non-zero coefficients. You must trim the polynomial to remove any trailing zeroes:

```
>>> poly = np.polynomial.Polynomial([1, 7, 0])
>>> print(poly)
1.0 + 7.0·x + 0.0·x²
```

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```
>>> poly.degree()
2
>>> poly.trim().degree()
1
```

method

polynomial.laguerre.Laguerre.**deriv**(*m=1*)

Differentiate.

Return a series instance of that is the derivative of the current series.

Parameters

m
[non-negative int] Find the derivative of order *m*.

Returns

new_series
[series] A new series representing the derivative. The domain is the same as the domain of the differentiated series.

method

classmethod polynomial.laguerre.Laguerre.**fit**(*x*, *y*, *deg*, *domain=None*, *rcond=None*, *full=False*, *w=None*, *window=None*, *symbol='x'*)

Least squares fit to data.

Return a series instance that is the least squares fit to the data *y* sampled at *x*. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,)] y-coordinates of the M sample points `(x[i], y[i])`.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

domain
[{None, [beg, end], []}, optional] Domain to use for the returned series. If `None`, then a minimal domain that covers the points *x* is chosen. If `[]` the class domain is used. The default value was the class domain in NumPy 1.4 and `None` in later versions. The `[]` option was added in numpy 1.5.0.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is `len(x)*eps`, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (M,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

window
[{[beg, end]}, optional] Window to use for the returned series. The default value is the default class domain

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series that represents the least squares fit to the data and has the domain and window specified in the call. If the coefficients for the unscaled and unshifted basis polynomials are of interest, do `new_series.convert().coef`.

[resid, rank, sv, rcond]
[list] These values are only returned if `full == True`

- resid – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- sv – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *linalg.lstsq*.

method

classmethod polynomial.laguerre.Laguerre.**fromroots**(*roots*, *domain=[]*, *window=None*, *symbol='x'*)

Return series instance that has the specified roots.

Returns a series representing the product `(x - r[0])*(x - r[1])*...*(x - r[n-1])`, where `r` is a list of roots.

Parameters

roots
[array_like] List of roots.

domain
[{[], None, array_like}, optional] Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [] the domain is the class domain. The default is [].

window
[{None, array_like}, optional] Window for the returned series. If None the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series with the specified roots.

method

polynomial.laguerre.Laguerre.**has_samecoef**(*other*)

Check if coefficients match.

Parameters

other
[class instance] The other class must have the `coef` attribute.

Returns

bool
[boolean] True if the coefficients are the same, False otherwise.

method

polynomial.laguerre.Laguerre.**has_samedomain**(*other*)

Check if domains match.

Parameters

other
[class instance] The other class must have the `domain` attribute.

Returns

bool
[boolean] True if the domains are the same, False otherwise.

method

polynomial.laguerre.Laguerre.**has_sametype**(*other*)

Check if types match.

Parameters

other
[object] Class instance.

Returns

bool
[boolean] True if other is same class as self

method

polynomial.laguerre.Laguerre.**has_samewindow**(*other*)

Check if windows match.

Parameters

other
[class instance] The other class must have the `window` attribute.

Returns

bool
[boolean] True if the windows are the same, False otherwise.

method

classmethod polynomial.laguerre.Laguerre.**identity**(*domain=None*, *window=None*, *symbol='x'*)

Identity function.

If `p` is the returned series, then `p(x) == x` for all values of x.

Parameters

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series of representing the identity.

method

polynomial.laguerre.Laguerre.**integ**(*m=1*, *k=[]*, *lbnd=None*)

Integrate.

Return a series instance that is the definite integral of the current series.

Parameters

m
[non-negative int] The number of integrations to perform.

k
[array_like] Integration constants. The first constant is applied to the first integration, the second to the second, and so on. The list of values must less than or equal to *m* in length and any missing values are set to zero.

lbnd
[Scalar] The lower bound of the definite integral.

Returns

new_series
[series] A new series representing the integral. The domain is the same as the domain of the integrated series.

method

polynomial.laguerre.Laguerre.**linspace**(*n=100*, *domain=None*)

Return x, y values at equally spaced points in domain.

Returns the x, y values at *n* linearly spaced points across the domain. Here y is the value of the polynomial at the points x. By default the domain is the same as that of the series instance. This method is intended mostly as a plotting aid.

Parameters

n
[int, optional] Number of point pairs to return. The default value is 100.

domain
[{None, array_like}, optional] If not None, the specified domain is used instead of that of the calling instance. It should be of the form `[beg,end]`. The default is None which case the class domain is used.

Returns

x, y
[ndarray] x is equal to linspace(self.domain[0], self.domain[1], n) and y is the series evaluated at element of x.

method

`polynomial.laguerre.Laguerre.`**`mapparms`**`()`

Return the mapping parameters.

The returned values define a linear map `off + scl*x` that is applied to the input arguments before the series is evaluated. The map depends on the `domain` and `window`; if the current `domain` is equal to the `window` the resulting map is the identity. If the coefficients of the series instance are to be used by themselves outside this class, then the linear function must be substituted for the `x` in the standard representation of the base polynomials.

Returns

off, scl
[float or complex] The mapping function is defined by `off + scl*x`.

Notes

If the current domain is the interval `[l1, r1]` and the window is `[l2, r2]`, then the linear mapping function `L` is defined by the equations:

```
L(l1) = l2
L(r1) = r2
```

method

`polynomial.laguerre.Laguerre.`**`roots`**`()`

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decreases the further outside the `domain` they lie.

Returns

roots
[ndarray] Array containing the roots of the series.

method

`polynomial.laguerre.Laguerre.`**`trim`**`(`*`tol=0`*`)`

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than *tol* or the beginning of the series is reached. If all the coefficients would be removed the series is set to `[0]`. A new series instance is returned with the new coefficients. The current instance remains unchanged.

Parameters

tol
[non-negative number.] All trailing coefficients less than *tol* will be removed.

Returns

new_series
[series] New instance of series with trimmed coefficients.

method

polynomial.laguerre.Laguerre.**truncate**(*size*)

Truncate series to length *size*.

Reduce the series to length *size* by discarding the high degree terms. The value of *size* must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

size
[positive int] The series is reduced to length *size* by discarding the high degree terms. The value of *size* must be a positive integer.

Returns

new_series
[series] New instance of series with truncated coefficients.

Constants

lagdomain	An array object represents a multidimensional, homogeneous array of fixed-size items.
lagzero	An array object represents a multidimensional, homogeneous array of fixed-size items.
lagone	An array object represents a multidimensional, homogeneous array of fixed-size items.
lagx	An array object represents a multidimensional, homogeneous array of fixed-size items.

polynomial.laguerre.**lagdomain = array([0., 1.])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.laguerre.`**`lagzero = array([0])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
: [tuple of ints] Shape of created array.

dtype
: [data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
: [object exposing buffer interface, optional] Used to fill the array with data.

offset
: [int, optional] Offset of array data in buffer.

strides
: [tuple of ints, optional] Strides of data in memory.

order
: [{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
: Construct an array.

zeros
: Create an array, each element of which is zero.

empty
: Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
: Create a data-type.

numpy.typing.NDArray
: An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using `__new__`:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No `__init__` method is needed because the array is fully initialized after the `__new__` method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

polynomial.laguerre.**lagone = array([1])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For

example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.laguerre.`**`lagx = array([ 1, -1])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
: [ndarray] Transpose of the array.

data
: [buffer] The array's elements, in memory.

dtype
: [dtype object] Describes the format of the elements in the array.

flags
: [dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
: [numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
: [ndarray] Imaginary part of the array.

real
: [ndarray] Real part of the array.

size
: [int] Number of elements in the array.

itemsize
: [int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

Arithmetic

lagadd(c1, c2)	Add one Laguerre series to another.
lagsub(c1, c2)	Subtract one Laguerre series from another.
lagmulx(c)	Multiply a Laguerre series by x.
lagmul(c1, c2)	Multiply one Laguerre series by another.
lagdiv(c1, c2)	Divide one Laguerre series by another.
lagpow(c, pow[, maxpower])	Raise a Laguerre series to a power.
lagval(x, c[, tensor])	Evaluate a Laguerre series at points x.
lagval2d(x, y, c)	Evaluate a 2-D Laguerre series at points (x, y).
lagval3d(x, y, z, c)	Evaluate a 3-D Laguerre series at points (x, y, z).
laggrid2d(x, y, c)	Evaluate a 2-D Laguerre series on the Cartesian product of x and y.
laggrid3d(x, y, z, c)	Evaluate a 3-D Laguerre series on the Cartesian product of x, y, and z.

`polynomial.laguerre.`**`lagadd`**(*c1*, *c2*)

Add one Laguerre series to another.

Returns the sum of two Laguerre series *c1* + *c2*. The arguments are sequences of coefficients ordered from lowest order term to highest, i.e., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Laguerre series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the Laguerre series of their sum.

See also:

lagsub*, *lagmulx*, *lagmul*, *lagdiv*, *lagpow

Notes

Unlike multiplication, division, etc., the sum of two Laguerre series is a Laguerre series (without having to "reproject" the result onto the basis set) so addition, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial.laguerre import lagadd
>>> lagadd([1, 2, 3], [1, 2, 3, 4])
array([2.,  4.,  6.,  4.])
```

polynomial.laguerre.**lagsub**(*c1*, *c2*)

Subtract one Laguerre series from another.

Returns the difference of two Laguerre series *c1* - *c2*. The sequences of coefficients are from lowest order term to highest, i.e., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Laguerre series coefficients ordered from low to high.

Returns

out
[ndarray] Of Laguerre series coefficients representing their difference.

See also:

lagadd*, *lagmulx*, *lagmul*, *lagdiv*, *lagpow

Notes

Unlike multiplication, division, etc., the difference of two Laguerre series is a Laguerre series (without having to "reproject" the result onto the basis set) so subtraction, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial.laguerre import lagsub
>>> lagsub([1, 2, 3, 4], [1, 2, 3])
array([0.,  0.,  0.,  4.])
```

polynomial.laguerre.**lagmulx**(*c*)

Multiply a Laguerre series by x.

Multiply the Laguerre series *c* by x, where x is the independent variable.

Parameters

c
[array_like] 1-D array of Laguerre series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the result of the multiplication.

See also:

lagadd*, *lagsub*, *lagmul*, *lagdiv*, *lagpow

Notes

The multiplication uses the recursion relationship for Laguerre polynomials in the form

$$xP_i(x) = (-(i+1) * P_{i+1}(x) + (2i+1)P_i(x) - iP_{i-1}(x))$$

Examples

```
>>> from numpy.polynomial.laguerre import lagmulx
>>> lagmulx([1, 2, 3])
array([-1.,  -1.,  11.,  -9.])
```

`polynomial.laguerre.`**`lagmul`**(*c1*, *c2*)

Multiply one Laguerre series by another.

Returns the product of two Laguerre series *c1* * *c2*. The arguments are sequences of coefficients, from lowest order "term" to highest, e.g., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
: [array_like] 1-D arrays of Laguerre series coefficients ordered from low to high.

Returns

out
: [ndarray] Of Laguerre series coefficients representing their product.

See also:

lagadd*, *lagsub*, *lagmulx*, *lagdiv*, *lagpow

Notes

In general, the (polynomial) product of two C-series results in terms that are not in the Laguerre polynomial basis set. Thus, to express the product as a Laguerre series, it is necessary to "reproject" the product onto said basis set, which may produce "unintuitive" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial.laguerre import lagmul
>>> lagmul([1, 2, 3], [0, 1, 2])
array([  8., -13.,  38., -51.,  36.])
```

`polynomial.laguerre.`**`lagdiv`**(*c1*, *c2*)

Divide one Laguerre series by another.

Returns the quotient-with-remainder of two Laguerre series *c1* / *c2*. The arguments are sequences of coefficients from lowest order "term" to highest, e.g., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Laguerre series coefficients ordered from low to high.

Returns

[quo, rem]
[ndarrays] Of Laguerre series coefficients representing the quotient and remainder.

See also:

lagadd*, *lagsub*, *lagmulx*, *lagmul*, *lagpow

Notes

In general, the (polynomial) division of one Laguerre series by another results in quotient and remainder terms that are not in the Laguerre polynomial basis set. Thus, to express these results as a Laguerre series, it is necessary to "reproject" the results onto the Laguerre basis set, which may produce "unintuitive" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial.laguerre import lagdiv
>>> lagdiv([  8., -13.,  38., -51.,  36.], [0, 1, 2])
(array([1., 2., 3.]), array([0.]))
>>> lagdiv([  9., -12.,  38., -51.,  36.], [0, 1, 2])
(array([1., 2., 3.]), array([1., 1.]))
```

polynomial.laguerre.**lagpow**(*c*, *pow*, *maxpower=16*)

Raise a Laguerre series to a power.

Returns the Laguerre series *c* raised to the power *pow*. The argument *c* is a sequence of coefficients ordered from low to high. i.e., [1,2,3] is the series `P_0 + 2*P_1 + 3*P_2.`

Parameters

c
[array_like] 1-D array of Laguerre series coefficients ordered from low to high.

pow
[integer] Power to which the series will be raised

maxpower
[integer, optional] Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

Returns

coef
[ndarray] Laguerre series of power.

See also:

lagadd*, *lagsub*, *lagmulx*, *lagmul*, *lagdiv

Examples

```
>>> from numpy.polynomial.laguerre import lagpow
>>> lagpow([1, 2, 3], 2)
array([ 14., -16.,  56., -72.,  54.])
```

polynomial.laguerre.**lagval**(*x*, *c*, *tensor=True*)

Evaluate a Laguerre series at points x.

If *c* is of length `n + 1`, this function returns the value:

$$p(x) = c_0 * L_0(x) + c_1 * L_1(x) + ... + c_n * L_n(x)$$

The parameter *x* is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either *x* or its elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array, then `p(x)` will have the same shape as *x*. If *c* is multidimensional, then the shape of the result depends on the value of *tensor*. If *tensor* is true the shape will be c.shape[1:] + x.shape. If *tensor* is false the shape will be c.shape[1:]. Note that scalars have shape (,).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

Parameters

x
: [array_like, compatible object] If *x* is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, *x* or its elements must support addition and multiplication with themselves and with the elements of *c*.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree n are contained in c[n]. If *c* is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of *c*.

tensor
: [boolean, optional] If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of *x*. Scalars have dimension 0 for this action. The result is that every column of coefficients in *c* is evaluated for every element of *x*. If False, *x* is broadcast over the columns of *c* for the evaluation. This keyword is useful when *c* is multidimensional. The default value is True.

Returns

values
: [ndarray, algebra_like] The shape of the return value is described above.

See also:

lagval2d, ***laggrid2d***, ***lagval3d***, ***laggrid3d***

Notes

The evaluation uses Clenshaw recursion, aka synthetic division.

Examples

```
>>> from numpy.polynomial.laguerre import lagval
>>> coef = [1, 2, 3]
>>> lagval(1, coef)
-0.5
>>> lagval([[1, 2],[3, 4]], coef)
array([[-0.5, -4. ],
       [-4.5, -2. ]])
```

polynomial.laguerre.**lagval2d**(*x*, *y*, *c*)

Evaluate a 2-D Laguerre series at points (x, y).

This function returns the values:

$$p(x,y) = \sum_{i,j} c_{i,j} * L_i(x) * L_j(y)$$

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

Parameters

x, y
: [array_like, compatible objects] The two dimensional series is evaluated at the points `(x, y)`, where *x* and *y* must have the same shape. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points formed with pairs of corresponding values from *x* and *y*.

See also:

lagval, ***laggrid2d***, ***lagval3d***, ***laggrid3d***

Examples

```
>>> from numpy.polynomial.laguerre import lagval2d
>>> c = [[1, 2],[3, 4]]
>>> lagval2d(1, 1, c)
1.0
```

polynomial.laguerre.**lagval3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D Laguerre series at points (x, y, z).

This function returns the values:

$$p(x,y,z) = \sum_{i,j,k} c_{i,j,k} * L_i(x) * L_j(y) * L_k(z)$$

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape.

Parameters

x, y, z
: [array_like, compatible object] The three dimensional series is evaluated at the points `(x, y, z)`, where *x*, *y*, and *z* must have the same shape. If any of *x*, *y*, or *z* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j,k is contained in `c[i,j,k]`. If *c* has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the multidimensional polynomial on points formed with triples of corresponding values from *x*, *y*, and *z*.

See also:

lagval, ***lagval2d***, ***laggrid2d***, ***laggrid3d***

Examples

```
>>> from numpy.polynomial.laguerre import lagval3d
>>> c = [[[1, 2], [3, 4]], [[5, 6], [7, 8]]]
>>> lagval3d(1, 1, 2, c)
-1.0
```

polynomial.laguerre.**laggrid2d**(*x*, *y*, *c*)

Evaluate a 2-D Laguerre series on the Cartesian product of x and y.

This function returns the values:

$$p(a,b) = \sum_{i,j} c_{i,j} * L_i(a) * L_j(b)$$

where the points `(a, b)` consist of all pairs formed by taking *a* from *x* and *b* from *y*. The resulting points form a grid with *x* in the first dimension and *y* in the second.

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape + y.shape.

Parameters

x, y
: [array_like, compatible objects] The two dimensional series is evaluated at the points in the Cartesian product of *x* and *y*. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional Chebyshev series at points in the Cartesian product of *x* and *y*.

See also:

lagval, ***lagval2d***, ***lagval3d***, ***laggrid3d***

Examples

```
>>> from numpy.polynomial.laguerre import laggrid2d
>>> c = [[1, 2], [3, 4]]
>>> laggrid2d([0, 1], [0, 1], c)
array([[10.,  4.],
       [ 3.,  1.]])
```

`polynomial.laguerre.`**`laggrid3d`**(*x*, *y*, *z*, *c*)

Evaluate a 3-D Laguerre series on the Cartesian product of x, y, and z.

This function returns the values:

$$p(a,b,c) = \sum_{i,j,k} c_{i,j,k} * L_i(a) * L_j(b) * L_k(c)$$

where the points `(a, b, c)` consist of all triples formed by taking *a* from *x*, *b* from *y*, and *c* from *z*. The resulting points form a grid with *x* in the first dimension, *y* in the second, and *z* in the third.

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape + y.shape + z.shape.

Parameters

x, y, z
: [array_like, compatible objects] The three dimensional series is evaluated at the points in the Cartesian product of *x*, *y*, and *z*. If *x*, *y*, or *z* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points in the Cartesian product of *x* and *y*.

See also:

lagval, ***lagval2d***, ***laggrid2d***, ***lagval3d***

Examples

```
>>> from numpy.polynomial.laguerre import laggrid3d
>>> c = [[[1, 2], [3, 4]], [[5, 6], [7, 8]]]
>>> laggrid3d([0, 1], [0, 1], [2, 4], c)
array([[[ -4., -44.],
        [ -2., -18.]],
       [[ -2., -14.],
        [ -1.,  -5.]]])
```

Calculus

lagder(c[, m, scl, axis])	Differentiate a Laguerre series.
lagint(c[, m, k, lbnd, scl, axis])	Integrate a Laguerre series.

`polynomial.laguerre.`**`lagder`**(*c*, *m=1*, *scl=1*, *axis=0*)

Differentiate a Laguerre series.

Returns the Laguerre series coefficients *c* differentiated *m* times along *axis*. At each iteration the result is multiplied by *scl* (the scaling factor is for use in a linear change of variable). The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series `1*L_0 + 2*L_1 + 3*L_2` while [[1,2],[1,2]] represents `1*L_0(x)*L_0(y) + 1*L_1(x)*L_0(y) + 2*L_0(x)*L_1(y) + 2*L_1(x)*L_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of Laguerre series coefficients. If *c* is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Number of derivatives taken, must be non-negative. (Default: 1)

scl
: [scalar, optional] Each differentiation is multiplied by *scl*. The end result is multiplication by `scl**m`. This is for use in a linear change of variable. (Default: 1)

axis
: [int, optional] Axis over which the derivative is taken. (Default: 0).

Returns

der
: [ndarray] Laguerre series of the derivative.

See also:

lagint

Notes

In general, the result of differentiating a Laguerre series does not resemble the same operation on a power series. Thus the result of this function may be "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial.laguerre import lagder
>>> lagder([ 1.,  1.,  1., -3.])
array([1.,  2.,  3.])
>>> lagder([ 1.,  0.,  0., -4.,  3.], m=2)
array([1.,  2.,  3.])
```

`polynomial.laguerre.`**`lagint`**(*c*, *m=1*, *k=[]*, *lbnd=0*, *scl=1*, *axis=0*)

Integrate a Laguerre series.

Returns the Laguerre series coefficients *c* integrated *m* times from *lbnd* along *axis*. At each iteration the resulting series is **multiplied** by *scl* and an integration constant, *k*, is added. The scaling factor is for use in a linear change of variable. ("Buyer beware": note that, depending on what one is doing, one may want *scl* to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series `L_0 + 2*L_1 + 3*L_2` while [[1,2],[1,2]] represents `1*L_0(x)*L_0(y) + 1*L_1(x)*L_0(y) + 2*L_0(x)*L_1(y) + 2*L_1(x)*L_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of Laguerre series coefficients. If *c* is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Order of integration, must be positive. (Default: 1)

k
: [{[], list, scalar}, optional] Integration constant(s). The value of the first integral at `lbnd` is the first value in the list, the value of the second integral at `lbnd` is the second value, etc. If `k == []` (the default), all constants are set to zero. If `m == 1`, a single scalar can be given instead of a list.

lbnd
: [scalar, optional] The lower bound of the integral. (Default: 0)

scl
: [scalar, optional] Following each integration the result is *multiplied* by *scl* before the integration constant is added. (Default: 1)

axis
: [int, optional] Axis over which the integral is taken. (Default: 0).

Returns

S
: [ndarray] Laguerre series coefficients of the integral.

Raises

ValueError
: If `m < 0`, `len(k) > m`, `np.ndim(lbnd) != 0`, or `np.ndim(scl) != 0`.

See also:

lagder

Notes

Note that the result of each integration is *multiplied* by *scl*. Why is this important to note? Say one is making a linear change of variable $u = ax + b$ in an integral relative to x. Then $dx = du/a$, so one will need to set *scl* equal to $1/a$ - perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be "reprojected" onto the C-series basis set. Thus, typically, the result of this function is "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial.laguerre import lagint
>>> lagint([1,2,3])
array([ 1.,  1.,  1., -3.])
>>> lagint([1,2,3], m=2)
array([ 1.,  0.,  0., -4.,  3.])
>>> lagint([1,2,3], k=1)
array([ 2.,  1.,  1., -3.])
>>> lagint([1,2,3], lbnd=-1)
array([11.5,  1. ,  1. , -3. ])
>>> lagint([1,2], m=2, k=[1,2], lbnd=-1)
array([ 11.16666667,  -5.        ,  -3.        ,   2.        ]) # may vary
```

Misc Functions

lagfromroots(roots)	Generate a Laguerre series with given roots.
lagroots(c)	Compute the roots of a Laguerre series.
lagvander(x, deg)	Pseudo-Vandermonde matrix of given degree.
lagvander2d(x, y, deg)	Pseudo-Vandermonde matrix of given degrees.
lagvander3d(x, y, z, deg)	Pseudo-Vandermonde matrix of given degrees.
laggauss(deg)	Gauss-Laguerre quadrature.
lagweight(x)	Weight function of the Laguerre polynomials.
lagcompanion(c)	Return the companion matrix of c.
lagfit(x, y, deg[, rcond, full, w])	Least squares fit of Laguerre series to data.
lagtrim(c[, tol])	Remove "small" "trailing" coefficients from a polynomial.
lagline(off, scl)	Laguerre series whose graph is a straight line.
lag2poly(c)	Convert a Laguerre series to a polynomial.
poly2lag(pol)	Convert a polynomial to a Laguerre series.

polynomial.laguerre.**lagfromroots**(*roots*)

Generate a Laguerre series with given roots.

The function returns the coefficients of the polynomial

$$p(x) = (x - r_0) * (x - r_1) * ... * (x - r_n),$$

in Laguerre form, where the r_n are the roots specified in *roots*. If a zero has multiplicity n, then it must appear in *roots* n times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then *roots* looks something like [2, 2, 2, 3, 3]. The roots can appear in any order.

If the returned coefficients are *c*, then

$$p(x) = c_0 + c_1 * L_1(x) + ... + c_n * L_n(x)$$

The coefficient of the last term is not generally 1 for monic polynomials in Laguerre form.

Parameters

roots
[array_like] Sequence containing the roots.

Returns

out
[ndarray] 1-D array of coefficients. If all roots are real then *out* is a real array, if some of the roots are complex, then *out* is complex even if all the coefficients in the result are real (see Examples below).

See also:

numpy.polynomial.polynomial.polyfromroots
numpy.polynomial.legendre.legfromroots
numpy.polynomial.chebyshev.chebfromroots
numpy.polynomial.hermite.hermfromroots
numpy.polynomial.hermite_e.hermefromroots

Examples

```
>>> from numpy.polynomial.laguerre import lagfromroots, lagval
>>> coef = lagfromroots((-1, 0, 1))
>>> lagval((-1, 0, 1), coef)
array([0.,  0.,  0.])
>>> coef = lagfromroots((-1j, 1j))
>>> lagval((-1j, 1j), coef)
array([0.+0.j, 0.+0.j])
```

polynomial.laguerre.**lagroots**(*c*)

Compute the roots of a Laguerre series.

Return the roots (a.k.a. "zeros") of the polynomial

$$p(x) = \sum_i c[i] * L_i(x).$$

Parameters

c
[1-D array_like] 1-D array of coefficients.

Returns

out
[ndarray] Array of the roots of the series. If all the roots are real, then *out* is also real, otherwise it is complex.

See also:

numpy.polynomial.polynomial.polyroots
numpy.polynomial.legendre.legroots
numpy.polynomial.chebyshev.chebroots
numpy.polynomial.hermite.hermroots
numpy.polynomial.hermite_e.hermeroots

Notes

The root estimates are obtained as the eigenvalues of the companion matrix, Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton's method.

The Laguerre series basis polynomials aren't powers of x so the results of this function may seem unintuitive.

Examples

```
>>> from numpy.polynomial.laguerre import lagroots, lagfromroots
>>> coef = lagfromroots([0, 1, 2])
>>> coef
array([  2.,  -8.,  12.,  -6.])
>>> lagroots(coef)
array([-4.4408921e-16,  1.0000000e+00,  2.0000000e+00])
```

polynomial.laguerre.**lagvander**(*x*, *deg*)

Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree *deg* and sample points *x*. The pseudo-Vandermonde matrix is defined by

$$V[..., i] = L_i(x)$$

where `0 <= i <= deg`. The leading indices of *V* index the elements of *x* and the last index is the degree of the Laguerre polynomial.

If *c* is a 1-D array of coefficients of length `n + 1` and *V* is the array `V = lagvander(x, n)`, then `np.dot(V, c)` and `lagval(x, c)` are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of Laguerre series of the same degree and sample points.

Parameters

x
: [array_like] Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If *x* is scalar it is converted to a 1-D array.

deg
: [int] Degree of the resulting matrix.

Returns

vander
: [ndarray] The pseudo-Vandermonde matrix. The shape of the returned matrix is `x.shape + (deg + 1,)`, where The last index is the degree of the corresponding Laguerre polynomial. The dtype will be the same as the converted *x*.

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.laguerre import lagvander
>>> x = np.array([0, 1, 2])
>>> lagvander(x, 3)
array([[ 1.        ,  1.        ,  1.        ,  1.        ],
       [ 1.        ,  0.        , -0.5       , -0.66666667],
       [ 1.        , -1.        , -1.        , -0.33333333]])
```

polynomial.laguerre.**lagvander2d**(*x*, *y*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y)`. The pseudo-Vandermonde matrix is defined by

$$V[..., (deg[1] + 1) * i + j] = L_i(x) * L_j(y),$$

where `0 <= i <= deg[0]` and `0 <= j <= deg[1]`. The leading indices of *V* index the points `(x, y)` and the last index encodes the degrees of the Laguerre polynomials.

If `V = lagvander2d(x, y, [xdeg, ydeg])`, then the columns of *V* correspond to the elements of a 2-D coefficient array *c* of shape (xdeg + 1, ydeg + 1) in the order

$$c_{00}, c_{01}, c_{02} ..., c_{10}, c_{11}, c_{12} ...$$

and `np.dot(V, c.flat)` and `lagval2d(x, y, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D Laguerre series of the same degrees and sample points.

Parameters

x, y
[array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
[list of ints] List of maximum degrees of the form [x_deg, y_deg].

Returns

vander2d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)$. The dtype will be the same as the converted *x* and *y*.

See also:

lagvander, ***lagvander3d***, ***lagval2d***, ***lagval3d***

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.laguerre import lagvander2d
>>> x = np.array([0])
>>> y = np.array([2])
>>> lagvander2d(x, y, [2, 1])
array([[ 1., -1.,  1., -1.,  1., -1.]])
```

`polynomial.laguerre.`**`lagvander3d`**(*x*, *y*, *z*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y, z)`. If *l*, *m*, *n* are the given degrees in *x*, *y*, *z*, then The pseudo-Vandermonde matrix is defined by

$$V[..., (m+1)(n+1)i + (n+1)j + k] = L_i(x) * L_j(y) * L_k(z),$$

where `0 <= i <= l`, `0 <= j <= m`, and `0 <= j <= n`. The leading indices of *V* index the points `(x, y, z)` and the last index encodes the degrees of the Laguerre polynomials.

If `V = lagvander3d(x, y, z, [xdeg, ydeg, zdeg])`, then the columns of *V* correspond to the elements of a 3-D coefficient array *c* of shape (xdeg + 1, ydeg + 1, zdeg + 1) in the order

$$c_{000}, c_{001}, c_{002}, ..., c_{010}, c_{011}, c_{012}, ...$$

and `np.dot(V, c.flat)` and `lagval3d(x, y, z, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D Laguerre series of the same degrees and sample points.

Parameters

x, y, z
[array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
[list of ints] List of maximum degrees of the form [x_deg, y_deg, z_deg].

Returns

vander3d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)*(deg[2]+1)$. The dtype will be the same as the converted x, y, and z.

See also:

lagvander, ***lagvander3d***, ***lagval2d***, ***lagval3d***

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.laguerre import lagvander3d
>>> x = np.array([0])
>>> y = np.array([2])
>>> z = np.array([0])
>>> lagvander3d(x, y, z, [2, 1, 3])
array([[ 1.,  1.,  1.,  1., -1., -1., -1., -1.,  1.,  1.,  1.,  1., -1.,
        -1., -1., -1.,  1.,  1.,  1.,  1., -1., -1., -1., -1.]])
```

polynomial.laguerre.**laggauss**(*deg*)

Gauss-Laguerre quadrature.

Computes the sample points and weights for Gauss-Laguerre quadrature. These sample points and weights will correctly integrate polynomials of degree $2*deg-1$ or less over the interval $[0, \inf]$ with the weight function $f(x) = \exp(-x)$.

Parameters

deg
[int] Number of sample points and weights. It must be >= 1.

Returns

x
[ndarray] 1-D ndarray containing the sample points.

y
[ndarray] 1-D ndarray containing the weights.

Notes

The results have only been tested up to degree 100 higher degrees may be problematic. The weights are determined by using the fact that

$$w_k = c/(L'_n(x_k) * L_{n-1}(x_k))$$

where c is a constant independent of k and x_k is the k'th root of L_n, and then scaling the results to get the right value when integrating 1.

Examples

```
>>> from numpy.polynomial.laguerre import laggauss
>>> laggauss(2)
(array([0.58578644, 3.41421356]), array([0.85355339, 0.14644661]))
```

polynomial.laguerre.**lagweight**(*x*)

Weight function of the Laguerre polynomials.

The weight function is $exp(-x)$ and the interval of integration is $[0, \text{inf}]$. The Laguerre polynomials are orthogonal, but not normalized, with respect to this weight function.

Parameters

x
[array_like] Values at which the weight function will be computed.

Returns

w
[ndarray] The weight function at *x*.

Examples

```
>>> from numpy.polynomial.laguerre import lagweight
>>> x = np.array([0, 1, 2])
>>> lagweight(x)
array([1.        , 0.36787944, 0.13533528])
```

polynomial.laguerre.**lagcompanion**(*c*)

Return the companion matrix of c.

The usual companion matrix of the Laguerre polynomials is already symmetric when *c* is a basis Laguerre polynomial, so no scaling is applied.

Parameters

c
[array_like] 1-D array of Laguerre series coefficients ordered from low to high degree.

Returns

mat
[ndarray] Companion matrix of dimensions (deg, deg).

Examples

```
>>> from numpy.polynomial.laguerre import lagcompanion
>>> lagcompanion([1, 2, 3])
array([[ 1.        , -0.33333333],
       [-1.        ,  4.33333333]])
```

polynomial.laguerre.**lagfit**(*x*, *y*, *deg*, *rcond=None*, *full=False*, *w=None*)

Least squares fit of Laguerre series to data.

Return the coefficients of a Laguerre series of degree *deg* that is the least squares fit to the data values *y* given at points *x*. If *y* is 1-D the returned coefficients will also be 1-D. If *y* is 2-D multiple fits are done, one for each column

of *y*, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

$$p(x) = c_0 + c_1 * L_1(x) + ... + c_n * L_n(x),$$

where `n` is *deg*.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,) or (M, K)] y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (*M*,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

Returns

coef
[ndarray, shape (M,) or (M, K)] Laguerre coefficients ordered from low to high. If *y* was 2-D, the coefficients for the data in column *k* of *y* are in column *k*.

[residuals, rank, singular_values, rcond]
[list] These values are only returned if `full == True`

- residuals – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- singular_values – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *numpy.linalg.lstsq*.

Warns

RankWarning
The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if `full == False`. The warnings can be turned off by

```
>>> import warnings
>>> warnings.simplefilter('ignore', np.exceptions.RankWarning)
```

See also:

numpy.polynomial.polynomial.polyfit
numpy.polynomial.legendre.legfit
numpy.polynomial.chebyshev.chebfit
numpy.polynomial.hermite.hermfit
numpy.polynomial.hermite_e.hermefit
lagval
: Evaluates a Laguerre series.

lagvander
: pseudo Vandermonde matrix of Laguerre series.

lagweight
: Laguerre weight function.

numpy.linalg.lstsq
: Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline
: Computes spline fits.

Notes

The solution is the coefficients of the Laguerre series `p` that minimizes the sum of the weighted squared errors

$$E = \sum_j w_j^2 * |y_j - p(x_j)|^2,$$

where the w_j are the weights. This problem is solved by setting up as the (typically) overdetermined matrix equation

$$V(x) * c = w * y,$$

where `V` is the weighted pseudo Vandermonde matrix of *x*, `c` are the coefficients to be solved for, *w* are the weights, and *y* are the observed values. This equation is then solved using the singular value decomposition of `V`.

If some of the singular values of *V* are so small that they are neglected, then a *RankWarning* will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The *rcond* parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using Laguerre series are probably most useful when the data can be approximated by `sqrt(w(x)) * p(x)`, where `w(x)` is the Laguerre weight. In that case the weight `sqrt(w(x[i]))` should be used together with data values `y[i]/sqrt(w(x[i]))`. The weight function is available as *lagweight*.

References

[1]

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.laguerre import lagfit, lagval
>>> x = np.linspace(0, 10)
>>> rng = np.random.default_rng()
>>> err = rng.normal(scale=1./10, size=len(x))
>>> y = lagval(x, [1, 2, 3]) + err
>>> lagfit(x, y, 2)
array([1.00578369, 1.99417356, 2.99827656]) # may vary
```

polynomial.laguerre.**lagtrim**(*c*, *tol=0*)

Remove "small" "trailing" coefficients from a polynomial.

"Small" means "small in absolute value" and is controlled by the parameter *tol*; "trailing" means highest order coefficient(s), e.g., in `[0, 1, 1, 0, 0]` (which represents `0 + x + x**2 + 0*x**3 + 0*x**4`) both the 3-rd and 4-th order coefficients would be "trimmed."

Parameters

c
[array_like] 1-d array of coefficients, ordered from lowest order to highest.

tol
[number, optional] Trailing (i.e., highest order) elements with absolute value less than or equal to *tol* (default value is zero) are removed.

Returns

trimmed
[ndarray] 1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError
If *tol* < 0

Examples

```
>>> from numpy.polynomial import polyutils as pu
>>> pu.trimcoef((0,0,3,0,5,0,0))
array([0.,  0.,  3.,  0.,  5.])
>>> pu.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([0.])
>>> i = complex(0,1) # works for complex
>>> pu.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([0.0003+0.j   , 0.001 -0.001j])
```

polynomial.laguerre.**lagline**(*off*, *scl*)

Laguerre series whose graph is a straight line.

Parameters

off, scl
[scalars] The specified line is given by `off + scl*x`.

Returns

y
[ndarray] This module's representation of the Laguerre series for `off + scl*x`.

See also:

numpy.polynomial.polynomial.polyline
numpy.polynomial.chebyshev.chebline
numpy.polynomial.legendre.legline
numpy.polynomial.hermite.hermline
numpy.polynomial.hermite_e.hermeline

Examples

```
>>> from numpy.polynomial.laguerre import lagline, lagval
>>> lagval(0,lagline(3, 2))
3.0
>>> lagval(1,lagline(3, 2))
5.0
```

polynomial.laguerre.**lag2poly**(*c*)

Convert a Laguerre series to a polynomial.

Convert an array representing the coefficients of a Laguerre series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest to highest degree.

Parameters

c
[array_like] 1-D array containing the Laguerre series coefficients, ordered from lowest order term to highest.

Returns

pol
[ndarray] 1-D array containing the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest order term to highest.

See also:

poly2lag

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> from numpy.polynomial.laguerre import lag2poly
>>> lag2poly([ 23., -63.,  58., -18.])
array([0., 1., 2., 3.])
```

polynomial.laguerre.**poly2lag**(*pol*)

Convert a polynomial to a Laguerre series.

Convert an array representing the coefficients of a polynomial (relative to the "standard" basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Laguerre series, ordered from lowest to highest degree.

Parameters

pol
[array_like] 1-D array containing the polynomial coefficients

Returns

c
[ndarray] 1-D array containing the coefficients of the equivalent Laguerre series.

See also:

lag2poly

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> import numpy as np
>>> from numpy.polynomial.laguerre import poly2lag
>>> poly2lag(np.arange(4))
array([ 23., -63.,  58., -18.])
```

See also

numpy.polynomial

Legendre Series (`numpy.polynomial.legendre`)

This module provides a number of objects (mostly functions) useful for dealing with Legendre series, including a *Legendre* class that encapsulates the usual arithmetic operations. (General information on how this module represents and works with such polynomials is in the docstring for its "parent" sub-package, *numpy.polynomial*).

Classes

Legendre(coef[, domain, window, symbol])	A Legendre series class.

class numpy.polynomial.legendre.**Legendre**(*coef*, *domain=None*, *window=None*, *symbol='x'*)

A Legendre series class.

The Legendre class provides the standard Python numerical methods '+', '-', '*', '//', '%', 'divmod', '**', and '()' as well as the attributes and methods listed below.

Parameters

coef
[array_like] Legendre coefficients in order of increasing degree, i.e., `(1, 2, 3)` gives `1*P_0(x) + 2*P_1(x) + 3*P_2(x)`.

domain
[(2,) array_like, optional] Domain to use. The interval `[domain[0], domain[1]]` is mapped to the interval `[window[0], window[1]]` by shifting and scaling. The default value is [-1., 1.].

window
[(2,) array_like, optional] Window, see `domain` for its use. The default value is [-1., 1.].

symbol
[str, optional] Symbol used to represent the independent variable in string representations of the polynomial expression, e.g. for printing. The symbol must be a valid Python identifier. Default value is 'x'.

New in version 1.24.

Attributes

symbol

Methods

`__call__`(arg)	Call self as a function.
`basis`(deg[, domain, window, symbol])	Series basis polynomial of degree *deg*.
`cast`(series[, domain, window])	Convert series to series of this class.
`convert`([domain, kind, window])	Convert series to a different kind and/or domain and/or window.
`copy`()	Return a copy.
`cutdeg`(deg)	Truncate series to the given degree.
`degree`()	The degree of the series.
`deriv`([m])	Differentiate.
`fit`(x, y, deg[, domain, rcond, full, w, ...])	Least squares fit to data.
`fromroots`(roots[, domain, window, symbol])	Return series instance that has the specified roots.
`has_samecoef`(other)	Check if coefficients match.
`has_samedomain`(other)	Check if domains match.
`has_sametype`(other)	Check if types match.
`has_samewindow`(other)	Check if windows match.
`identity`([domain, window, symbol])	Identity function.
`integ`([m, k, lbnd])	Integrate.
`linspace`([n, domain])	Return x, y values at equally spaced points in domain.
`mapparms`()	Return the mapping parameters.
`roots`()	Return the roots of the series polynomial.
`trim`([tol])	Remove trailing coefficients
`truncate`(size)	Truncate series to length *size*.

method

polynomial.legendre.Legendre.**__call__**(*arg*)

Call self as a function.

method

classmethod polynomial.legendre.Legendre.**basis**(*deg*, *domain=None*, *window=None*, *symbol='x'*)

Series basis polynomial of degree *deg*.

Returns the series representing the basis polynomial of degree *deg*.

Parameters

deg
[int] Degree of the basis polynomial for the series. Must be >= 0.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series with the coefficient of the *deg* term set to one and all others zero.

method

classmethod polynomial.legendre.Legendre.**cast**(*series*, *domain=None*, *window=None*)

Convert series to series of this class.

The *series* is expected to be an instance of some polynomial series of one of the types supported by by the numpy.polynomial module, but could be some other class that supports the convert method.

Parameters

series
[series] The series instance to be converted.

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

Returns

new_series
[series] A series of the same kind as the calling class and equal to *series* when evaluated.

See also:

convert
similar instance method

method

polynomial.legendre.Legendre.**convert**(*domain=None*, *kind=None*, *window=None*)

Convert series to a different kind and/or domain and/or window.

Parameters

domain
[array_like, optional] The domain of the converted series. If the value is None, the default domain of *kind* is used.

kind
[class, optional] The polynomial series type class to which the current instance should be converted. If kind is None, then the class of the current instance is used.

window
[array_like, optional] The window of the converted series. If the value is None, the default window of *kind* is used.

Returns

new_series
[series] The returned class can be of different type than the current instance and/or have a different domain and/or different window.

Notes

Conversion between domains and class types can result in numerically ill defined series.

method

polynomial.legendre.Legendre.**copy**()

Return a copy.

Returns

new_series
[series] Copy of self.

method

polynomial.legendre.Legendre.**cutdeg**(*deg*)

Truncate series to the given degree.

Reduce the degree of the series to *deg* by discarding the high order terms. If *deg* is greater than the current degree a copy of the current series is returned. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

deg
[non-negative int] The series is reduced to degree *deg* by discarding the high order terms. The value of *deg* must be a non-negative integer.

Returns

new_series
[series] New instance of series with reduced degree.

method

polynomial.legendre.Legendre.**degree**()

The degree of the series.

Returns

degree
[int] Degree of the series, one less than the number of coefficients.

Examples

Create a polynomial object for `1 + 7*x + 4*x**2`:

```
>>> poly = np.polynomial.Polynomial([1, 7, 4])
>>> print(poly)
1.0 + 7.0·x + 4.0·x²
>>> poly.degree()
2
```

Note that this method does not check for non-zero coefficients. You must trim the polynomial to remove any trailing zeroes:

```
>>> poly = np.polynomial.Polynomial([1, 7, 0])
>>> print(poly)
1.0 + 7.0·x + 0.0·x²
```

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```
>>> poly.degree()
2
>>> poly.trim().degree()
1
```

method

polynomial.legendre.Legendre.**deriv**(*m=1*)

Differentiate.

Return a series instance of that is the derivative of the current series.

Parameters

m
[non-negative int] Find the derivative of order *m*.

Returns

new_series
[series] A new series representing the derivative. The domain is the same as the domain of the differentiated series.

method

classmethod polynomial.legendre.Legendre.**fit**(*x*, *y*, *deg*, *domain=None*, *rcond=None*, *full=False*, *w=None*, *window=None*, *symbol='x'*)

Least squares fit to data.

Return a series instance that is the least squares fit to the data *y* sampled at *x*. The domain of the returned instance can be specified and this will often result in a superior fit with less chance of ill conditioning.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,)] y-coordinates of the M sample points `(x[i], y[i])`.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

domain
[{None, [beg, end], []}, optional] Domain to use for the returned series. If `None`, then a minimal domain that covers the points *x* is chosen. If `[]` the class domain is used. The default value was the class domain in NumPy 1.4 and `None` in later versions. The `[]` option was added in numpy 1.5.0.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is `len(x)*eps`, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (M,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

window
[{[beg, end]}, optional] Window to use for the returned series. The default value is the default class domain

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] A series that represents the least squares fit to the data and has the domain and window specified in the call. If the coefficients for the unscaled and unshifted basis polynomials are of interest, do `new_series.convert().coef`.

[resid, rank, sv, rcond]
[list] These values are only returned if `full == True`

- resid – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- sv – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *linalg.lstsq*.

method

classmethod polynomial.legendre.Legendre.**fromroots**(*roots*, *domain=[]*, *window=None*, *symbol='x'*)

Return series instance that has the specified roots.

Returns a series representing the product `(x - r[0])*(x - r[1])*...*(x - r[n-1])`, where `r` is a list of roots.

Parameters

roots
[array_like] List of roots.

domain
[{[], None, array_like}, optional] Domain for the resulting series. If None the domain is the interval from the smallest root to the largest. If [] the domain is the class domain. The default is [].

window
[{None, array_like}, optional] Window for the returned series. If None the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series with the specified roots.

method

polynomial.legendre.Legendre.**has_samecoef**(*other*)

Check if coefficients match.

Parameters

other
[class instance] The other class must have the `coef` attribute.

Returns

bool
[boolean] True if the coefficients are the same, False otherwise.

method

polynomial.legendre.Legendre.**has_samedomain**(*other*)

Check if domains match.

Parameters

other
[class instance] The other class must have the `domain` attribute.

Returns

bool
[boolean] True if the domains are the same, False otherwise.

method

polynomial.legendre.Legendre.**has_sametype**(*other*)

Check if types match.

Parameters

other
[object] Class instance.

Returns

bool
[boolean] True if other is same class as self

method

polynomial.legendre.Legendre.**has_samewindow**(*other*)

Check if windows match.

Parameters

other
[class instance] The other class must have the `window` attribute.

Returns

bool
[boolean] True if the windows are the same, False otherwise.

method

classmethod polynomial.legendre.Legendre.**identity**(*domain=None*, *window=None*, *symbol='x'*)

Identity function.

If `p` is the returned series, then `p(x) == x` for all values of x.

Parameters

domain
[{None, array_like}, optional] If given, the array must be of the form `[beg, end]`, where `beg` and `end` are the endpoints of the domain. If None is given then the class domain is used. The default is None.

window
[{None, array_like}, optional] If given, the resulting array must be if the form `[beg, end]`, where `beg` and `end` are the endpoints of the window. If None is given then the class window is used. The default is None.

symbol
[str, optional] Symbol representing the independent variable. Default is 'x'.

Returns

new_series
[series] Series of representing the identity.

method

polynomial.legendre.Legendre.**integ**(*m=1*, *k=[]*, *lbnd=None*)

Integrate.

Return a series instance that is the definite integral of the current series.

Parameters

m
[non-negative int] The number of integrations to perform.

k
[array_like] Integration constants. The first constant is applied to the first integration, the second to the second, and so on. The list of values must less than or equal to *m* in length and any missing values are set to zero.

lbnd
[Scalar] The lower bound of the definite integral.

Returns

new_series
[series] A new series representing the integral. The domain is the same as the domain of the integrated series.

method

polynomial.legendre.Legendre.**linspace**(*n=100*, *domain=None*)

Return x, y values at equally spaced points in domain.

Returns the x, y values at *n* linearly spaced points across the domain. Here y is the value of the polynomial at the points x. By default the domain is the same as that of the series instance. This method is intended mostly as a plotting aid.

Parameters

n
[int, optional] Number of point pairs to return. The default value is 100.

domain
[{None, array_like}, optional] If not None, the specified domain is used instead of that of the calling instance. It should be of the form `[beg,end]`. The default is None which case the class domain is used.

Returns

x, y
[ndarray] x is equal to linspace(self.domain[0], self.domain[1], n) and y is the series evaluated at element of x.

method

`polynomial.legendre.Legendre.`**`mapparms`**`()`

Return the mapping parameters.

The returned values define a linear map `off + scl*x` that is applied to the input arguments before the series is evaluated. The map depends on the `domain` and `window`; if the current `domain` is equal to the `window` the resulting map is the identity. If the coefficients of the series instance are to be used by themselves outside this class, then the linear function must be substituted for the `x` in the standard representation of the base polynomials.

Returns

off, scl
[float or complex] The mapping function is defined by `off + scl*x`.

Notes

If the current domain is the interval `[l1, r1]` and the window is `[l2, r2]`, then the linear mapping function `L` is defined by the equations:

```
L(l1) = l2
L(r1) = r2
```

method

`polynomial.legendre.Legendre.`**`roots`**`()`

Return the roots of the series polynomial.

Compute the roots for the series. Note that the accuracy of the roots decreases the further outside the `domain` they lie.

Returns

roots
[ndarray] Array containing the roots of the series.

method

`polynomial.legendre.Legendre.`**`trim`**`(`*`tol=0`*`)`

Remove trailing coefficients

Remove trailing coefficients until a coefficient is reached whose absolute value greater than *tol* or the beginning of the series is reached. If all the coefficients would be removed the series is set to `[0]`. A new series instance is returned with the new coefficients. The current instance remains unchanged.

Parameters

tol
[non-negative number.] All trailing coefficients less than *tol* will be removed.

Returns

new_series
[series] New instance of series with trimmed coefficients.

method

polynomial.legendre.Legendre.**truncate**(*size*)

Truncate series to length *size*.

Reduce the series to length *size* by discarding the high degree terms. The value of *size* must be a positive integer. This can be useful in least squares where the coefficients of the high degree terms may be very small.

Parameters

size
[positive int] The series is reduced to length *size* by discarding the high degree terms. The value of *size* must be a positive integer.

Returns

new_series
[series] New instance of series with truncated coefficients.

Constants

legdomain	An array object represents a multidimensional, homogeneous array of fixed-size items.
legzero	An array object represents a multidimensional, homogeneous array of fixed-size items.
legone	An array object represents a multidimensional, homogeneous array of fixed-size items.
legx	An array object represents a multidimensional, homogeneous array of fixed-size items.

polynomial.legendre.**legdomain = array([-1., 1.])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.legendre.`**`legzero = array([0])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
: [tuple of ints] Shape of created array.

dtype
: [data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
: [object exposing buffer interface, optional] Used to fill the array with data.

offset
: [int, optional] Offset of array data in buffer.

strides
: [tuple of ints, optional] Strides of data in memory.

order
: [{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
: Construct an array.

zeros
: Create an array, each element of which is zero.

empty
: Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
: Create a data-type.

numpy.typing.NDArray
: An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using `__new__`:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No `__init__` method is needed because the array is fully initialized after the `__new__` method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

polynomial.legendre.**legone = array([1])**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)

shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using __new__:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No __init__ method is needed because the array is fully initialized after the __new__ method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
[ndarray] Transpose of the array.

data
[buffer] The array's elements, in memory.

dtype
[dtype object] Describes the format of the elements in the array.

flags
[dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
[numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
[ndarray] Imaginary part of the array.

real
[ndarray] Real part of the array.

size
[int] Number of elements in the array.

itemsize
[int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For

example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

`polynomial.legendre.`**`legx = array([0, 1])`**

An array object represents a multidimensional, homogeneous array of fixed-size items. An associated data-type object describes the format of each element in the array (its byte-order, how many bytes it occupies in memory, whether it is an integer, a floating point number, or something else, etc.)

Arrays should be constructed using *array*, *zeros* or *empty* (refer to the See Also section below). The parameters given here refer to a low-level method (*ndarray(…)*) for instantiating an array.

For more information, refer to the *numpy* module and examine the methods and attributes of an array.

Parameters

(for the __new__ method; see Notes below)
shape
[tuple of ints] Shape of created array.

dtype
[data-type, optional] Any object that can be interpreted as a numpy data type.

buffer
[object exposing buffer interface, optional] Used to fill the array with data.

offset
[int, optional] Offset of array data in buffer.

strides
[tuple of ints, optional] Strides of data in memory.

order
[{'C', 'F'}, optional] Row-major (C-style) or column-major (Fortran-style) order.

See also:

array
Construct an array.

zeros
Create an array, each element of which is zero.

empty
Create an array, but leave its allocated memory unchanged (i.e., it contains "garbage").

dtype
Create a data-type.

numpy.typing.NDArray
An ndarray alias generic w.r.t. its *dtype.type*.

Notes

There are two modes of creating an array using `__new__`:

1. If *buffer* is None, then only *shape*, *dtype*, and *order* are used.
2. If *buffer* is an object exposing the buffer interface, then all keywords are interpreted.

No `__init__` method is needed because the array is fully initialized after the `__new__` method.

Examples

These examples illustrate the low-level *ndarray* constructor. Refer to the *See Also* section above for easier ways of constructing an ndarray.

First mode, *buffer* is None:

```
>>> import numpy as np
>>> np.ndarray(shape=(2,2), dtype=float, order='F')
array([[0.0e+000, 0.0e+000], # random
       [     nan, 2.5e-323]])
```

Second mode:

```
>>> np.ndarray((2,), buffer=np.array([1,2,3]),
...            offset=np.int_().itemsize,
...            dtype=int) # offset = 1*itemsize, i.e. skip first element
array([2, 3])
```

Attributes

T
: [ndarray] Transpose of the array.

data
: [buffer] The array's elements, in memory.

dtype
: [dtype object] Describes the format of the elements in the array.

flags
: [dict] Dictionary containing information related to memory use, e.g., 'C_CONTIGUOUS', 'OWNDATA', 'WRITEABLE', etc.

flat
: [numpy.flatiter object] Flattened version of the array as an iterator. The iterator allows assignments, e.g., `x.flat = 3` (See *ndarray.flat* for assignment examples; TODO).

imag
: [ndarray] Imaginary part of the array.

real
: [ndarray] Real part of the array.

size
: [int] Number of elements in the array.

itemsize
: [int] The memory use of each array element in bytes.

nbytes
[int] The total number of bytes required to store the array data, i.e., `itemsize * size`.

ndim
[int] The array's number of dimensions.

shape
[tuple of ints] Shape of the array.

strides
[tuple of ints] The step-size required to move from one element to the next in memory. For example, a contiguous `(3, 4)` array of type `int16` in C-order has strides `(8, 2)`. This implies that to move from element to element in memory requires jumps of 2 bytes. To move from row-to-row, one needs to jump 8 bytes at a time (`2 * 4`).

ctypes
[ctypes object] Class containing properties of the array needed for interaction with ctypes.

base
[ndarray] If the array is a view into another array, that array is its *base* (unless that array is also a view). The *base* array is where the array data is actually stored.

Arithmetic

legadd(c1, c2)	Add one Legendre series to another.
legsub(c1, c2)	Subtract one Legendre series from another.
legmulx(c)	Multiply a Legendre series by x.
legmul(c1, c2)	Multiply one Legendre series by another.
legdiv(c1, c2)	Divide one Legendre series by another.
legpow(c, pow[, maxpower])	Raise a Legendre series to a power.
legval(x, c[, tensor])	Evaluate a Legendre series at points x.
legval2d(x, y, c)	Evaluate a 2-D Legendre series at points (x, y).
legval3d(x, y, z, c)	Evaluate a 3-D Legendre series at points (x, y, z).
leggrid2d(x, y, c)	Evaluate a 2-D Legendre series on the Cartesian product of x and y.
leggrid3d(x, y, z, c)	Evaluate a 3-D Legendre series on the Cartesian product of x, y, and z.

`polynomial.legendre.`**`legadd`**(*c1*, *c2*)

Add one Legendre series to another.

Returns the sum of two Legendre series *c1* + *c2*. The arguments are sequences of coefficients ordered from lowest order term to highest, i.e., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Legendre series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the Legendre series of their sum.

See also:

legsub*, *legmulx*, *legmul*, *legdiv*, *legpow

Notes

Unlike multiplication, division, etc., the sum of two Legendre series is a Legendre series (without having to "reproject" the result onto the basis set) so addition, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial import legendre as L
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> L.legadd(c1,c2)
array([4.,  4.,  4.])
```

polynomial.legendre.**legsub**(*c1*, *c2*)

Subtract one Legendre series from another.

Returns the difference of two Legendre series *c1* - *c2*. The sequences of coefficients are from lowest order term to highest, i.e., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Legendre series coefficients ordered from low to high.

Returns

out
[ndarray] Of Legendre series coefficients representing their difference.

See also:

legadd*, *legmulx*, *legmul*, *legdiv*, *legpow

Notes

Unlike multiplication, division, etc., the difference of two Legendre series is a Legendre series (without having to "reproject" the result onto the basis set) so subtraction, just like that of "standard" polynomials, is simply "component-wise."

Examples

```
>>> from numpy.polynomial import legendre as L
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> L.legsub(c1,c2)
array([-2.,  0.,  2.])
>>> L.legsub(c2,c1) # -C.legsub(c1,c2)
array([ 2.,  0., -2.])
```

polynomial.legendre.**legmulx**(*c*)

Multiply a Legendre series by x.

Multiply the Legendre series *c* by x, where x is the independent variable.

Parameters

c
[array_like] 1-D array of Legendre series coefficients ordered from low to high.

Returns

out
[ndarray] Array representing the result of the multiplication.

See also:

legadd*, *legsub*, *legmul*, *legdiv*, *legpow

Notes

The multiplication uses the recursion relationship for Legendre polynomials in the form

$$xP_i(x) = ((i+1) * P_{i+1}(x) + i * P_{i-1}(x))/(2i+1)$$

Examples

```
>>> from numpy.polynomial import legendre as L
>>> L.legmulx([1,2,3])
array([ 0.66666667, 2.2, 1.33333333, 1.8]) # may vary
```

polynomial.legendre.**legmul**(*c1*, *c2*)

Multiply one Legendre series by another.

Returns the product of two Legendre series *c1 * c2*. The arguments are sequences of coefficients, from lowest order "term" to highest, e.g., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Legendre series coefficients ordered from low to high.

Returns

out
[ndarray] Of Legendre series coefficients representing their product.

See also:

legadd*, *legsub*, *legmulx*, *legdiv*, *legpow

Notes

In general, the (polynomial) product of two C-series results in terms that are not in the Legendre polynomial basis set. Thus, to express the product as a Legendre series, it is necessary to "reproject" the product onto said basis set, which may produce "unintuitive" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial import legendre as L
>>> c1 = (1,2,3)
>>> c2 = (3,2)
>>> L.legmul(c1,c2) # multiplication requires "reprojection"
array([  4.33333333,  10.4       ,  11.66666667,   3.6       ]) # may vary
```

polynomial.legendre.**legdiv**(*c1*, *c2*)

Divide one Legendre series by another.

Returns the quotient-with-remainder of two Legendre series *c1* / *c2*. The arguments are sequences of coefficients from lowest order "term" to highest, e.g., [1,2,3] represents the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c1, c2
[array_like] 1-D arrays of Legendre series coefficients ordered from low to high.

Returns

quo, rem
[ndarrays] Of Legendre series coefficients representing the quotient and remainder.

See also:

legadd, ***legsub***, ***legmulx***, ***legmul***, ***legpow***

Notes

In general, the (polynomial) division of one Legendre series by another results in quotient and remainder terms that are not in the Legendre polynomial basis set. Thus, to express these results as a Legendre series, it is necessary to "reproject" the results onto the Legendre basis set, which may produce "unintuitive" (but correct) results; see Examples section below.

Examples

```
>>> from numpy.polynomial import legendre as L
>>> c1 = (1,2,3)
>>> c2 = (3,2,1)
>>> L.legdiv(c1,c2) # quotient "intuitive," remainder not
(array([3.]), array([-8., -4.]))
>>> c2 = (0,1,2,3)
>>> L.legdiv(c2,c1) # neither "intuitive"
(array([-0.07407407,  1.66666667]), array([-1.03703704, -2.51851852])) # may vary
```

polynomial.legendre.**legpow**(*c*, *pow*, *maxpower=16*)

Raise a Legendre series to a power.

Returns the Legendre series *c* raised to the power *pow*. The argument *c* is a sequence of coefficients ordered from low to high. i.e., [1,2,3] is the series `P_0 + 2*P_1 + 3*P_2`.

Parameters

c
[array_like] 1-D array of Legendre series coefficients ordered from low to high.

pow
[integer] Power to which the series will be raised

maxpower
[integer, optional] Maximum power allowed. This is mainly to limit growth of the series to unmanageable size. Default is 16

Returns

coef
[ndarray] Legendre series of power.

See also:

legadd*, *legsub*, *legmulx*, *legmul*, *legdiv

polynomial.legendre.**legval**(*x*, *c*, *tensor=True*)

Evaluate a Legendre series at points x.

If *c* is of length `n + 1`, this function returns the value:

$$p(x) = c_0 * L_0(x) + c_1 * L_1(x) + ... + c_n * L_n(x)$$

The parameter *x* is converted to an array only if it is a tuple or a list, otherwise it is treated as a scalar. In either case, either *x* or its elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array, then `p(x)` will have the same shape as *x*. If *c* is multidimensional, then the shape of the result depends on the value of *tensor*. If *tensor* is true the shape will be c.shape[1:] + x.shape. If *tensor* is false the shape will be c.shape[1:]. Note that scalars have shape (,).

Trailing zeros in the coefficients will be used in the evaluation, so they should be avoided if efficiency is a concern.

Parameters

x
[array_like, compatible object] If *x* is a list or tuple, it is converted to an ndarray, otherwise it is left unchanged and treated as a scalar. In either case, *x* or its elements must support addition and multiplication with themselves and with the elements of *c*.

c
[array_like] Array of coefficients ordered so that the coefficients for terms of degree n are contained in c[n]. If *c* is multidimensional the remaining indices enumerate multiple polynomials. In the two dimensional case the coefficients may be thought of as stored in the columns of *c*.

tensor
[boolean, optional] If True, the shape of the coefficient array is extended with ones on the right, one for each dimension of *x*. Scalars have dimension 0 for this action. The result is that every column of coefficients in *c* is evaluated for every element of *x*. If False, *x* is broadcast over the columns of *c* for the evaluation. This keyword is useful when *c* is multidimensional. The default value is True.

Returns

values
[ndarray, algebra_like] The shape of the return value is described above.

See also:

legval2d*, *leggrid2d*, *legval3d*, *leggrid3d

Notes

The evaluation uses Clenshaw recursion, aka synthetic division.

polynomial.legendre.**legval2d**(*x*, *y*, *c*)

Evaluate a 2-D Legendre series at points (x, y).

This function returns the values:

$$p(x,y) = \sum_{i,j} c_{i,j} * L_i(x) * L_j(y)$$

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* is a 1-D array a one is implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape.

Parameters

x, y
: [array_like, compatible objects] The two dimensional series is evaluated at the points `(x, y)`, where *x* and *y* must have the same shape. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional Legendre series at points formed from pairs of corresponding values from *x* and *y*.

See also:

legval, ***leggrid2d***, ***legval3d***, ***leggrid3d***

polynomial.legendre.**legval3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D Legendre series at points (x, y, z).

This function returns the values:

$$p(x,y,z) = \sum_{i,j,k} c_{i,j,k} * L_i(x) * L_j(y) * L_k(z)$$

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars and they must have the same shape after conversion. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than 3 dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape.

Parameters

x, y, z
: [array_like, compatible object] The three dimensional series is evaluated at the points `(x, y, z)`, where *x*, *y*, and *z* must have the same shape. If any of *x*, *y*, or *z* is a list or tuple, it is first

converted to an ndarray, otherwise it is left unchanged and if it isn't an ndarray it is treated as a scalar.

c

[array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j,k is contained in `c[i,j,k]`. If *c* has dimension greater than 3 the remaining indices enumerate multiple sets of coefficients.

Returns

values

[ndarray, compatible object] The values of the multidimensional polynomial on points formed with triples of corresponding values from *x*, *y*, and *z*.

See also:

legval*, *legval2d*, *leggrid2d*, *leggrid3d

`polynomial.legendre.`**leggrid2d**(*x*, *y*, *c*)

Evaluate a 2-D Legendre series on the Cartesian product of x and y.

This function returns the values:

$$p(a,b) = \sum_{i,j} c_{i,j} * L_i(a) * L_j(b)$$

where the points `(a, b)` consist of all pairs formed by taking *a* from *x* and *b* from *y*. The resulting points form a grid with *x* in the first dimension and *y* in the second.

The parameters *x* and *y* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x* and *y* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than two dimensions, ones are implicitly appended to its shape to make it 2-D. The shape of the result will be c.shape[2:] + x.shape + y.shape.

Parameters

x, y

[array_like, compatible objects] The two dimensional series is evaluated at the points in the Cartesian product of *x* and *y*. If *x* or *y* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c

[array_like] Array of coefficients ordered so that the coefficient of the term of multi-degree i,j is contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values

[ndarray, compatible object] The values of the two dimensional Chebyshev series at points in the Cartesian product of *x* and *y*.

See also:

legval*, *legval2d*, *legval3d*, *leggrid3d

polynomial.legendre.**leggrid3d**(*x*, *y*, *z*, *c*)

Evaluate a 3-D Legendre series on the Cartesian product of x, y, and z.

This function returns the values:

$$p(a,b,c) = \sum_{i,j,k} c_{i,j,k} * L_i(a) * L_j(b) * L_k(c)$$

where the points `(a, b, c)` consist of all triples formed by taking *a* from *x*, *b* from *y*, and *c* from *z*. The resulting points form a grid with *x* in the first dimension, *y* in the second, and *z* in the third.

The parameters *x*, *y*, and *z* are converted to arrays only if they are tuples or a lists, otherwise they are treated as a scalars. In either case, either *x*, *y*, and *z* or their elements must support multiplication and addition both with themselves and with the elements of *c*.

If *c* has fewer than three dimensions, ones are implicitly appended to its shape to make it 3-D. The shape of the result will be c.shape[3:] + x.shape + y.shape + z.shape.

Parameters

x, y, z
: [array_like, compatible objects] The three dimensional series is evaluated at the points in the Cartesian product of *x*, *y*, and *z*. If *x*, *y*, or *z* is a list or tuple, it is first converted to an ndarray, otherwise it is left unchanged and, if it isn't an ndarray, it is treated as a scalar.

c
: [array_like] Array of coefficients ordered so that the coefficients for terms of degree i,j are contained in `c[i,j]`. If *c* has dimension greater than two the remaining indices enumerate multiple sets of coefficients.

Returns

values
: [ndarray, compatible object] The values of the two dimensional polynomial at points in the Cartesian product of *x* and *y*.

See also:

legval*, *legval2d*, *leggrid2d*, *legval3d

Calculus

legder(c[, m, scl, axis])	Differentiate a Legendre series.
legint(c[, m, k, lbnd, scl, axis])	Integrate a Legendre series.

polynomial.legendre.**legder**(*c*, *m=1*, *scl=1*, *axis=0*)

Differentiate a Legendre series.

Returns the Legendre series coefficients *c* differentiated *m* times along *axis*. At each iteration the result is multiplied by *scl* (the scaling factor is for use in a linear change of variable). The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series `1*L_0 + 2*L_1 + 3*L_2` while [[1,2],[1,2]] represents `1*L_0(x)*L_0(y) + 1*L_1(x)*L_0(y) + 2*L_0(x)*L_1(y) + 2*L_1(x)*L_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of Legendre series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Number of derivatives taken, must be non-negative. (Default: 1)

scl
: [scalar, optional] Each differentiation is multiplied by *scl*. The end result is multiplication by `scl**m`. This is for use in a linear change of variable. (Default: 1)

axis
: [int, optional] Axis over which the derivative is taken. (Default: 0).

Returns

der
: [ndarray] Legendre series of the derivative.

See also:

legint

Notes

In general, the result of differentiating a Legendre series does not resemble the same operation on a power series. Thus the result of this function may be "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial import legendre as L
>>> c = (1,2,3,4)
>>> L.legder(c)
array([  6.,   9.,  20.])
>>> L.legder(c, 3)
array([60.])
>>> L.legder(c, scl=-1)
array([ -6.,  -9., -20.])
>>> L.legder(c, 2,-1)
array([  9.,  60.])
```

`polynomial.legendre.`**`legint`**(*c*, *m=1*, *k=[]*, *lbnd=0*, *scl=1*, *axis=0*)

Integrate a Legendre series.

Returns the Legendre series coefficients *c* integrated *m* times from *lbnd* along *axis*. At each iteration the resulting series is **multiplied** by *scl* and an integration constant, *k*, is added. The scaling factor is for use in a linear change of variable. ("Buyer beware": note that, depending on what one is doing, one may want *scl* to be the reciprocal of what one might expect; for more information, see the Notes section below.) The argument *c* is an array of coefficients from low to high degree along each axis, e.g., [1,2,3] represents the series `L_0 + 2*L_1 + 3*L_2` while [[1,2],[1,2]] represents `1*L_0(x)*L_0(y) + 1*L_1(x)*L_0(y) + 2*L_0(x)*L_1(y) + 2*L_1(x)*L_1(y)` if axis=0 is `x` and axis=1 is `y`.

Parameters

c
: [array_like] Array of Legendre series coefficients. If c is multidimensional the different axis correspond to different variables with the degree in each axis given by the corresponding index.

m
: [int, optional] Order of integration, must be positive. (Default: 1)

k
: [{[], list, scalar}, optional] Integration constant(s). The value of the first integral at `lbnd` is the first value in the list, the value of the second integral at `lbnd` is the second value, etc. If `k == []` (the default), all constants are set to zero. If `m == 1`, a single scalar can be given instead of a list.

lbnd
: [scalar, optional] The lower bound of the integral. (Default: 0)

scl
: [scalar, optional] Following each integration the result is *multiplied* by *scl* before the integration constant is added. (Default: 1)

axis
: [int, optional] Axis over which the integral is taken. (Default: 0).

Returns

S
: [ndarray] Legendre series coefficient array of the integral.

Raises

ValueError
: If `m < 0`, `len(k) > m`, `np.ndim(lbnd) != 0`, or `np.ndim(scl) != 0`.

See also:

legder

Notes

Note that the result of each integration is *multiplied* by *scl*. Why is this important to note? Say one is making a linear change of variable $u = ax + b$ in an integral relative to x. Then $dx = du/a$, so one will need to set *scl* equal to $1/a$ - perhaps not what one would have first thought.

Also note that, in general, the result of integrating a C-series needs to be "reprojected" onto the C-series basis set. Thus, typically, the result of this function is "unintuitive," albeit correct; see Examples section below.

Examples

```
>>> from numpy.polynomial import legendre as L
>>> c = (1,2,3)
>>> L.legint(c)
array([ 0.33333333,  0.4       ,  0.66666667,  0.6       ]) # may vary
>>> L.legint(c, 3)
array([  1.66666667e-02,  -1.78571429e-02,   4.76190476e-02, # may vary
        -1.73472348e-18,   1.90476190e-02,   9.52380952e-03])
>>> L.legint(c, k=3)
 array([ 3.33333333,  0.4       ,  0.66666667,  0.6       ]) # may vary
>>> L.legint(c, lbnd=-2)
array([ 7.33333333,  0.4       ,  0.66666667,  0.6       ]) # may vary
>>> L.legint(c, scl=2)
array([ 0.66666667,  0.8       ,  1.33333333,  1.2       ]) # may vary
```

Misc Functions

legfromroots(roots)	Generate a Legendre series with given roots.
legroots(c)	Compute the roots of a Legendre series.
legvander(x, deg)	Pseudo-Vandermonde matrix of given degree.
legvander2d(x, y, deg)	Pseudo-Vandermonde matrix of given degrees.
legvander3d(x, y, z, deg)	Pseudo-Vandermonde matrix of given degrees.
leggauss(deg)	Gauss-Legendre quadrature.
legweight(x)	Weight function of the Legendre polynomials.
legcompanion(c)	Return the scaled companion matrix of c.
legfit(x, y, deg[, rcond, full, w])	Least squares fit of Legendre series to data.
legtrim(c[, tol])	Remove "small" "trailing" coefficients from a polynomial.
legline(off, scl)	Legendre series whose graph is a straight line.
leg2poly(c)	Convert a Legendre series to a polynomial.
poly2leg(pol)	Convert a polynomial to a Legendre series.

polynomial.legendre.**legfromroots**(*roots*)

Generate a Legendre series with given roots.

The function returns the coefficients of the polynomial

$$p(x) = (x - r_0) * (x - r_1) * ... * (x - r_n),$$

in Legendre form, where the r_n are the roots specified in *roots*. If a zero has multiplicity n, then it must appear in *roots* n times. For instance, if 2 is a root of multiplicity three and 3 is a root of multiplicity 2, then *roots* looks something like [2, 2, 2, 3, 3]. The roots can appear in any order.

If the returned coefficients are *c*, then

$$p(x) = c_0 + c_1 * L_1(x) + ... + c_n * L_n(x)$$

The coefficient of the last term is not generally 1 for monic polynomials in Legendre form.

Parameters

roots
[array_like] Sequence containing the roots.

Returns

out
[ndarray] 1-D array of coefficients. If all roots are real then *out* is a real array, if some of the roots are complex, then *out* is complex even if all the coefficients in the result are real (see Examples below).

See also:

numpy.polynomial.polynomial.polyfromroots
numpy.polynomial.chebyshev.chebfromroots
numpy.polynomial.laguerre.lagfromroots
numpy.polynomial.hermite.hermfromroots
numpy.polynomial.hermite_e.hermefromroots

Examples

```
>>> import numpy.polynomial.legendre as L
>>> L.legfromroots((-1,0,1)) # x^3 - x relative to the standard basis
array([ 0. , -0.4,  0. ,  0.4])
>>> j = complex(0,1)
>>> L.legfromroots((-j,j)) # x^2 + 1 relative to the standard basis
array([ 1.33333333+0.j,  0.00000000+0.j,  0.66666667+0.j]) # may vary
```

polynomial.legendre.**legroots**(*c*)

Compute the roots of a Legendre series.

Return the roots (a.k.a. "zeros") of the polynomial

$$p(x) = \sum_i c[i] * L_i(x).$$

Parameters

c
: [1-D array_like] 1-D array of coefficients.

Returns

out
: [ndarray] Array of the roots of the series. If all the roots are real, then *out* is also real, otherwise it is complex.

See also:

numpy.polynomial.polynomial.polyroots
numpy.polynomial.chebyshev.chebroots
numpy.polynomial.laguerre.lagroots
numpy.polynomial.hermite.hermroots
numpy.polynomial.hermite_e.hermeroots

Notes

The root estimates are obtained as the eigenvalues of the companion matrix, Roots far from the origin of the complex plane may have large errors due to the numerical instability of the series for such values. Roots with multiplicity greater than 1 will also show larger errors as the value of the series near such points is relatively insensitive to errors in the roots. Isolated roots near the origin can be improved by a few iterations of Newton's method.

The Legendre series basis polynomials aren't powers of `x` so the results of this function may seem unintuitive.

Examples

```
>>> import numpy.polynomial.legendre as leg
>>> leg.legroots((1, 2, 3, 4)) # 4L_3 + 3L_2 + 2L_1 + 1L_0, all real roots
array([-0.85099543, -0.11407192,  0.51506735]) # may vary
```

polynomial.legendre.**legvander**(*x*, *deg*)

Pseudo-Vandermonde matrix of given degree.

Returns the pseudo-Vandermonde matrix of degree *deg* and sample points *x*. The pseudo-Vandermonde matrix is defined by

$$V[..., i] = L_i(x)$$

where `0 <= i <= deg`. The leading indices of *V* index the elements of *x* and the last index is the degree of the Legendre polynomial.

If *c* is a 1-D array of coefficients of length `n + 1` and *V* is the array `V = legvander(x, n)`, then `np.dot(V, c)` and `legval(x, c)` are the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of Legendre series of the same degree and sample points.

Parameters

x
[array_like] Array of points. The dtype is converted to float64 or complex128 depending on whether any of the elements are complex. If *x* is scalar it is converted to a 1-D array.

deg
[int] Degree of the resulting matrix.

Returns

vander
[ndarray] The pseudo-Vandermonde matrix. The shape of the returned matrix is `x.shape + (deg + 1,)`, where The last index is the degree of the corresponding Legendre polynomial. The dtype will be the same as the converted *x*.

`polynomial.legendre.`**`legvander2d`**(*x*, *y*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y)`. The pseudo-Vandermonde matrix is defined by

$$V[..., (deg[1] + 1) * i + j] = L_i(x) * L_j(y),$$

where `0 <= i <= deg[0]` and `0 <= j <= deg[1]`. The leading indices of *V* index the points `(x, y)` and the last index encodes the degrees of the Legendre polynomials.

If `V = legvander2d(x, y, [xdeg, ydeg])`, then the columns of *V* correspond to the elements of a 2-D coefficient array *c* of shape (xdeg + 1, ydeg + 1) in the order

$$c_{00}, c_{01}, c_{02}..., c_{10}, c_{11}, c_{12}...$$

and `np.dot(V, c.flat)` and `legval2d(x, y, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 2-D Legendre series of the same degrees and sample points.

Parameters

x, y
[array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
[list of ints] List of maximum degrees of the form [x_deg, y_deg].

Returns

vander2d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)$. The dtype will be the same as the converted *x* and *y*.

See also:

legvander, ***legvander3d***, ***legval2d***, ***legval3d***

`polynomial.legendre.`**`legvander3d`**(*x*, *y*, *z*, *deg*)

Pseudo-Vandermonde matrix of given degrees.

Returns the pseudo-Vandermonde matrix of degrees *deg* and sample points `(x, y, z)`. If *l*, *m*, *n* are the given degrees in *x*, *y*, *z*, then The pseudo-Vandermonde matrix is defined by

$$V[..., (m+1)(n+1)i + (n+1)j + k] = L_i(x) * L_j(y) * L_k(z),$$

where `0 <= i <= l`, `0 <= j <= m`, and `0 <= j <= n`. The leading indices of *V* index the points `(x, y, z)` and the last index encodes the degrees of the Legendre polynomials.

If `V = legvander3d(x, y, z, [xdeg, ydeg, zdeg])`, then the columns of *V* correspond to the elements of a 3-D coefficient array *c* of shape (xdeg + 1, ydeg + 1, zdeg + 1) in the order

$$c_{000}, c_{001}, c_{002}, ..., c_{010}, c_{011}, c_{012}, ...$$

and `np.dot(V, c.flat)` and `legval3d(x, y, z, c)` will be the same up to roundoff. This equivalence is useful both for least squares fitting and for the evaluation of a large number of 3-D Legendre series of the same degrees and sample points.

Parameters

x, y, z
[array_like] Arrays of point coordinates, all of the same shape. The dtypes will be converted to either float64 or complex128 depending on whether any of the elements are complex. Scalars are converted to 1-D arrays.

deg
[list of ints] List of maximum degrees of the form [x_deg, y_deg, z_deg].

Returns

vander3d
[ndarray] The shape of the returned matrix is `x.shape + (order,)`, where $order = (deg[0]+1)*(deg[1]+1)*(deg[2]+1)$. The dtype will be the same as the converted *x*, *y*, and *z*.

See also:

legvander, ***legvander3d***, ***legval2d***, ***legval3d***

`polynomial.legendre.`**`leggauss`**(*deg*)

Gauss-Legendre quadrature.

Computes the sample points and weights for Gauss-Legendre quadrature. These sample points and weights will correctly integrate polynomials of degree $2*deg - 1$ or less over the interval $[-1, 1]$ with the weight function $f(x) = 1$.

Parameters

deg
[int] Number of sample points and weights. It must be >= 1.

Returns

x
[ndarray] 1-D ndarray containing the sample points.

y
[ndarray] 1-D ndarray containing the weights.

Notes

The results have only been tested up to degree 100, higher degrees may be problematic. The weights are determined by using the fact that

$$w_k = c/(L'_n(x_k) * L_{n-1}(x_k))$$

where c is a constant independent of k and x_k is the k'th root of L_n, and then scaling the results to get the right value when integrating 1.

`polynomial.legendre.`**`legweight`**`(x)`

Weight function of the Legendre polynomials.

The weight function is 1 and the interval of integration is $[-1, 1]$. The Legendre polynomials are orthogonal, but not normalized, with respect to this weight function.

Parameters

x
[array_like] Values at which the weight function will be computed.

Returns

w
[ndarray] The weight function at *x*.

`polynomial.legendre.`**`legcompanion`**`(c)`

Return the scaled companion matrix of c.

The basis polynomials are scaled so that the companion matrix is symmetric when *c* is an Legendre basis polynomial. This provides better eigenvalue estimates than the unscaled case and for basis polynomials the eigenvalues are guaranteed to be real if *numpy.linalg.eigvalsh* is used to obtain them.

Parameters

c
[array_like] 1-D array of Legendre series coefficients ordered from low to high degree.

Returns

mat
[ndarray] Scaled companion matrix of dimensions (deg, deg).

`polynomial.legendre.`**`legfit`**`(x, y, deg, rcond=None, full=False, w=None)`

Least squares fit of Legendre series to data.

Return the coefficients of a Legendre series of degree *deg* that is the least squares fit to the data values *y* given at points *x*. If *y* is 1-D the returned coefficients will also be 1-D. If *y* is 2-D multiple fits are done, one for each column of *y*, and the resulting coefficients are stored in the corresponding columns of a 2-D return. The fitted polynomial(s) are in the form

$$p(x) = c_0 + c_1 * L_1(x) + ... + c_n * L_n(x),$$

where *n* is *deg*.

Parameters

x
[array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
[array_like, shape (M,) or (M, K)] y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg
[int or 1-D array_like] Degree(s) of the fitting polynomials. If *deg* is a single integer all terms up to and including the *deg*'th term are included in the fit. For NumPy versions >= 1.11.0 a list of integers specifying the degrees of the terms to include may be used instead.

rcond
[float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
[bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
[array_like, shape (*M*,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

Returns

coef
[ndarray, shape (M,) or (M, K)] Legendre coefficients ordered from low to high. If *y* was 2-D, the coefficients for the data in column k of *y* are in column *k*. If *deg* is specified as a list, coefficients for terms not included in the fit are set equal to zero in the returned *coef*.

[residuals, rank, singular_values, rcond]
[list] These values are only returned if `full == True`

- residuals – sum of squared residuals of the least squares fit
- rank – the numerical rank of the scaled Vandermonde matrix
- singular_values – singular values of the scaled Vandermonde matrix
- rcond – value of *rcond*.

For more details, see *numpy.linalg.lstsq*.

Warns

RankWarning
The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if `full == False`. The warnings can be turned off by

```
>>> import warnings
>>> warnings.simplefilter('ignore', np.exceptions.RankWarning)
```

See also:

numpy.polynomial.polynomial.polyfit
numpy.polynomial.chebyshev.chebfit
numpy.polynomial.laguerre.lagfit
numpy.polynomial.hermite.hermfit
numpy.polynomial.hermite_e.hermefit
legval
Evaluates a Legendre series.

legvander
Vandermonde matrix of Legendre series.

legweight
Legendre weight function (= 1).

numpy.linalg.lstsq
Computes a least-squares fit from the matrix.

scipy.interpolate.UnivariateSpline
Computes spline fits.

Notes

The solution is the coefficients of the Legendre series *p* that minimizes the sum of the weighted squared errors

$$E = \sum_j w_j^2 * |y_j - p(x_j)|^2,$$

where w_j are the weights. This problem is solved by setting up as the (typically) overdetermined matrix equation

$$V(x) * c = w * y,$$

where *V* is the weighted pseudo Vandermonde matrix of *x*, *c* are the coefficients to be solved for, *w* are the weights, and *y* are the observed values. This equation is then solved using the singular value decomposition of *V*.

If some of the singular values of *V* are so small that they are neglected, then a `RankWarning` will be issued. This means that the coefficient values may be poorly determined. Using a lower order fit will usually get rid of the warning. The *rcond* parameter can also be set to a value smaller than its default, but the resulting fit may be spurious and have large contributions from roundoff error.

Fits using Legendre series are usually better conditioned than fits using power series, but much can depend on the distribution of the sample points and the smoothness of the data. If the quality of the fit is inadequate splines may be a good alternative.

References

[1]

polynomial.legendre.**legtrim**(*c*, *tol=0*)
Remove "small" "trailing" coefficients from a polynomial.

"Small" means "small in absolute value" and is controlled by the parameter *tol*; "trailing" means highest order coefficient(s), e.g., in `[0, 1, 1, 0, 0]` (which represents `0 + x + x**2 + 0*x**3 + 0*x**4`) both the 3-rd and 4-th order coefficients would be "trimmed."

Parameters

c
[array_like] 1-d array of coefficients, ordered from lowest order to highest.

tol
: [number, optional] Trailing (i.e., highest order) elements with absolute value less than or equal to *tol* (default value is zero) are removed.

Returns

trimmed
: [ndarray] 1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError
: If *tol* < 0

Examples

```
>>> from numpy.polynomial import polyutils as pu
>>> pu.trimcoef((0,0,3,0,5,0,0))
array([0.,  0.,  3.,  0.,  5.])
>>> pu.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([0.])
>>> i = complex(0,1) # works for complex
>>> pu.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([0.0003+0.j   , 0.001 -0.001j])
```

polynomial.legendre.**legline**(*off*, *scl*)

Legendre series whose graph is a straight line.

Parameters

off, scl
: [scalars] The specified line is given by `off + scl*x`.

Returns

y
: [ndarray] This module's representation of the Legendre series for `off + scl*x`.

See also:

numpy.polynomial.polynomial.polyline
numpy.polynomial.chebyshev.chebline
numpy.polynomial.laguerre.lagline
numpy.polynomial.hermite.hermline
numpy.polynomial.hermite_e.hermeline

Examples

```
>>> import numpy.polynomial.legendre as L
>>> L.legline(3,2)
array([3, 2])
>>> L.legval(-3, L.legline(3,2)) # should be -3
-3.0
```

polynomial.legendre.**leg2poly**(*c*)

Convert a Legendre series to a polynomial.

Convert an array representing the coefficients of a Legendre series, ordered from lowest degree to highest, to an array of the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest to highest degree.

Parameters

c
[array_like] 1-D array containing the Legendre series coefficients, ordered from lowest order term to highest.

Returns

pol
[ndarray] 1-D array containing the coefficients of the equivalent polynomial (relative to the "standard" basis) ordered from lowest order term to highest.

See also:

poly2leg

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> from numpy import polynomial as P
>>> c = P.Legendre(range(4))
>>> c
Legendre([0., 1., 2., 3.], domain=[-1.,  1.], window=[-1.,  1.], symbol='x')
>>> p = c.convert(kind=P.Polynomial)
>>> p
Polynomial([-1. , -3.5,  3. ,  7.5], domain=[-1.,  1.], window=[-1., ...
>>> P.legendre.leg2poly(range(4))
array([-1. , -3.5,  3. ,  7.5])
```

polynomial.legendre.**poly2leg**(*pol*)

Convert a polynomial to a Legendre series.

Convert an array representing the coefficients of a polynomial (relative to the "standard" basis) ordered from lowest degree to highest, to an array of the coefficients of the equivalent Legendre series, ordered from lowest to highest degree.

Parameters

pol
[array_like] 1-D array containing the polynomial coefficients

Returns

c
[ndarray] 1-D array containing the coefficients of the equivalent Legendre series.

See also:

leg2poly

Notes

The easy way to do conversions between polynomial basis sets is to use the convert method of a class instance.

Examples

```
>>> import numpy as np
>>> from numpy import polynomial as P
>>> p = P.Polynomial(np.arange(4))
>>> p
Polynomial([0.,  1.,  2.,  3.], domain=[-1.,  1.], window=[-1.,  1.], ...
>>> c = P.Legendre(P.legendre.poly2leg(p.coef))
>>> c
Legendre([ 1.  ,  3.25,  1.  ,  0.75], domain=[-1,  1], window=[-1,  1]) # may␣
↪vary
```

See also

numpy.polynomial

Polyutils

Utility classes and functions for the polynomial modules.

This module provides: error and warning objects; a polynomial base class; and some routines used in both the *polynomial* and *chebyshev* modules.

Functions

as_series(alist[, trim])	Return argument as a list of 1-d arrays.
trimseq(seq)	Remove small Poly series coefficients.
trimcoef(c[, tol])	Remove "small" "trailing" coefficients from a polynomial.
getdomain(x)	Return a domain suitable for given abscissae.
mapdomain(x, old, new)	Apply linear map to input points.
mapparms(old, new)	Linear map parameters between domains.

polynomial.polyutils.**as_series**(*alist*, *trim=True*)

Return argument as a list of 1-d arrays.

The returned list contains array(s) of dtype double, complex double, or object. A 1-d argument of shape `(N,)` is parsed into `N` arrays of size one; a 2-d argument of shape `(M,N)` is parsed into `M` arrays of size `N` (i.e., is "parsed by row"); and a higher dimensional array raises a Value Error if it is not first reshaped into either a 1-d or 2-d array.

Parameters

alist
[array_like] A 1- or 2-d array_like

trim
[boolean, optional] When True, trailing zeros are removed from the inputs. When False, the inputs are passed through intact.

Returns

[a1, a2,...]
[list of 1-D arrays] A copy of the input data as a list of 1-d arrays.

Raises

ValueError
Raised when *as_series* cannot convert its input to 1-d arrays, or at least one of the resulting arrays is empty.

Examples

```
>>> import numpy as np
>>> from numpy.polynomial import polyutils as pu
>>> a = np.arange(4)
>>> pu.as_series(a)
[array([0.]), array([1.]), array([2.]), array([3.])]
>>> b = np.arange(6).reshape((2,3))
>>> pu.as_series(b)
[array([0., 1., 2.]), array([3., 4., 5.])]
```

```
>>> pu.as_series((1, np.arange(3), np.arange(2, dtype=np.float16)))
[array([1.]), array([0., 1., 2.]), array([0., 1.])]
```

```
>>> pu.as_series([2, [1.1, 0.]])
[array([2.]), array([1.1])]
```

```
>>> pu.as_series([2, [1.1, 0.]], trim=False)
[array([2.]), array([1.1, 0. ])]
```

polynomial.polyutils.**trimseq**(*seq*)

Remove small Poly series coefficients.

Parameters

seq
[sequence] Sequence of Poly series coefficients.

Returns

series
[sequence] Subsequence with trailing zeros removed. If the resulting sequence would be empty, return the first element. The returned sequence may or may not be a view.

Notes

Do not lose the type info if the sequence contains unknown objects.

polynomial.polyutils.**trimcoef**(*c*, *tol=0*)

Remove "small" "trailing" coefficients from a polynomial.

"Small" means "small in absolute value" and is controlled by the parameter *tol*; "trailing" means highest order coefficient(s), e.g., in `[0, 1, 1, 0, 0]` (which represents `0 + x + x**2 + 0*x**3 + 0*x**4`) both the 3-rd and 4-th order coefficients would be "trimmed."

Parameters

c
: [array_like] 1-d array of coefficients, ordered from lowest order to highest.

tol
: [number, optional] Trailing (i.e., highest order) elements with absolute value less than or equal to *tol* (default value is zero) are removed.

Returns

trimmed
: [ndarray] 1-d array with trailing zeros removed. If the resulting series would be empty, a series containing a single zero is returned.

Raises

ValueError
: If *tol* < 0

Examples

```
>>> from numpy.polynomial import polyutils as pu
>>> pu.trimcoef((0,0,3,0,5,0,0))
array([0.,  0.,  3.,  0.,  5.])
>>> pu.trimcoef((0,0,1e-3,0,1e-5,0,0),1e-3) # item == tol is trimmed
array([0.])
>>> i = complex(0,1) # works for complex
>>> pu.trimcoef((3e-4,1e-3*(1-i),5e-4,2e-5*(1+i)), 1e-3)
array([0.0003+0.j   , 0.001 -0.001j])
```

polynomial.polyutils.**getdomain**(*x*)

Return a domain suitable for given abscissae.

Find a domain suitable for a polynomial or Chebyshev series defined at the values supplied.

Parameters

x
: [array_like] 1-d array of abscissae whose domain will be determined.

Returns

domain
: [ndarray] 1-d array containing two values. If the inputs are complex, then the two returned points are the lower left and upper right corners of the smallest rectangle (aligned with the axes) in the complex plane containing the points *x*. If the inputs are real, then the two points are the ends of the smallest interval containing the points *x*.

See also:

mapparms, ***mapdomain***

Examples

```
>>> import numpy as np
>>> from numpy.polynomial import polyutils as pu
>>> points = np.arange(4)**2 - 5; points
array([-5, -4, -1,  4])
>>> pu.getdomain(points)
array([-5.,  4.])
>>> c = np.exp(complex(0,1)*np.pi*np.arange(12)/6) # unit circle
>>> pu.getdomain(c)
array([-1.-1.j,  1.+1.j])
```

polynomial.polyutils.**mapdomain**(*x*, *old*, *new*)

Apply linear map to input points.

The linear map `offset + scale*x` that maps the domain *old* to the domain *new* is applied to the points *x*.

Parameters

x
: [array_like] Points to be mapped. If *x* is a subtype of ndarray the subtype will be preserved.

old, new
: [array_like] The two domains that determine the map. Each must (successfully) convert to 1-d arrays containing precisely two values.

Returns

x_out
: [ndarray] Array of points of the same shape as *x*, after application of the linear map between the two domains.

See also:

getdomain, *mapparms*

Notes

Effectively, this implements:

$$x\_out = new[0] + m(x - old[0])$$

where

$$m = \frac{new[1] - new[0]}{old[1] - old[0]}$$

Examples

```
>>> import numpy as np
>>> from numpy.polynomial import polyutils as pu
>>> old_domain = (-1,1)
>>> new_domain = (0,2*np.pi)
>>> x = np.linspace(-1,1,6); x
array([-1. , -0.6, -0.2,  0.2,  0.6,  1. ])
>>> x_out = pu.mapdomain(x, old_domain, new_domain); x_out
```

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```
array([ 0.        ,  1.25663706,  2.51327412,  3.76991118,  5.02654825, # may vary
        6.28318531])
>>> x - pu.mapdomain(x_out, new_domain, old_domain)
array([0., 0., 0., 0., 0., 0.])
```

Also works for complex numbers (and thus can be used to map any line in the complex plane to any other line therein).

```
>>> i = complex(0,1)
>>> old = (-1 - i, 1 + i)
>>> new = (-1 + i, 1 - i)
>>> z = np.linspace(old[0], old[1], 6); z
array([-1. -1.j , -0.6-0.6j, -0.2-0.2j,  0.2+0.2j,  0.6+0.6j,  1. +1.j ])
>>> new_z = pu.mapdomain(z, old, new); new_z
array([-1.0+1.j , -0.6+0.6j, -0.2+0.2j,  0.2-0.2j,  0.6-0.6j,  1.0-1.j ]) # may␣
↪vary
```

`polynomial.polyutils.`**`mapparms`**(*old*, *new*)

Linear map parameters between domains.

Return the parameters of the linear map `offset + scale*x` that maps *old* to *new* such that `old[i] -> new[i],i = 0, 1`.

Parameters

old, new
: [array_like] Domains. Each domain must (successfully) convert to a 1-d array containing precisely two values.

Returns

offset, scale
: [scalars] The map `L(x) = offset + scale*x` maps the first domain to the second.

See also:

getdomain*, *mapdomain

Notes

Also works for complex numbers, and thus can be used to calculate the parameters required to map any line in the complex plane to any other line therein.

Examples

```
>>> from numpy.polynomial import polyutils as pu
>>> pu.mapparms((-1,1),(-1,1))
(0.0, 1.0)
>>> pu.mapparms((1,-1),(-1,1))
(-0.0, -1.0)
>>> i = complex(0,1)
>>> pu.mapparms((-i,-1),(1,i))
((1+1j), (1-0j))
```

Documentation for legacy polynomials

Poly1d

Basics

poly1d(c_or_r[, r, variable])	A one-dimensional polynomial class.
polyval(p, x)	Evaluate a polynomial at specific values.
poly(seq_of_zeros)	Find the coefficients of a polynomial with the given sequence of roots.
roots(p)	Return the roots of a polynomial with coefficients given in p.

class numpy.**poly1d**(*c_or_r*, *r=False*, *variable=None*)

A one-dimensional polynomial class.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

A convenience class, used to encapsulate "natural" operations on polynomials so that said operations may take on their customary form in code (see Examples).

Parameters

c_or_r
[array_like] The polynomial's coefficients, in decreasing powers, or if the value of the second parameter is True, the polynomial's roots (values where the polynomial evaluates to 0). For example, `poly1d([1, 2, 3])` returns an object that represents $x^2 + 2x + 3$, whereas `poly1d([1, 2, 3], True)` returns one that represents $(x - 1)(x - 2)(x - 3) = x^3 - 6x^2 + 11x - 6$.

r
[bool, optional] If True, *c_or_r* specifies the polynomial's roots; the default is False.

variable
[str, optional] Changes the variable used when printing *p* from *x* to `variable` (see Examples).

Examples

Construct the polynomial $x^2 + 2x + 3$:

```
>>> import numpy as np
```

```
>>> p = np.poly1d([1, 2, 3])
>>> print(np.poly1d(p))
   2
1 x + 2 x + 3
```

Evaluate the polynomial at $x = 0.5$:

```
>>> p(0.5)
4.25
```

Find the roots:

```
>>> p.r
array([-1.+1.41421356j, -1.-1.41421356j])
>>> p(p.r)
array([ -4.44089210e-16+0.j,  -4.44089210e-16+0.j]) # may vary
```

These numbers in the previous line represent (0, 0) to machine precision

Show the coefficients:

```
>>> p.c
array([1, 2, 3])
```

Display the order (the leading zero-coefficients are removed):

```
>>> p.order
2
```

Show the coefficient of the k-th power in the polynomial (which is equivalent to `p.c[-(i+1)]`):

```
>>> p[1]
2
```

Polynomials can be added, subtracted, multiplied, and divided (returns quotient and remainder):

```
>>> p * p
poly1d([ 1,  4, 10, 12,  9])
```

```
>>> (p**3 + 4) / p
(poly1d([ 1.,  4., 10., 12.,  9.]), poly1d([4.]))
```

`asarray(p)` gives the coefficient array, so polynomials can be used in all functions that accept arrays:

```
>>> p**2 # square of polynomial
poly1d([ 1,  4, 10, 12,  9])
```

```
>>> np.square(p) # square of individual coefficients
array([1, 4, 9])
```

The variable used in the string representation of *p* can be modified, using the `variable` parameter:

```
>>> p = np.poly1d([1,2,3], variable='z')
>>> print(p)
   2
1 z + 2 z + 3
```

Construct a polynomial from its roots:

```
>>> np.poly1d([1, 2], True)
poly1d([ 1., -3.,  2.])
```

This is the same polynomial as obtained by:

```
>>> np.poly1d([1, -1]) * np.poly1d([1, -2])
poly1d([ 1, -3,  2])
```

Attributes

c
The polynomial coefficients

coef
The polynomial coefficients

coefficients
The polynomial coefficients

coeffs
The polynomial coefficients

o
The order or degree of the polynomial

order
The order or degree of the polynomial

r
The roots of the polynomial, where self(x) == 0

roots
The roots of the polynomial, where self(x) == 0

variable
The name of the polynomial variable

Methods

__call__(val)	Call self as a function.
deriv([m])	Return a derivative of this polynomial.
integ([m, k])	Return an antiderivative (indefinite integral) of this polynomial.

method

poly1d.**__call__**(*val*)
Call self as a function.

method

poly1d.**deriv**(*m=1*)
Return a derivative of this polynomial.

Refer to *polyder* for full documentation.

See also:

polyder
equivalent function

method

poly1d.**integ**(*m=1*, *k=0*)
Return an antiderivative (indefinite integral) of this polynomial.

Refer to *polyint* for full documentation.

See also:

polyint
equivalent function

numpy.**polyval**(*p*, *x*)

Evaluate a polynomial at specific values.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

If *p* is of length N, this function returns the value:

```
p[0]*x**(N-1) + p[1]*x**(N-2) + ... + p[N-2]*x + p[N-1]
```

If *x* is a sequence, then `p(x)` is returned for each element of `x`. If *x* is another polynomial then the composite polynomial `p(x(t))` is returned.

Parameters

p
[array_like or poly1d object] 1D array of polynomial coefficients (including coefficients equal to zero) from highest degree to the constant term, or an instance of poly1d.

x
[array_like or poly1d object] A number, an array of numbers, or an instance of poly1d, at which to evaluate *p*.

Returns

values
[ndarray or poly1d] If *x* is a poly1d instance, the result is the composition of the two polynomials, i.e., *x* is "substituted" in *p* and the simplified result is returned. In addition, the type of *x* - array_like or poly1d - governs the type of the output: *x* array_like => *values* array_like, *x* a poly1d object => *values* is also.

See also:

poly1d
A polynomial class.

Notes

Horner's scheme [1] is used to evaluate the polynomial. Even so, for polynomials of high degree the values may be inaccurate due to rounding errors. Use carefully.

If *x* is a subtype of *ndarray* the return value will be of the same type.

References

[1]

Examples

```
>>> import numpy as np
>>> np.polyval([3,0,1], 5)  # 3 * 5**2 + 0 * 5**1 + 1
76
>>> np.polyval([3,0,1], np.poly1d(5))
poly1d([76])
>>> np.polyval(np.poly1d([3,0,1]), 5)
76
>>> np.polyval(np.poly1d([3,0,1]), np.poly1d(5))
poly1d([76])
```

numpy.**poly**(*seq_of_zeros*)

Find the coefficients of a polynomial with the given sequence of roots.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

Returns the coefficients of the polynomial whose leading coefficient is one for the given sequence of zeros (multiple roots must be included in the sequence as many times as their multiplicity; see Examples). A square matrix (or array, which will be treated as a matrix) can also be given, in which case the coefficients of the characteristic polynomial of the matrix are returned.

Parameters

seq_of_zeros
: [array_like, shape (N,) or (N, N)] A sequence of polynomial roots, or a square array or matrix object.

Returns

c
: [ndarray] 1D array of polynomial coefficients from highest to lowest degree:

`c[0] * x**(N) + c[1] * x**(N-1) + ... + c[N-1] * x + c[N]` where c[0] always equals 1.

Raises

ValueError
: If input is the wrong shape (the input must be a 1-D or square 2-D array).

See also:

polyval
: Compute polynomial values.

roots
: Return the roots of a polynomial.

polyfit
: Least squares polynomial fit.

poly1d
A one-dimensional polynomial class.

Notes

Specifying the roots of a polynomial still leaves one degree of freedom, typically represented by an undetermined leading coefficient. [1] In the case of this function, that coefficient - the first one in the returned array - is always taken as one. (If for some reason you have one other point, the only automatic way presently to leverage that information is to use `polyfit`.)

The characteristic polynomial, $p_a(t)$, of an *n*-by-*n* matrix **A** is given by

$p_a(t) = \det(t\,\mathbf{I} - \mathbf{A})$,

where **I** is the *n*-by-*n* identity matrix. [2]

References

[1], [2]

Examples

Given a sequence of a polynomial's zeros:

```
>>> import numpy as np
```

```
>>> np.poly((0, 0, 0)) # Multiple root example
array([1., 0., 0., 0.])
```

The line above represents z**3 + 0*z**2 + 0*z + 0.

```
>>> np.poly((-1./2, 0, 1./2))
array([ 1.  ,  0.  , -0.25,  0.  ])
```

The line above represents z**3 - z/4

```
>>> np.poly((np.random.random(1)[0], 0, np.random.random(1)[0]))
array([ 1.        , -0.77086955,  0.08618131,  0.        ]) # random
```

Given a square array object:

```
>>> P = np.array([[0, 1./3], [-1./2, 0]])
>>> np.poly(P)
array([1.        , 0.        , 0.16666667])
```

Note how in all cases the leading coefficient is always 1.

`numpy.roots`(*p*)
Return the roots of a polynomial with coefficients given in p.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

The values in the rank-1 array *p* are coefficients of a polynomial. If the length of *p* is n+1 then the polynomial is described by:

```
p[0] * x**n + p[1] * x**(n-1) + ... + p[n-1]*x + p[n]
```

Parameters

p
[array_like] Rank-1 array of polynomial coefficients.

Returns

out
[ndarray] An array containing the roots of the polynomial.

Raises

ValueError
When *p* cannot be converted to a rank-1 array.

See also:

poly
Find the coefficients of a polynomial with a given sequence of roots.

polyval
Compute polynomial values.

polyfit
Least squares polynomial fit.

poly1d
A one-dimensional polynomial class.

Notes

The algorithm relies on computing the eigenvalues of the companion matrix [1].

References

[1]

Examples

```
>>> import numpy as np
>>> coeff = [3.2, 2, 1]
>>> np.roots(coeff)
array([-0.3125+0.46351241j, -0.3125-0.46351241j])
```

Fitting

polyfit(x, y, deg[, rcond, full, w, cov])	Least squares polynomial fit.

numpy.**polyfit**(*x*, *y*, *deg*, *rcond=None*, *full=False*, *w=None*, *cov=False*)

Least squares polynomial fit.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

Fit a polynomial `p(x) = p[0] * x**deg + ... + p[deg]` of degree *deg* to points *(x, y)*. Returns a vector of coefficients *p* that minimises the squared error in the order *deg*, *deg-1*, … *0*.

The *Polynomial.fit* class method is recommended for new code as it is more stable numerically. See the documentation of the method for more information.

Parameters

x
: [array_like, shape (M,)] x-coordinates of the M sample points `(x[i], y[i])`.

y
: [array_like, shape (M,) or (M, K)] y-coordinates of the sample points. Several data sets of sample points sharing the same x-coordinates can be fitted at once by passing in a 2D-array that contains one dataset per column.

deg
: [int] Degree of the fitting polynomial

rcond
: [float, optional] Relative condition number of the fit. Singular values smaller than this relative to the largest singular value will be ignored. The default value is len(x)*eps, where eps is the relative precision of the float type, about 2e-16 in most cases.

full
: [bool, optional] Switch determining nature of return value. When it is False (the default) just the coefficients are returned, when True diagnostic information from the singular value decomposition is also returned.

w
: [array_like, shape (M,), optional] Weights. If not None, the weight `w[i]` applies to the unsquared residual `y[i] - y_hat[i]` at `x[i]`. Ideally the weights are chosen so that the errors of the products `w[i]*y[i]` all have the same variance. When using inverse-variance weighting, use `w[i] = 1/sigma(y[i])`. The default value is None.

cov
: [bool or str, optional] If given and not *False*, return not just the estimate but also its covariance matrix. By default, the covariance are scaled by chi2/dof, where dof = M - (deg + 1), i.e., the weights are presumed to be unreliable except in a relative sense and everything is scaled such that the reduced chi2 is unity. This scaling is omitted if `cov='unscaled'`, as is relevant for the case that the weights are w = 1/sigma, with sigma known to be a reliable estimate of the uncertainty.

Returns

p
: [ndarray, shape (deg + 1,) or (deg + 1, K)] Polynomial coefficients, highest power first. If *y* was 2-D, the coefficients for *k*-th data set are in `p[:,k]`.

residuals, rank, singular_values, rcond
: These values are only returned if `full == True`

- residuals – sum of squared residuals of the least squares fit
- **rank – the effective rank of the scaled Vandermonde**
  coefficient matrix
- **singular_values – singular values of the scaled Vandermonde**
  coefficient matrix
- rcond – value of *rcond*.

For more details, see *numpy.linalg.lstsq*.

V
: [ndarray, shape (deg + 1, deg + 1) or (deg + 1, deg + 1, K)] Present only if `full == False` and `cov == True`. The covariance matrix of the polynomial coefficient estimates. The diagonal of this matrix are the variance estimates for each coefficient. If y is a 2-D array, then the covariance matrix for the *k*-th data set are in `V[:,:,k]`

Warns

RankWarning
: The rank of the coefficient matrix in the least-squares fit is deficient. The warning is only raised if `full == False`.

The warnings can be turned off by

```
>>> import warnings
>>> warnings.simplefilter('ignore', np.exceptions.RankWarning)
```

See also:

polyval
: Compute polynomial values.

linalg.lstsq
: Computes a least-squares fit.

scipy.interpolate.UnivariateSpline
: Computes spline fits.

Notes

The solution minimizes the squared error

$$E = \sum_{j=0}^{k} |p(x_j) - y_j|^2$$

in the equations:

```
x[0]**n * p[0] + ... + x[0] * p[n-1] + p[n] = y[0]
x[1]**n * p[0] + ... + x[1] * p[n-1] + p[n] = y[1]
...
x[k]**n * p[0] + ... + x[k] * p[n-1] + p[n] = y[k]
```

The coefficient matrix of the coefficients *p* is a Vandermonde matrix.

polyfit issues a *RankWarning* when the least-squares fit is badly conditioned. This implies that the best fit is not well-defined due to numerical error. The results may be improved by lowering the polynomial degree or by replacing *x* by *x* - *x*.mean(). The *rcond* parameter can also be set to a value smaller than its default, but the resulting fit may be spurious: including contributions from the small singular values can add numerical noise to the result.

Note that fitting polynomial coefficients is inherently badly conditioned when the degree of the polynomial is large or the interval of sample points is badly centered. The quality of the fit should always be checked in these cases. When polynomial fits are not satisfactory, splines may be a good alternative.

References

[1], [2]

Examples

```
>>> import numpy as np
>>> import warnings
>>> x = np.array([0.0, 1.0, 2.0, 3.0,  4.0,  5.0])
>>> y = np.array([0.0, 0.8, 0.9, 0.1, -0.8, -1.0])
>>> z = np.polyfit(x, y, 3)
>>> z
array([ 0.08703704, -0.81349206,  1.69312169, -0.03968254]) # may vary
```

It is convenient to use *poly1d* objects for dealing with polynomials:

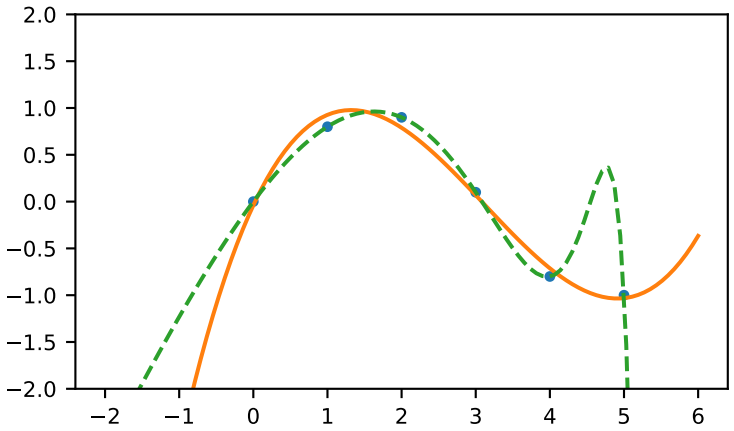
```
>>> p = np.poly1d(z)
>>> p(0.5)
0.6143849206349179 # may vary
>>> p(3.5)
-0.34732142857143039 # may vary
>>> p(10)
22.579365079365115 # may vary
```

High-order polynomials may oscillate wildly:

```
>>> with warnings.catch_warnings():
...     warnings.simplefilter('ignore', np.exceptions.RankWarning)
...     p30 = np.poly1d(np.polyfit(x, y, 30))
...
>>> p30(4)
-0.80000000000000204 # may vary
>>> p30(5)
-0.99999999999999445 # may vary
>>> p30(4.5)
-0.10547061179440398 # may vary
```

Illustration:

```
>>> import matplotlib.pyplot as plt
>>> xp = np.linspace(-2, 6, 100)
>>> _ = plt.plot(x, y, '.', xp, p(xp), '-', xp, p30(xp), '--')
>>> plt.ylim(-2,2)
(-2, 2)
>>> plt.show()
```



Calculus

polyder(p[, m])	Return the derivative of the specified order of a polynomial.
polyint(p[, m, k])	Return an antiderivative (indefinite integral) of a polynomial.

numpy.**polyder**(*p*, *m=1*)

Return the derivative of the specified order of a polynomial.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

Parameters

p
[poly1d or sequence] Polynomial to differentiate. A sequence is interpreted as polynomial coefficients, see *poly1d*.

m
[int, optional] Order of differentiation (default: 1)

Returns

der
[poly1d] A new polynomial representing the derivative.

See also:

polyint
Anti-derivative of a polynomial.

poly1d
Class for one-dimensional polynomials.

Examples

The derivative of the polynomial $x^3 + x^2 + x^1 + 1$ is:

```
>>> import numpy as np
```

```
>>> p = np.poly1d([1,1,1,1])
>>> p2 = np.polyder(p)
>>> p2
poly1d([3, 2, 1])
```

which evaluates to:

```
>>> p2(2.)
17.0
```

We can verify this, approximating the derivative with `(f(x + h) - f(x))/h`:

```
>>> (p(2. + 0.001) - p(2.)) / 0.001
17.007000999997857
```

The fourth-order derivative of a 3rd-order polynomial is zero:

```
>>> np.polyder(p, 2)
poly1d([6, 2])
>>> np.polyder(p, 3)
poly1d([6])
>>> np.polyder(p, 4)
poly1d([0])
```

numpy.**polyint**(*p*, *m=1*, *k=None*)
Return an antiderivative (indefinite integral) of a polynomial.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

The returned order *m* antiderivative *P* of polynomial *p* satisfies $\frac{d^m}{dx^m}P(x) = p(x)$ and is defined up to *m - 1* integration constants *k*. The constants determine the low-order polynomial part

$$\frac{k_{m-1}}{0!}x^0 + \ldots + \frac{k_0}{(m-1)!}x^{m-1}$$

of *P* so that $P^{(j)}(0) = k_{m-j-1}$.

Parameters

p
[array_like or poly1d] Polynomial to integrate. A sequence is interpreted as polynomial coefficients, see *poly1d*.

m
[int, optional] Order of the antiderivative. (Default: 1)

k

[list of *m* scalars or scalar, optional] Integration constants. They are given in the order of integration: those corresponding to highest-order terms come first.

If `None` (default), all constants are assumed to be zero. If *m = 1*, a single scalar can be given instead of a list.

See also:

polyder
derivative of a polynomial

poly1d.integ
equivalent method

Examples

The defining property of the antiderivative:

```
>>> import numpy as np
```

```
>>> p = np.poly1d([1,1,1])
>>> P = np.polyint(p)
>>> P
 poly1d([ 0.33333333,  0.5       ,  1.        ,  0.        ]) # may vary
>>> np.polyder(P) == p
True
```

The integration constants default to zero, but can be specified:

```
>>> P = np.polyint(p, 3)
>>> P(0)
0.0
>>> np.polyder(P)(0)
0.0
>>> np.polyder(P, 2)(0)
0.0
>>> P = np.polyint(p, 3, k=[6,5,3])
>>> P
poly1d([ 0.01666667,  0.04166667,  0.16666667,  3. ,  5. ,  3. ]) # may vary
```

Note that 3 = 6 / 2!, and that the constants are given in the order of integrations. Constant of the highest-order polynomial term comes first:

```
>>> np.polyder(P, 2)(0)
6.0
>>> np.polyder(P, 1)(0)
5.0
>>> P(0)
3.0
```

Arithmetic

polyadd(a1, a2)	Find the sum of two polynomials.
polydiv(u, v)	Returns the quotient and remainder of polynomial division.
polymul(a1, a2)	Find the product of two polynomials.
polysub(a1, a2)	Difference (subtraction) of two polynomials.

numpy.**polyadd**(*a1*, *a2*)

Find the sum of two polynomials.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

Returns the polynomial resulting from the sum of two input polynomials. Each input must be either a poly1d object or a 1D sequence of polynomial coefficients, from highest to lowest degree.

Parameters

a1, a2
[array_like or poly1d object] Input polynomials.

Returns

out
[ndarray or poly1d object] The sum of the inputs. If either input is a poly1d object, then the output is also a poly1d object. Otherwise, it is a 1D array of polynomial coefficients from highest to lowest degree.

See also:

poly1d
A one-dimensional polynomial class.

poly*, *polyadd*, *polyder*, *polydiv*, *polyfit*, *polyint*, *polysub*, *polyval

Examples

```
>>> import numpy as np
>>> np.polyadd([1, 2], [9, 5, 4])
array([9, 6, 6])
```

Using poly1d objects:

```
>>> p1 = np.poly1d([1, 2])
>>> p2 = np.poly1d([9, 5, 4])
>>> print(p1)
1 x + 2
>>> print(p2)
   2
9 x + 5 x + 4
>>> print(np.polyadd(p1, p2))
   2
9 x + 6 x + 6
```

numpy.**polydiv**(*u*, *v*)

Returns the quotient and remainder of polynomial division.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

The input arrays are the coefficients (including any coefficients equal to zero) of the "numerator" (dividend) and "denominator" (divisor) polynomials, respectively.

Parameters

u
: [array_like or poly1d] Dividend polynomial's coefficients.

v
: [array_like or poly1d] Divisor polynomial's coefficients.

Returns

q
: [ndarray] Coefficients, including those equal to zero, of the quotient.

r
: [ndarray] Coefficients, including those equal to zero, of the remainder.

See also:

poly, ***polyadd***, ***polyder***, ***polydiv***, ***polyfit***, ***polyint***, ***polymul***, ***polysub***
polyval

Notes

Both *u* and *v* must be 0-d or 1-d (ndim = 0 or 1), but *u.ndim* need not equal *v.ndim*. In other words, all four possible combinations - `u.ndim = v.ndim = 0`, `u.ndim = v.ndim = 1`, `u.ndim = 1, v.ndim = 0`, and `u.ndim = 0, v.ndim = 1` - work.

Examples

$$\frac{3x^2 + 5x + 2}{2x + 1} = 1.5x + 1.75, remainder 0.25$$

```
>>> import numpy as np
>>> x = np.array([3.0, 5.0, 2.0])
>>> y = np.array([2.0, 1.0])
>>> np.polydiv(x, y)
(array([1.5 , 1.75]), array([0.25]))
```

numpy.**polymul**(*a1*, *a2*)

Find the product of two polynomials.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

Finds the polynomial resulting from the multiplication of the two input polynomials. Each input must be either a poly1d object or a 1D sequence of polynomial coefficients, from highest to lowest degree.

Parameters

a1, a2
[array_like or poly1d object] Input polynomials.

Returns

out
[ndarray or poly1d object] The polynomial resulting from the multiplication of the inputs. If either inputs is a poly1d object, then the output is also a poly1d object. Otherwise, it is a 1D array of polynomial coefficients from highest to lowest degree.

See also:

poly1d
A one-dimensional polynomial class.

poly, *polyadd*, *polyder*, *polydiv*, *polyfit*, *polyint*, *polysub*, *polyval*
convolve
Array convolution. Same output as polymul, but has parameter for overlap mode.

Examples

```
>>> import numpy as np
>>> np.polymul([1, 2, 3], [9, 5, 1])
array([ 9, 23, 38, 17,  3])
```

Using poly1d objects:

```
>>> p1 = np.poly1d([1, 2, 3])
>>> p2 = np.poly1d([9, 5, 1])
>>> print(p1)
   2
1 x + 2 x + 3
>>> print(p2)
   2
9 x + 5 x + 1
>>> print(np.polymul(p1, p2))
   4      3      2
9 x + 23 x + 38 x + 17 x + 3
```

numpy.**polysub**(*a1*, *a2*)

Difference (subtraction) of two polynomials.

Note: This forms part of the old polynomial API. Since version 1.4, the new polynomial API defined in *numpy.polynomial* is preferred. A summary of the differences can be found in the *transition guide*.

Given two polynomials *a1* and *a2*, returns `a1 - a2`. *a1* and *a2* can be either array_like sequences of the polynomials' coefficients (including coefficients equal to zero), or *poly1d* objects.

Parameters

a1, a2
[array_like or poly1d] Minuend and subtrahend polynomials, respectively.

Returns

out
[ndarray or poly1d] Array or *poly1d* object of the difference polynomial's coefficients.

See also:

polyval*, *polydiv*, *polymul*, *polyadd

Examples

$$(2x^2 + 10x - 2) - (3x^2 + 10x - 4) = (-x^2 + 2)$$

```
>>> import numpy as np
```

```
>>> np.polysub([2, 10, -2], [3, 10, -4])
array([-1,  0,  2])
```

1.4.15 Set routines

Making proper sets

unique(ar[, return_index, return_inverse, ...])	Find the unique elements of an array.
unique_all(x)	Find the unique elements of an array, and counts, inverse, and indices.
unique_counts(x)	Find the unique elements and counts of an input array *x*.
unique_inverse(x)	Find the unique elements of *x* and indices to reconstruct *x*.
unique_values(x)	Returns the unique elements of an input array *x*.

numpy.**unique_all**(*x*)

Find the unique elements of an array, and counts, inverse, and indices.

This function is an Array API compatible alternative to:

```
np.unique(x, return_index=True, return_inverse=True,
          return_counts=True, equal_nan=False)
```

but returns a namedtuple for easier access to each output.

Parameters

x
[array_like] Input array. It will be flattened if it is not already 1-D.

Returns

out
[namedtuple] The result containing:

- values - The unique elements of an input array.
- indices - The first occurring indices for each unique element.
- inverse_indices - The indices from the set of unique elements that reconstruct *x*.

- counts - The corresponding counts for each unique element.

See also:

unique
Find the unique elements of an array.

Examples

```
>>> import numpy as np
>>> x = [1, 1, 2]
>>> uniq = np.unique_all(x)
>>> uniq.values
array([1, 2])
>>> uniq.indices
array([0, 2])
>>> uniq.inverse_indices
array([0, 0, 1])
>>> uniq.counts
array([2, 1])
```

numpy.**unique_counts**(*x*)

Find the unique elements and counts of an input array *x*.

This function is an Array API compatible alternative to:

```
np.unique(x, return_counts=True, equal_nan=False)
```

but returns a namedtuple for easier access to each output.

Parameters

x
[array_like] Input array. It will be flattened if it is not already 1-D.

Returns

out
[namedtuple] The result containing:

- values - The unique elements of an input array.
- counts - The corresponding counts for each unique element.

See also:

unique
Find the unique elements of an array.

Examples

```
>>> import numpy as np
>>> x = [1, 1, 2]
>>> uniq = np.unique_counts(x)
>>> uniq.values
array([1, 2])
>>> uniq.counts
array([2, 1])
```

numpy.**unique_inverse**(*x*)

Find the unique elements of *x* and indices to reconstruct *x*.

This function is an Array API compatible alternative to:

```
np.unique(x, return_inverse=True, equal_nan=False)
```

but returns a namedtuple for easier access to each output.

Parameters

x
[array_like] Input array. It will be flattened if it is not already 1-D.

Returns

out
[namedtuple] The result containing:

- values - The unique elements of an input array.
- inverse_indices - The indices from the set of unique elements that reconstruct *x*.

See also:

unique
Find the unique elements of an array.

Examples

```
>>> import numpy as np
>>> x = [1, 1, 2]
>>> uniq = np.unique_inverse(x)
>>> uniq.values
array([1, 2])
>>> uniq.inverse_indices
array([0, 0, 1])
```

numpy.**unique_values**(*x*)

Returns the unique elements of an input array *x*.

This function is an Array API compatible alternative to:

```
np.unique(x, equal_nan=False)
```

Parameters

x
[array_like] Input array. It will be flattened if it is not already 1-D.

Returns

out
[ndarray] The unique elements of an input array.

See also:

unique
Find the unique elements of an array.

Examples

```
>>> import numpy as np
>>> np.unique_values([1, 1, 2])
array([1, 2])
```

Boolean operations

in1d(ar1, ar2[, assume_unique, invert, kind])	Test whether each element of a 1-D array is also present in a second array.
intersect1d(ar1, ar2[, assume_unique, ...])	Find the intersection of two arrays.
isin(element, test_elements[, ...])	Calculates `element in test_elements`, broadcasting over *element* only.
setdiff1d(ar1, ar2[, assume_unique])	Find the set difference of two arrays.
setxor1d(ar1, ar2[, assume_unique])	Find the set exclusive-or of two arrays.
union1d(ar1, ar2)	Find the union of two arrays.

numpy.**in1d**(*ar1*, *ar2*, *assume_unique=False*, *invert=False*, ***, *kind=None*)

Test whether each element of a 1-D array is also present in a second array.

Deprecated since version 2.0: Use *isin* instead of *in1d* for new code.

Returns a boolean array the same length as *ar1* that is True where an element of *ar1* is in *ar2* and False otherwise.

Parameters

ar1
[(M,) array_like] Input array.

ar2
[array_like] The values against which to test each value of *ar1*.

assume_unique
[bool, optional] If True, the input arrays are both assumed to be unique, which can speed up the calculation. Default is False.

invert
[bool, optional] If True, the values in the returned array are inverted (that is, False where an element of *ar1* is in *ar2* and True otherwise). Default is False. `np.in1d(a, b, invert=True)` is equivalent to (but is faster than) `np.invert(in1d(a, b))`.

kind
[{None, 'sort', 'table'}, optional] The algorithm to use. This will not affect the final result, but will affect the speed and memory use. The default, None, will select automatically based on memory considerations.

- If 'sort', will use a mergesort-based approach. This will have a memory usage of roughly 6 times the sum of the sizes of *ar1* and *ar2*, not accounting for size of dtypes.
- If 'table', will use a lookup table approach similar to a counting sort. This is only available for boolean and integer arrays. This will have a memory usage of the size of *ar1* plus the max-min value of *ar2*. *assume_unique* has no effect when the 'table' option is used.
- If None, will automatically choose 'table' if the required memory allocation is less than or equal to 6 times the sum of the sizes of *ar1* and *ar2*, otherwise will use 'sort'. This is done to not use a large amount of memory by default, even though 'table' may be faster in most cases. If 'table' is chosen, *assume_unique* will have no effect.

Returns

in1d
[(M,) ndarray, bool] The values *ar1[in1d]* are in *ar2*.

See also:

isin
Version of this function that preserves the shape of ar1.

Notes

in1d can be considered as an element-wise function version of the python keyword *in*, for 1-D sequences. `in1d(a, b)` is roughly equivalent to `np.array([item in b for item in a])`. However, this idea fails if *ar2* is a set, or similar (non-sequence) container: As `ar2` is converted to an array, in those cases `asarray(ar2)` is an object array rather than the expected array of contained values.

Using `kind='table'` tends to be faster than *kind='sort'* if the following relationship is true: `log10(len(ar2)) > (log10(max(ar2)-min(ar2)) - 2.27) / 0.927`, but may use greater memory. The default value for *kind* will be automatically selected based only on memory usage, so one may manually set `kind='table'` if memory constraints can be relaxed.

Examples

```
>>> import numpy as np
>>> test = np.array([0, 1, 2, 5, 0])
>>> states = [0, 2]
>>> mask = np.in1d(test, states)
>>> mask
array([ True, False,  True, False,  True])
>>> test[mask]
array([0, 2, 0])
>>> mask = np.in1d(test, states, invert=True)
>>> mask
array([False,  True, False,  True, False])
>>> test[mask]
array([1, 5])
```

numpy.**intersect1d**(*ar1*, *ar2*, *assume_unique=False*, *return_indices=False*)

Find the intersection of two arrays.

Return the sorted, unique values that are in both of the input arrays.

Parameters

ar1, ar2
[array_like] Input arrays. Will be flattened if not already 1D.

assume_unique
[bool] If True, the input arrays are both assumed to be unique, which can speed up the calculation. If True but `ar1` or `ar2` are not unique, incorrect results and out-of-bounds indices could result. Default is False.

return_indices
[bool] If True, the indices which correspond to the intersection of the two arrays are returned. The first instance of a value is used if there are multiple. Default is False.

Returns

intersect1d
[ndarray] Sorted 1D array of common and unique elements.

comm1
[ndarray] The indices of the first occurrences of the common values in *ar1*. Only provided if *return_indices* is True.

comm2
[ndarray] The indices of the first occurrences of the common values in *ar2*. Only provided if *return_indices* is True.

Examples

```
>>> import numpy as np
>>> np.intersect1d([1, 3, 4, 3], [3, 1, 2, 1])
array([1, 3])
```

To intersect more than two arrays, use functools.reduce:

```
>>> from functools import reduce
>>> reduce(np.intersect1d, ([1, 3, 4, 3], [3, 1, 2, 1], [6, 3, 4, 2]))
array([3])
```

To return the indices of the values common to the input arrays along with the intersected values:

```
>>> x = np.array([1, 1, 2, 3, 4])
>>> y = np.array([2, 1, 4, 6])
>>> xy, x_ind, y_ind = np.intersect1d(x, y, return_indices=True)
>>> x_ind, y_ind
(array([0, 2, 4]), array([1, 0, 2]))
>>> xy, x[x_ind], y[y_ind]
(array([1, 2, 4]), array([1, 2, 4]), array([1, 2, 4]))
```

numpy.**isin**(*element*, *test_elements*, *assume_unique=False*, *invert=False*, ***, *kind=None*)

Calculates `element in test_elements`, broadcasting over *element* only. Returns a boolean array of the same shape as *element* that is True where an element of *element* is in *test_elements* and False otherwise.

Parameters

element
[array_like] Input array.

test_elements
[array_like] The values against which to test each value of *element*. This argument is flattened if it is an array or array_like. See notes for behavior with non-array-like parameters.

assume_unique
[bool, optional] If True, the input arrays are both assumed to be unique, which can speed up the calculation. Default is False.

invert
[bool, optional] If True, the values in the returned array are inverted, as if calculating *element not in test_elements*. Default is False. `np.isin(a, b, invert=True)` is equivalent to (but faster than) `np.invert(np.isin(a, b))`.

kind
[{None, 'sort', 'table'}, optional] The algorithm to use. This will not affect the final result, but will affect the speed and memory use. The default, None, will select automatically based on memory considerations.

- If 'sort', will use a mergesort-based approach. This will have a memory usage of roughly 6 times the sum of the sizes of *element* and *test_elements*, not accounting for size of dtypes.
- If 'table', will use a lookup table approach similar to a counting sort. This is only available for boolean and integer arrays. This will have a memory usage of the size of *element* plus the max-min value of *test_elements*. *assume_unique* has no effect when the 'table' option is used.
- If None, will automatically choose 'table' if the required memory allocation is less than or equal to 6 times the sum of the sizes of *element* and *test_elements*, otherwise will use 'sort'. This is done to not use a large amount of memory by default, even though 'table' may be faster in most cases. If 'table' is chosen, *assume_unique* will have no effect.

Returns

isin
[ndarray, bool] Has the same shape as *element*. The values *element[isin]* are in *test_elements*.

Notes

isin is an element-wise function version of the python keyword *in*. `isin(a, b)` is roughly equivalent to `np.array([item in b for item in a])` if *a* and *b* are 1-D sequences.

element and *test_elements* are converted to arrays if they are not already. If *test_elements* is a set (or other non-sequence collection) it will be converted to an object array with one element, rather than an array of the values contained in *test_elements*. This is a consequence of the *array* constructor's way of handling non-sequence collections. Converting the set to a list usually gives the desired behavior.

Using `kind='table'` tends to be faster than *kind='sort'* if the following relationship is true: `log10(len(test_elements)) > (log10(max(test_elements)-min(test_elements)) - 2.27) / 0.927`, but may use greater memory. The default value for *kind* will be automatically selected based only on memory usage, so one may manually set `kind='table'` if memory constraints can be relaxed.

Examples

```
>>> import numpy as np
>>> element = 2*np.arange(4).reshape((2, 2))
>>> element
array([[0, 2],
       [4, 6]])
>>> test_elements = [1, 2, 4, 8]
>>> mask = np.isin(element, test_elements)
>>> mask
array([[False,  True],
       [ True, False]])
>>> element[mask]
array([2, 4])
```

The indices of the matched values can be obtained with *nonzero*:

```
>>> np.nonzero(mask)
(array([0, 1]), array([1, 0]))
```

The test can also be inverted:

```
>>> mask = np.isin(element, test_elements, invert=True)
>>> mask
array([[ True, False],
       [False,  True]])
>>> element[mask]
array([0, 6])
```

Because of how *array* handles sets, the following does not work as expected:

```
>>> test_set = {1, 2, 4, 8}
>>> np.isin(element, test_set)
array([[False, False],
       [False, False]])
```

Casting the set to a list gives the expected result:

```
>>> np.isin(element, list(test_set))
array([[False,  True],
       [ True, False]])
```

numpy.**setdiff1d**(*ar1*, *ar2*, *assume_unique=False*)

Find the set difference of two arrays.

Return the unique values in *ar1* that are not in *ar2*.

Parameters

ar1
[array_like] Input array.

ar2
[array_like] Input comparison array.

assume_unique
[bool] If True, the input arrays are both assumed to be unique, which can speed up the calculation. Default is False.

Returns

setdiff1d
[ndarray] 1D array of values in *ar1* that are not in *ar2*. The result is sorted when *assume_unique=False*, but otherwise only sorted if the input is sorted.

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2, 3, 2, 4, 1])
>>> b = np.array([3, 4, 5, 6])
>>> np.setdiff1d(a, b)
array([1, 2])
```

numpy.**setxor1d**(*ar1*, *ar2*, *assume_unique=False*)

Find the set exclusive-or of two arrays.

Return the sorted, unique values that are in only one (not both) of the input arrays.

Parameters

ar1, ar2
[array_like] Input arrays.

assume_unique
[bool] If True, the input arrays are both assumed to be unique, which can speed up the calculation. Default is False.

Returns

setxor1d
[ndarray] Sorted 1D array of unique values that are in only one of the input arrays.

Examples

```
>>> import numpy as np
>>> a = np.array([1, 2, 3, 2, 4])
>>> b = np.array([2, 3, 5, 7, 5])
>>> np.setxor1d(a,b)
array([1, 4, 5, 7])
```

numpy.**union1d**(*ar1*, *ar2*)

Find the union of two arrays.

Return the unique, sorted array of values that are in either of the two input arrays.

Parameters

ar1, ar2
[array_like] Input arrays. They are flattened if they are not already 1D.

Returns

union1d
[ndarray] Unique, sorted union of the input arrays.

Examples

```
>>> import numpy as np
>>> np.union1d([-1, 0, 1], [-2, 0, 2])
array([-2, -1,  0,  1,  2])
```

To find the union of more than two arrays, use functools.reduce:

```
>>> from functools import reduce
>>> reduce(np.union1d, ([1, 3, 4, 3], [3, 1, 2, 1], [6, 3, 4, 2]))
array([1, 2, 3, 4, 6])
```

1.4.16 Sorting, searching, and counting

Sorting

sort(a[, axis, kind, order, stable])	Return a sorted copy of an array.
lexsort(keys[, axis])	Perform an indirect stable sort using a sequence of keys.
argsort(a[, axis, kind, order, stable])	Returns the indices that would sort an array.
ndarray.sort([axis, kind, order])	Sort an array in-place.
sort_complex(a)	Sort a complex array using the real part first, then the imaginary part.
partition(a, kth[, axis, kind, order])	Return a partitioned copy of an array.
argpartition(a, kth[, axis, kind, order])	Perform an indirect partition along the given axis using the algorithm specified by the *kind* keyword.

numpy.**sort**(*a*, *axis=-1*, *kind=None*, *order=None*, *, *stable=None*)

Return a sorted copy of an array.

Parameters

a
[array_like] Array to be sorted.

axis
[int or None, optional] Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.

kind
[{'quicksort', 'mergesort', 'heapsort', 'stable'}, optional] Sorting algorithm. The default is 'quicksort'. Note that both 'stable' and 'mergesort' use timsort or radix sort under the covers and, in general, the actual implementation will vary with data type. The 'mergesort' option is retained for backwards compatibility.

order
[str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

stable
[bool, optional] Sort stability. If `True`, the returned array will maintain the relative order of `a` values which compare as equal. If `False` or `None`, this is not guaranteed. Internally, this option selects `kind='stable'`. Default: `None`.

New in version 2.0.0.

Returns

sorted_array
[ndarray] Array of the same type and shape as *a*.

See also:

ndarray.sort
Method to sort an array in-place.

argsort
Indirect sort.

lexsort
Indirect stable sort on multiple keys.

searchsorted
Find elements in a sorted array.

partition
Partial sort.

Notes

The various sorting algorithms are characterized by their average speed, worst case performance, work space size, and whether they are stable. A stable sort keeps items with the same key in the same relative order. The four algorithms implemented in NumPy have the following properties:

kind	speed	worst case	work space	stable
'quicksort'	1	O(n^2)	0	no
'heapsort'	3	O(n*log(n))	0	no
'mergesort'	2	O(n*log(n))	~n/2	yes
'timsort'	2	O(n*log(n))	~n/2	yes

Note: The datatype determines which of 'mergesort' or 'timsort' is actually used, even if 'mergesort' is specified. User selection at a finer scale is not currently available.

For performance, `sort` makes a temporary copy if needed to make the data contiguous in memory along the sort axis. For even better performance and reduced memory consumption, ensure that the array is already contiguous along the sort axis.

The sort order for complex numbers is lexicographic. If both the real and imaginary parts are non-nan then the order is determined by the real parts except when they are equal, in which case the order is determined by the imaginary parts.

Previous to numpy 1.4.0 sorting real and complex arrays containing nan values led to undefined behaviour. In numpy versions >= 1.4.0 nan values are sorted to the end. The extended sort order is:

- Real: [R, nan]
- Complex: [R + Rj, R + nanj, nan + Rj, nan + nanj]

where R is a non-nan real value. Complex values with the same nan placements are sorted according to the non-nan part if it exists. Non-nan values are sorted as before.

quicksort has been changed to: introsort. When sorting does not make enough progress it switches to heapsort. This implementation makes quicksort O(n*log(n)) in the worst case.

'stable' automatically chooses the best stable sorting algorithm for the data type being sorted. It, along with 'mergesort' is currently mapped to timsort or radix sort depending on the data type. API forward compatibility currently limits the ability to select the implementation and it is hardwired for the different data types.

Timsort is added for better performance on already or nearly sorted data. On random data timsort is almost identical to mergesort. It is now used for stable sort while quicksort is still the default sort if none is chosen. For timsort details, refer to CPython listsort.txt 'mergesort' and 'stable' are mapped to radix sort for integer data types. Radix sort is an O(n) sort instead of O(n log n).

NaT now sorts to the end of arrays for consistency with NaN.

Examples

```
>>> import numpy as np
>>> a = np.array([[1,4],[3,1]])
>>> np.sort(a)                # sort along the last axis
array([[1, 4],
       [1, 3]])
>>> np.sort(a, axis=None)     # sort the flattened array
array([1, 1, 3, 4])
>>> np.sort(a, axis=0)        # sort along the first axis
array([[1, 1],
       [3, 4]])
```

Use the *order* keyword to specify a field to use when sorting a structured array:

```
>>> dtype = [('name', 'S10'), ('height', float), ('age', int)]
>>> values = [('Arthur', 1.8, 41), ('Lancelot', 1.9, 38),
...           ('Galahad', 1.7, 38)]
>>> a = np.array(values, dtype=dtype)       # create a structured array
>>> np.sort(a, order='height')
array([('Galahad', 1.7, 38), ('Arthur', 1.8, 41),
       ('Lancelot', 1.8999999999999999, 38)],
      dtype=[('name', '|S10'), ('height', '<f8'), ('age', '<i4')])
```

Sort by age, then height if ages are equal:

```
>>> np.sort(a, order=['age', 'height'])
array([('Galahad', 1.7, 38), ('Lancelot', 1.8999999999999999, 38),
       ('Arthur', 1.8, 41)],
      dtype=[('name', '|S10'), ('height', '<f8'), ('age', '<i4')])
```

numpy.**lexsort**(*keys*, *axis=-1*)

Perform an indirect stable sort using a sequence of keys.

Given multiple sorting keys, lexsort returns an array of integer indices that describes the sort order by multiple keys. The last key in the sequence is used for the primary sort order, ties are broken by the second-to-last key, and so on.

Parameters

keys

[(k, m, n, …) array-like] The *k* keys to be sorted. The *last* key (e.g, the last row if *keys* is a 2D array) is the primary sort key. Each element of *keys* along the zeroth axis must be an array-like object of the same shape.

axis
: [int, optional] Axis to be indirectly sorted. By default, sort over the last axis of each sequence. Separate slices along *axis* sorted over independently; see last example.

Returns

indices
: [(m, n, …) ndarray of ints] Array of indices that sort the keys along the specified axis.

See also:

argsort
: Indirect sort.

ndarray.sort
: In-place sort.

sort
: Return a sorted copy of an array.

Examples

Sort names: first by surname, then by name.

```
>>> import numpy as np
>>> surnames =    ('Hertz',    'Galilei', 'Hertz')
>>> first_names = ('Heinrich', 'Galileo', 'Gustav')
>>> ind = np.lexsort((first_names, surnames))
>>> ind
array([1, 2, 0])
```

```
>>> [surnames[i] + ", " + first_names[i] for i in ind]
['Galilei, Galileo', 'Hertz, Gustav', 'Hertz, Heinrich']
```

Sort according to two numerical keys, first by elements of `a`, then breaking ties according to elements of `b`:

```
>>> a = [1, 5, 1, 4, 3, 4, 4]  # First sequence
>>> b = [9, 4, 0, 4, 0, 2, 1]  # Second sequence
>>> ind = np.lexsort((b, a))  # Sort by `a`, then by `b`
>>> ind
array([2, 0, 4, 6, 5, 3, 1])
>>> [(a[i], b[i]) for i in ind]
[(1, 0), (1, 9), (3, 0), (4, 1), (4, 2), (4, 4), (5, 4)]
```

Compare against *argsort*, which would sort each key independently.

```
>>> np.argsort((b, a), kind='stable')
array([[2, 4, 6, 5, 1, 3, 0],
       [0, 2, 4, 3, 5, 6, 1]])
```

To sort lexicographically with *argsort*, we would need to provide a structured array.

```
>>> x = np.array([(ai, bi) for ai, bi in zip(a, b)],
...              dtype = np.dtype([('x', int), ('y', int)]))
>>> np.argsort(x)  # or np.argsort(x, order=('x', 'y'))
array([2, 0, 4, 6, 5, 3, 1])
```

The zeroth axis of *keys* always corresponds with the sequence of keys, so 2D arrays are treated just like other sequences of keys.

```
>>> arr = np.asarray([b, a])
>>> ind2 = np.lexsort(arr)
>>> np.testing.assert_equal(ind2, ind)
```

Accordingly, the *axis* parameter refers to an axis of *each* key, not of the *keys* argument itself. For instance, the array `arr` is treated as a sequence of two 1-D keys, so specifying `axis=0` is equivalent to using the default axis, `axis=-1`.

```
>>> np.testing.assert_equal(np.lexsort(arr, axis=0),
...                         np.lexsort(arr, axis=-1))
```

For higher-dimensional arrays, the axis parameter begins to matter. The resulting array has the same shape as each key, and the values are what we would expect if *lexsort* were performed on corresponding slices of the keys independently. For instance,

```
>>> x = [[1, 2, 3, 4],
...      [4, 3, 2, 1],
...      [2, 1, 4, 3]]
>>> y = [[2, 2, 1, 1],
...      [1, 2, 1, 2],
...      [1, 1, 2, 1]]
>>> np.lexsort((x, y), axis=1)
array([[2, 3, 0, 1],
       [2, 0, 3, 1],
       [1, 0, 3, 2]])
```

Each row of the result is what we would expect if we were to perform *lexsort* on the corresponding row of the keys:

```
>>> for i in range(3):
...     print(np.lexsort((x[i], y[i])))
[2 3 0 1]
[2 0 3 1]
[1 0 3 2]
```

numpy.**argsort**(*a*, *axis=-1*, *kind=None*, *order=None*, ***, *stable=None*)

Returns the indices that would sort an array.

Perform an indirect sort along the given axis using the algorithm specified by the *kind* keyword. It returns an array of indices of the same shape as *a* that index data along the given axis in sorted order.

Parameters

a
: [array_like] Array to sort.

axis
: [int or None, optional] Axis along which to sort. The default is -1 (the last axis). If None, the flattened array is used.

kind
: [{'quicksort', 'mergesort', 'heapsort', 'stable'}, optional] Sorting algorithm. The default is 'quicksort'. Note that both 'stable' and 'mergesort' use timsort under the covers and, in general, the actual implementation will vary with data type. The 'mergesort' option is retained for backwards compatibility.

order
: [str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

stable
: [bool, optional] Sort stability. If `True`, the returned array will maintain the relative order of `a` values which compare as equal. If `False` or `None`, this is not guaranteed. Internally, this option selects `kind='stable'`. Default: `None`.

  New in version 2.0.0.

Returns

index_array
: [ndarray, int] Array of indices that sort *a* along the specified *axis*. If *a* is one-dimensional, `a[index_array]` yields a sorted *a*. More generally, `np.take_along_axis(a, index_array, axis=axis)` always yields the sorted *a*, irrespective of dimensionality.

See also:

sort
: Describes sorting algorithms used.

lexsort
: Indirect stable sort with multiple keys.

ndarray.sort
: Inplace sort.

argpartition
: Indirect partial sort.

take_along_axis
: Apply `index_array` from argsort to an array as if by calling sort.

Notes

See *sort* for notes on the different sorting algorithms.

As of NumPy 1.4.0 *argsort* works with real/complex arrays containing nan values. The enhanced sort order is documented in *sort*.

Examples

One dimensional array:

```
>>> import numpy as np
>>> x = np.array([3, 1, 2])
>>> np.argsort(x)
array([1, 2, 0])
```

Two-dimensional array:

```
>>> x = np.array([[0, 3], [2, 2]])
>>> x
array([[0, 3],
       [2, 2]])
```

```
>>> ind = np.argsort(x, axis=0)  # sorts along first axis (down)
>>> ind
array([[0, 1],
       [1, 0]])
>>> np.take_along_axis(x, ind, axis=0)  # same as np.sort(x, axis=0)
array([[0, 2],
       [2, 3]])
```

```
>>> ind = np.argsort(x, axis=1)  # sorts along last axis (across)
>>> ind
array([[0, 1],
       [0, 1]])
>>> np.take_along_axis(x, ind, axis=1)  # same as np.sort(x, axis=1)
array([[0, 3],
       [2, 2]])
```

Indices of the sorted elements of a N-dimensional array:

```
>>> ind = np.unravel_index(np.argsort(x, axis=None), x.shape)
>>> ind
(array([0, 1, 1, 0]), array([0, 0, 1, 1]))
>>> x[ind]  # same as np.sort(x, axis=None)
array([0, 2, 2, 3])
```

Sorting with keys:

```
>>> x = np.array([(1, 0), (0, 1)], dtype=[('x', '<i4'), ('y', '<i4')])
>>> x
array([(1, 0), (0, 1)],
      dtype=[('x', '<i4'), ('y', '<i4')])
```

```
>>> np.argsort(x, order=('x','y'))
array([1, 0])
```

```
>>> np.argsort(x, order=('y','x'))
array([0, 1])
```

numpy.**sort_complex**(*a*)

Sort a complex array using the real part first, then the imaginary part.

Parameters

a

[array_like] Input array

Returns

out

[complex ndarray] Always returns a sorted complex array.

Examples

```
>>> import numpy as np
>>> np.sort_complex([5, 3, 6, 2, 1])
array([1.+0.j, 2.+0.j, 3.+0.j, 5.+0.j, 6.+0.j])
```

```
>>> np.sort_complex([1 + 2j, 2 - 1j, 3 - 2j, 3 - 3j, 3 + 5j])
array([1.+2.j,  2.-1.j,  3.-3.j,  3.-2.j,  3.+5.j])
```

numpy.**partition**(*a*, *kth*, *axis=-1*, *kind='introselect'*, *order=None*)

Return a partitioned copy of an array.

Creates a copy of the array and partially sorts it in such a way that the value of the element in k-th position is in the position it would be in a sorted array. In the output array, all elements smaller than the k-th element are located to the left of this element and all equal or greater are located to its right. The ordering of the elements in the two partitions on the either side of the k-th element in the output array is undefined.

Parameters

a
: [array_like] Array to be sorted.

kth
: [int or sequence of ints] Element index to partition by. The k-th value of the element will be in its final sorted position and all smaller elements will be moved before it and all equal or greater elements behind it. The order of all elements in the partitions is undefined. If provided with a sequence of k-th it will partition all elements indexed by k-th of them into their sorted position at once.

  Deprecated since version 1.22.0: Passing booleans as index is deprecated.

axis
: [int or None, optional] Axis along which to sort. If None, the array is flattened before sorting. The default is -1, which sorts along the last axis.

kind
: [{'introselect'}, optional] Selection algorithm. Default is 'introselect'.

order
: [str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string. Not all fields need be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

Returns

partitioned_array
: [ndarray] Array of the same type and shape as *a*.

See also:

ndarray.partition
: Method to sort an array in-place.

argpartition
: Indirect partition.

sort
: Full sorting

Notes

The various selection algorithms are characterized by their average speed, worst case performance, work space size, and whether they are stable. A stable sort keeps items with the same key in the same relative order. The available algorithms have the following properties:

kind	speed	worst case	work space	stable
'introselect'	1	O(n)	0	no

All the partition algorithms make temporary copies of the data when partitioning along any but the last axis. Consequently, partitioning along the last axis is faster and uses less space than partitioning along any other axis.

The sort order for complex numbers is lexicographic. If both the real and imaginary parts are non-nan then the order is determined by the real parts except when they are equal, in which case the order is determined by the imaginary parts.

The sort order of `np.nan` is bigger than `np.inf`.

Examples

```
>>> import numpy as np
>>> a = np.array([7, 1, 7, 7, 1, 5, 7, 2, 3, 2, 6, 2, 3, 0])
>>> p = np.partition(a, 4)
>>> p
array([0, 1, 2, 1, 2, 5, 2, 3, 3, 6, 7, 7, 7, 7]) # may vary
```

`p[4]` is 2; all elements in `p[:4]` are less than or equal to `p[4]`, and all elements in `p[5:]` are greater than or equal to `p[4]`. The partition is:

```
[0, 1, 2, 1], [2], [5, 2, 3, 3, 6, 7, 7, 7, 7]
```

The next example shows the use of multiple values passed to *kth*.

```
>>> p2 = np.partition(a, (4, 8))
>>> p2
array([0, 1, 2, 1, 2, 3, 3, 2, 5, 6, 7, 7, 7, 7])
```

`p2[4]` is 2 and `p2[8]` is 5. All elements in `p2[:4]` are less than or equal to `p2[4]`, all elements in `p2[5:8]` are greater than or equal to `p2[4]` and less than or equal to `p2[8]`, and all elements in `p2[9:]` are greater than or equal to `p2[8]`. The partition is:

```
[0, 1, 2, 1], [2], [3, 3, 2], [5], [6, 7, 7, 7, 7]
```

`numpy.`**`argpartition`**(*a*, *kth*, *axis=-1*, *kind='introselect'*, *order=None*)

Perform an indirect partition along the given axis using the algorithm specified by the *kind* keyword. It returns an array of indices of the same shape as *a* that index data along the given axis in partitioned order.

Parameters

a
: [array_like] Array to sort.

kth
: [int or sequence of ints] Element index to partition by. The k-th element will be in its final sorted position and all smaller elements will be moved before it and all larger elements behind

it. The order of all elements in the partitions is undefined. If provided with a sequence of k-th it will partition all of them into their sorted position at once.

Deprecated since version 1.22.0: Passing booleans as index is deprecated.

axis
[int or None, optional] Axis along which to sort. The default is -1 (the last axis). If None, the flattened array is used.

kind
[{'introselect'}, optional] Selection algorithm. Default is 'introselect'

order
[str or list of str, optional] When *a* is an array with fields defined, this argument specifies which fields to compare first, second, etc. A single field can be specified as a string, and not all fields need be specified, but unspecified fields will still be used, in the order in which they come up in the dtype, to break ties.

Returns

index_array
[ndarray, int] Array of indices that partition *a* along the specified axis. If *a* is one-dimensional, `a[index_array]` yields a partitioned *a*. More generally, `np.take_along_axis(a, index_array, axis=axis)` always yields the partitioned *a*, irrespective of dimensionality.

See also:

partition
Describes partition algorithms used.

ndarray.partition
Inplace partition.

argsort
Full indirect sort.

take_along_axis
Apply `index_array` from argpartition to an array as if by calling partition.

Notes

The returned indices are not guaranteed to be sorted according to the values. Furthermore, the default selection algorithm `introselect` is unstable, and hence the returned indices are not guaranteed to be the earliest/latest occurrence of the element.

argpartition works for real/complex inputs with nan values, see *partition* for notes on the enhanced sort order and different selection algorithms.

Examples

One dimensional array:

```
>>> import numpy as np
>>> x = np.array([3, 4, 2, 1])
>>> x[np.argpartition(x, 3)]
array([2, 1, 3, 4]) # may vary
>>> x[np.argpartition(x, (1, 3))]
array([1, 2, 3, 4]) # may vary
```

```
>>> x = [3, 4, 2, 1]
>>> np.array(x)[np.argpartition(x, 3)]
array([2, 1, 3, 4]) # may vary
```

Multi-dimensional array:

```
>>> x = np.array([[3, 4, 2], [1, 3, 1]])
>>> index_array = np.argpartition(x, kth=1, axis=-1)
>>> # below is the same as np.partition(x, kth=1)
>>> np.take_along_axis(x, index_array, axis=-1)
array([[2, 3, 4],
       [1, 1, 3]])
```

Searching

argmax(a[, axis, out, keepdims])	Returns the indices of the maximum values along an axis.
nanargmax(a[, axis, out, keepdims])	Return the indices of the maximum values in the specified axis ignoring NaNs.
argmin(a[, axis, out, keepdims])	Returns the indices of the minimum values along an axis.
nanargmin(a[, axis, out, keepdims])	Return the indices of the minimum values in the specified axis ignoring NaNs.
argwhere(a)	Find the indices of array elements that are non-zero, grouped by element.
nonzero(a)	Return the indices of the elements that are non-zero.
flatnonzero(a)	Return indices that are non-zero in the flattened version of a.
where(condition, [x, y], /)	Return elements chosen from *x* or *y* depending on *condition*.
searchsorted(a, v[, side, sorter])	Find indices where elements should be inserted to maintain order.
extract(condition, arr)	Return the elements of an array that satisfy some condition.

numpy.**argmax**(*a*, *axis=None*, *out=None*, *, *keepdims=<no value>*)

Returns the indices of the maximum values along an axis.

Parameters

a

[array_like] Input array.

axis
: [int, optional] By default, the index is into the flattened array, otherwise along the specified axis.

out
: [array, optional] If provided, the result will be inserted into this array. It should be of the appropriate shape and dtype.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

  New in version 1.22.0.

Returns

index_array
: [ndarray of ints] Array of indices into the array. It has the same shape as `a.shape` with the dimension along *axis* removed. If *keepdims* is set to True, then the size of *axis* will be 1 with the resulting array having same shape as `a.shape`.

See also:

ndarray.argmax*, *argmin
amax
: The maximum value along a given axis.

unravel_index
: Convert a flat index into an index tuple.

take_along_axis
: Apply `np.expand_dims(index_array, axis)` from argmax to an array as if by calling max.

Notes

In case of multiple occurrences of the maximum values, the indices corresponding to the first occurrence are returned.

Examples

```
>>> import numpy as np
>>> a = np.arange(6).reshape(2,3) + 10
>>> a
array([[10, 11, 12],
       [13, 14, 15]])
>>> np.argmax(a)
5
>>> np.argmax(a, axis=0)
array([1, 1, 1])
>>> np.argmax(a, axis=1)
array([2, 2])
```

Indexes of the maximal elements of a N-dimensional array:

```
>>> ind = np.unravel_index(np.argmax(a, axis=None), a.shape)
>>> ind
(1, 2)
```

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```
>>> a[ind]
15
```

```
>>> b = np.arange(6)
>>> b[1] = 5
>>> b
array([0, 5, 2, 3, 4, 5])
>>> np.argmax(b)  # Only the first occurrence is returned.
1
```

```
>>> x = np.array([[4,2,3], [1,0,3]])
>>> index_array = np.argmax(x, axis=-1)
>>> # Same as np.amax(x, axis=-1, keepdims=True)
>>> np.take_along_axis(x, np.expand_dims(index_array, axis=-1), axis=-1)
array([[4],
       [3]])
>>> # Same as np.amax(x, axis=-1)
>>> np.take_along_axis(x, np.expand_dims(index_array, axis=-1),
...     axis=-1).squeeze(axis=-1)
array([4, 3])
```

Setting *keepdims* to *True*,

```
>>> x = np.arange(24).reshape((2, 3, 4))
>>> res = np.argmax(x, axis=1, keepdims=True)
>>> res.shape
(2, 1, 4)
```

numpy.**nanargmax**(*a*, *axis=None*, *out=None*, ***, *keepdims=<no value>*)

Return the indices of the maximum values in the specified axis ignoring NaNs. For all-NaN slices `ValueError` is raised. Warning: the results cannot be trusted if a slice contains only NaNs and -Infs.

Parameters

a
[array_like] Input data.

axis
[int, optional] Axis along which to operate. By default flattened input is used.

out
[array, optional] If provided, the result will be inserted into this array. It should be of the appropriate shape and dtype.

New in version 1.22.0.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

New in version 1.22.0.

Returns

index_array
[ndarray] An array of indices or a single index value.

See also:

argmax, *nanargmin*

Examples

```
>>> import numpy as np
>>> a = np.array([[np.nan, 4], [2, 3]])
>>> np.argmax(a)
0
>>> np.nanargmax(a)
1
>>> np.nanargmax(a, axis=0)
array([1, 0])
>>> np.nanargmax(a, axis=1)
array([1, 1])
```

numpy.**argmin**(*a*, *axis=None*, *out=None*, ***, *keepdims=<no value>*)

Returns the indices of the minimum values along an axis.

Parameters

a
[array_like] Input array.

axis
[int, optional] By default, the index is into the flattened array, otherwise along the specified axis.

out
[array, optional] If provided, the result will be inserted into this array. It should be of the appropriate shape and dtype.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

New in version 1.22.0.

Returns

index_array
[ndarray of ints] Array of indices into the array. It has the same shape as *a.shape* with the dimension along *axis* removed. If *keepdims* is set to True, then the size of *axis* will be 1 with the resulting array having same shape as *a.shape*.

See also:

ndarray.argmin, *argmax*
amin
The minimum value along a given axis.

unravel_index
Convert a flat index into an index tuple.

take_along_axis
Apply `np.expand_dims(index_array, axis)` from argmin to an array as if by calling min.

Notes

In case of multiple occurrences of the minimum values, the indices corresponding to the first occurrence are returned.

Examples

```
>>> import numpy as np
>>> a = np.arange(6).reshape(2,3) + 10
>>> a
array([[10, 11, 12],
       [13, 14, 15]])
>>> np.argmin(a)
0
>>> np.argmin(a, axis=0)
array([0, 0, 0])
>>> np.argmin(a, axis=1)
array([0, 0])
```

Indices of the minimum elements of a N-dimensional array:

```
>>> ind = np.unravel_index(np.argmin(a, axis=None), a.shape)
>>> ind
(0, 0)
>>> a[ind]
10
```

```
>>> b = np.arange(6) + 10
>>> b[4] = 10
>>> b
array([10, 11, 12, 13, 10, 15])
>>> np.argmin(b)  # Only the first occurrence is returned.
0
```

```
>>> x = np.array([[4,2,3], [1,0,3]])
>>> index_array = np.argmin(x, axis=-1)
>>> # Same as np.amin(x, axis=-1, keepdims=True)
>>> np.take_along_axis(x, np.expand_dims(index_array, axis=-1), axis=-1)
array([[2],
       [0]])
>>> # Same as np.amax(x, axis=-1)
>>> np.take_along_axis(x, np.expand_dims(index_array, axis=-1),
...     axis=-1).squeeze(axis=-1)
array([2, 0])
```

Setting *keepdims* to *True*,

```
>>> x = np.arange(24).reshape((2, 3, 4))
>>> res = np.argmin(x, axis=1, keepdims=True)
>>> res.shape
(2, 1, 4)
```

numpy.**nanargmin**(*a*, *axis=None*, *out=None*, ***, *keepdims=<no value>*)

Return the indices of the minimum values in the specified axis ignoring NaNs. For all-NaN slices `ValueError` is raised. Warning: the results cannot be trusted if a slice contains only NaNs and Infs.

Parameters

a
[array_like] Input data.

axis
[int, optional] Axis along which to operate. By default flattened input is used.

out
[array, optional] If provided, the result will be inserted into this array. It should be of the appropriate shape and dtype.

New in version 1.22.0.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the array.

New in version 1.22.0.

Returns

index_array
[ndarray] An array of indices or a single index value.

See also:

argmin, *nanargmax*

Examples

```
>>> import numpy as np
>>> a = np.array([[np.nan, 4], [2, 3]])
>>> np.argmin(a)
0
>>> np.nanargmin(a)
2
>>> np.nanargmin(a, axis=0)
array([1, 1])
>>> np.nanargmin(a, axis=1)
array([1, 0])
```

numpy.**argwhere**(*a*)

Find the indices of array elements that are non-zero, grouped by element.

Parameters

a
[array_like] Input data.

Returns

index_array
[(N, a.ndim) ndarray] Indices of elements that are non-zero. Indices are grouped by element. This array will have shape `(N, a.ndim)` where `N` is the number of non-zero items.

See also:

where, *nonzero*

Notes

`np.argwhere(a)` is almost the same as `np.transpose(np.nonzero(a))`, but produces a result of the correct shape for a 0D array.

The output of `argwhere` is not suitable for indexing arrays. For this purpose use `nonzero(a)` instead.

Examples

```
>>> import numpy as np
>>> x = np.arange(6).reshape(2,3)
>>> x
array([[0, 1, 2],
       [3, 4, 5]])
>>> np.argwhere(x>1)
array([[0, 2],
       [1, 0],
       [1, 1],
       [1, 2]])
```

numpy.**flatnonzero**(*a*)

Return indices that are non-zero in the flattened version of a.

This is equivalent to `np.nonzero(np.ravel(a))[0]`.

Parameters

a
[array_like] Input data.

Returns

res
[ndarray] Output array, containing the indices of the elements of `a.ravel()` that are non-zero.

See also:

nonzero
Return the indices of the non-zero elements of the input array.

ravel
Return a 1-D array containing the elements of the input array.

Examples

```
>>> import numpy as np
>>> x = np.arange(-2, 3)
>>> x
array([-2, -1,  0,  1,  2])
>>> np.flatnonzero(x)
array([0, 1, 3, 4])
```

Use the indices of the non-zero elements as an index array to extract these elements:

```
>>> x.ravel()[np.flatnonzero(x)]
array([-2, -1,  1,  2])
```

numpy.**searchsorted**(*a*, *v*, *side='left'*, *sorter=None*)

Find indices where elements should be inserted to maintain order.

Find the indices into a sorted array *a* such that, if the corresponding elements in *v* were inserted before the indices, the order of *a* would be preserved.

Assuming that *a* is sorted:

side	returned index *i* satisfies
left	`a[i-1] < v <= a[i]`
right	`a[i-1] <= v < a[i]`

Parameters

a
: [1-D array_like] Input array. If *sorter* is None, then it must be sorted in ascending order, otherwise *sorter* must be an array of indices that sort it.

v
: [array_like] Values to insert into *a*.

side
: [{'left', 'right'}, optional] If 'left', the index of the first suitable location found is given. If 'right', return the last such index. If there is no suitable index, return either 0 or N (where N is the length of *a*).

sorter
: [1-D array_like, optional] Optional array of integer indices that sort array a into ascending order. They are typically the result of argsort.

Returns

indices
: [int or array of ints] Array of insertion points with the same shape as *v*, or an integer if *v* is a scalar.

See also:

sort
: Return a sorted copy of an array.

histogram
: Produce histogram from 1-D data.

Notes

Binary search is used to find the required insertion points.

As of NumPy 1.4.0 *searchsorted* works with real/complex arrays containing *nan* values. The enhanced sort order is documented in *sort*.

This function uses the same algorithm as the builtin python `bisect.bisect_left` (`side='left'`) and `bisect.bisect_right` (`side='right'`) functions, which is also vectorized in the *v* argument.

Examples

```
>>> import numpy as np
>>> np.searchsorted([11,12,13,14,15], 13)
2
>>> np.searchsorted([11,12,13,14,15], 13, side='right')
3
>>> np.searchsorted([11,12,13,14,15], [-10, 20, 12, 13])
array([0, 5, 1, 2])
```

When *sorter* is used, the returned indices refer to the sorted array of *a* and not *a* itself:

```
>>> a = np.array([40, 10, 20, 30])
>>> sorter = np.argsort(a)
>>> sorter
array([1, 2, 3, 0])  # Indices that would sort the array 'a'
>>> result = np.searchsorted(a, 25, sorter=sorter)
>>> result
2
>>> a[sorter[result]]
30  # The element at index 2 of the sorted array is 30.
```

numpy.**extract**(*condition*, *arr*)

Return the elements of an array that satisfy some condition.

This is equivalent to `np.compress(ravel(condition), ravel(arr))`. If *condition* is boolean `np.extract` is equivalent to `arr[condition]`.

Note that *place* does the exact opposite of *extract*.

Parameters

condition
[array_like] An array whose nonzero or True entries indicate the elements of *arr* to extract.

arr
[array_like] Input array of the same size as *condition*.

Returns

extract
[ndarray] Rank 1 array of values from *arr* where *condition* is True.

See also:

take*, *put*, *copyto*, *compress*, *place

Examples

```
>>> import numpy as np
>>> arr = np.arange(12).reshape((3, 4))
>>> arr
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
>>> condition = np.mod(arr, 3)==0
>>> condition
array([[ True, False, False,  True],
```

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```
       [False, False,  True, False],
       [False,  True, False, False]])
>>> np.extract(condition, arr)
array([0, 3, 6, 9])
```

If *condition* is boolean:

```
>>> arr[condition]
array([0, 3, 6, 9])
```

Counting

count_nonzero(a[, axis, keepdims])	Counts the number of non-zero values in the array `a`.

numpy.**count_nonzero**(*a*, *axis=None*, ***, *keepdims=False*)

Counts the number of non-zero values in the array `a`.

The word "non-zero" is in reference to the Python 2.x built-in method `__nonzero__()` (renamed `__bool__()` in Python 3.x) of Python objects that tests an object's "truthfulness". For example, any number is considered truthful if it is nonzero, whereas any string is considered truthful if it is not the empty string. Thus, this function (recursively) counts how many elements in `a` (and in sub-arrays thereof) have their `__nonzero__()` or `__bool__()` method evaluated to `True`.

Parameters

a
: [array_like] The array for which to count non-zeros.

axis
: [int or tuple, optional] Axis or tuple of axes along which to count non-zeros. Default is None, meaning that non-zeros will be counted along a flattened version of `a`.

keepdims
: [bool, optional] If this is set to True, the axes that are counted are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

Returns

count
: [int or array of int] Number of non-zero values in the array along a given axis. Otherwise, the total number of non-zero values in the array is returned.

See also:

nonzero
: Return the coordinates of all the non-zero values.

Examples

```
>>> import numpy as np
>>> np.count_nonzero(np.eye(4))
4
>>> a = np.array([[0, 1, 7, 0],
...               [3, 0, 2, 19]])
>>> np.count_nonzero(a)
5
>>> np.count_nonzero(a, axis=0)
array([1, 1, 2, 1])
>>> np.count_nonzero(a, axis=1)
array([2, 3])
>>> np.count_nonzero(a, axis=1, keepdims=True)
array([[2],
       [3]])
```

1.4.17 Statistics

Order statistics

ptp(a[, axis, out, keepdims])	Range of values (maximum - minimum) along an axis.
percentile(a, q[, axis, out, ...])	Compute the q-th percentile of the data along the specified axis.
nanpercentile(a, q[, axis, out, ...])	Compute the qth percentile of the data along the specified axis, while ignoring nan values.
quantile(a, q[, axis, out, overwrite_input, ...])	Compute the q-th quantile of the data along the specified axis.
nanquantile(a, q[, axis, out, ...])	Compute the qth quantile of the data along the specified axis, while ignoring nan values.

numpy.**ptp**(*a*, *axis=None*, *out=None*, *keepdims=<no value>*)

Range of values (maximum - minimum) along an axis.

The name of the function comes from the acronym for 'peak to peak'.

Warning: *ptp* preserves the data type of the array. This means the return value for an input of signed integers with n bits (e.g. *numpy.int8*, *numpy.int16*, etc) is also a signed integer with n bits. In that case, peak-to-peak values greater than `2**(n-1)-1` will be returned as negative values. An example with a work-around is shown below.

Parameters

a
: [array_like] Input values.

axis
: [None or int or tuple of ints, optional] Axis along which to find the peaks. By default, flatten the array. *axis* may be negative, in which case it counts from the last to the first axis. If this is a tuple of ints, a reduction is performed on multiple axes, instead of a single axis or all the axes as before.

out
: [array_like] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output, but the type of the output values will be cast if necessary.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

  If the default value is passed, then *keepdims* will not be passed through to the *ptp* method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

Returns

ptp
: [ndarray or scalar] The range of a given array - *scalar* if array is one-dimensional or a new array holding the result along the given axis

Examples

```
>>> import numpy as np
>>> x = np.array([[4, 9, 2, 10],
...               [6, 9, 7, 12]])
```

```
>>> np.ptp(x, axis=1)
array([8, 6])
```

```
>>> np.ptp(x, axis=0)
array([2, 0, 5, 2])
```

```
>>> np.ptp(x)
10
```

This example shows that a negative value can be returned when the input is an array of signed integers.

```
>>> y = np.array([[1, 127],
...               [0, 127],
...               [-1, 127],
...               [-2, 127]], dtype=np.int8)
>>> np.ptp(y, axis=1)
array([ 126,  127, -128, -127], dtype=int8)
```

A work-around is to use the *view()* method to view the result as unsigned integers with the same bit width:

```
>>> np.ptp(y, axis=1).view(np.uint8)
array([126, 127, 128, 129], dtype=uint8)
```

numpy.**percentile**(*a*, *q*, *axis=None*, *out=None*, *overwrite_input=False*, *method='linear'*, *keepdims=False*, ***, *weights=None*, *interpolation=None*)

Compute the q-th percentile of the data along the specified axis.

Returns the q-th percentile(s) of the array elements.

Parameters

a
[array_like of real numbers] Input array or object that can be converted to an array.

q
[array_like of float] Percentage or sequence of percentages for the percentiles to compute. Values must be between 0 and 100 inclusive.

axis
[{int, tuple of int, None}, optional] Axis or axes along which the percentiles are computed. The default is to compute the percentile(s) along a flattened version of the array.

out
[ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output, but the type (of the output) will be cast if necessary.

overwrite_input
[bool, optional] If True, then allow the input array *a* to be modified by intermediate calculations, to save memory. In this case, the contents of the input *a* after this function completes is undefined.

method
[str, optional] This parameter specifies the method to use for estimating the percentile. There are many different methods, some unique to NumPy. See the notes for explanation. The options sorted by their R type as summarized in the H&F paper [1] are:

1. 'inverted_cdf'
2. 'averaged_inverted_cdf'
3. 'closest_observation'
4. 'interpolated_inverted_cdf'
5. 'hazen'
6. 'weibull'
7. 'linear' (default)
8. 'median_unbiased'
9. 'normal_unbiased'

The first three methods are discontinuous. NumPy further defines the following discontinuous variations of the default 'linear' (7.) option:

- 'lower'
- 'higher',
- 'midpoint'
- 'nearest'

Changed in version 1.22.0: This argument was previously called "interpolation" and only offered the "linear" default and last four options.

keepdims
[bool, optional]

If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original array *a*.

weights
[array_like, optional] An array of weights associated with the values in *a*. Each value in *a* contributes to the percentile according to its associated weight. The weights array can either be 1-D (in which case its length must be the size of *a* along the given axis) or of the same shape as *a*. If *weights=None*, then all data in *a* are assumed to have a weight equal to one. Only *method="inverted_cdf"* supports weights. See the notes for more details.

New in version 2.0.0.

interpolation
[str, optional] Deprecated name for the method keyword argument.

Deprecated since version 1.22.0.

Returns

percentile
[scalar or ndarray] If *q* is a single percentile and *axis=None*, then the result is a scalar. If multiple percentiles are given, first axis of the result corresponds to the percentiles. The other axes are the axes that remain after the reduction of *a*. If the input contains integers or floats smaller than `float64`, the output data-type is `float64`. Otherwise, the output data-type is the same as that of the input. If *out* is specified, that array is returned instead.

See also:

mean
median
equivalent to `percentile(..., 50)`

nanpercentile
quantile
equivalent to percentile, except q in the range [0, 1].

Notes

The behavior of *numpy.percentile* with percentage *q* is that of *numpy.quantile* with argument `q/100`. For more information, please see *numpy.quantile*.

References

[1]

Examples

```
>>> import numpy as np
>>> a = np.array([[10, 7, 4], [3, 2, 1]])
>>> a
array([[10,  7,  4],
       [ 3,  2,  1]])
>>> np.percentile(a, 50)
3.5
>>> np.percentile(a, 50, axis=0)
array([6.5, 4.5, 2.5])
>>> np.percentile(a, 50, axis=1)
```

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```
array([7.,  2.])
>>> np.percentile(a, 50, axis=1, keepdims=True)
array([[7.],
       [2.]])
```

```
>>> m = np.percentile(a, 50, axis=0)
>>> out = np.zeros_like(m)
>>> np.percentile(a, 50, axis=0, out=out)
array([6.5, 4.5, 2.5])
>>> m
array([6.5, 4.5, 2.5])
```

```
>>> b = a.copy()
>>> np.percentile(b, 50, axis=1, overwrite_input=True)
array([7.,  2.])
>>> assert not np.all(a == b)
```

The different methods can be visualized graphically:

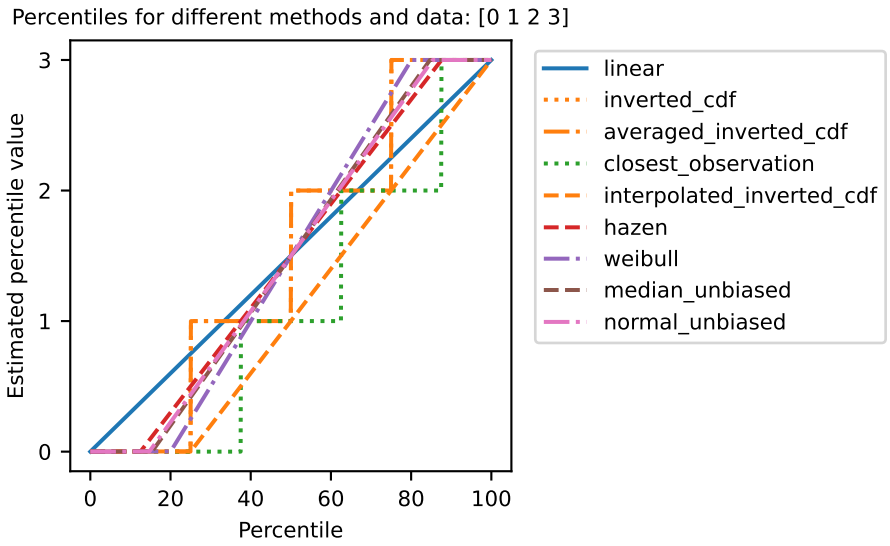
```
import matplotlib.pyplot as plt

a = np.arange(4)
p = np.linspace(0, 100, 6001)
ax = plt.gca()
lines = [
    ('linear', '-', 'C0'),
    ('inverted_cdf', ':', 'C1'),
    # Almost the same as `inverted_cdf`:
    ('averaged_inverted_cdf', '-.', 'C1'),
    ('closest_observation', ':', 'C2'),
    ('interpolated_inverted_cdf', '--', 'C1'),
    ('hazen', '--', 'C3'),
    ('weibull', '-.', 'C4'),
    ('median_unbiased', '--', 'C5'),
    ('normal_unbiased', '-.', 'C6'),
    ]
for method, style, color in lines:
    ax.plot(
        p, np.percentile(a, p, method=method),
        label=method, linestyle=style, color=color)
ax.set(
    title='Percentiles for different methods and data: ' + str(a),
    xlabel='Percentile',
    ylabel='Estimated percentile value',
    yticks=a)
ax.legend(bbox_to_anchor=(1.03, 1))
plt.tight_layout()
plt.show()
```

numpy.**nanpercentile**(*a*, *q*, *axis=None*, *out=None*, *overwrite_input=False*, *method='linear'*, *keepdims=<no value>*, ***, *weights=None*, *interpolation=None*)

Compute the qth percentile of the data along the specified axis, while ignoring nan values.

Returns the qth percentile(s) of the array elements.

Parameters



a
: [array_like] Input array or object that can be converted to an array, containing nan values to be ignored.

q
: [array_like of float] Percentile or sequence of percentiles to compute, which must be between 0 and 100 inclusive.

axis
: [{int, tuple of int, None}, optional] Axis or axes along which the percentiles are computed. The default is to compute the percentile(s) along a flattened version of the array.

out
: [ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output, but the type (of the output) will be cast if necessary.

overwrite_input
: [bool, optional] If True, then allow the input array *a* to be modified by intermediate calculations, to save memory. In this case, the contents of the input *a* after this function completes is undefined.

method
: [str, optional] This parameter specifies the method to use for estimating the percentile. There are many different methods, some unique to NumPy. See the notes for explanation. The options sorted by their R type as summarized in the H&F paper [1] are:

1. 'inverted_cdf'
2. 'averaged_inverted_cdf'
3. 'closest_observation'
4. 'interpolated_inverted_cdf'
5. 'hazen'
6. 'weibull'
7. 'linear' (default)

8. 'median_unbiased'
9. 'normal_unbiased'

The first three methods are discontinuous. NumPy further defines the following discontinuous variations of the default 'linear' (7.) option:

- 'lower'
- 'higher',
- 'midpoint'
- 'nearest'

Changed in version 1.22.0: This argument was previously called "interpolation" and only offered the "linear" default and last four options.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original array *a*.

If this is anything but the default value it will be passed through (in the special case of an empty array) to the `mean` function of the underlying array. If the array is a sub-class and `mean` does not have the kwarg *keepdims* this will raise a RuntimeError.

weights
[array_like, optional] An array of weights associated with the values in *a*. Each value in *a* contributes to the percentile according to its associated weight. The weights array can either be 1-D (in which case its length must be the size of *a* along the given axis) or of the same shape as *a*. If *weights=None*, then all data in *a* are assumed to have a weight equal to one. Only *method="inverted_cdf"* supports weights.

New in version 2.0.0.

interpolation
[str, optional] Deprecated name for the method keyword argument.

Deprecated since version 1.22.0.

Returns

percentile
[scalar or ndarray] If *q* is a single percentile and *axis=None*, then the result is a scalar. If multiple percentiles are given, first axis of the result corresponds to the percentiles. The other axes are the axes that remain after the reduction of *a*. If the input contains integers or floats smaller than `float64`, the output data-type is `float64`. Otherwise, the output data-type is the same as that of the input. If *out* is specified, that array is returned instead.

See also:

nanmean
nanmedian
equivalent to `nanpercentile(..., 50)`

percentile*, *median*, *mean
nanquantile
equivalent to nanpercentile, except q in range [0, 1].

Notes

The behavior of *numpy.nanpercentile* with percentage *q* is that of *numpy.quantile* with argument `q/100` (ignoring nan values). For more information, please see *numpy.quantile*.

References

[1]

Examples

```
>>> import numpy as np
>>> a = np.array([[10., 7., 4.], [3., 2., 1.]])
>>> a[0][1] = np.nan
>>> a
array([[10.,  nan,  4.],
       [ 3.,  2.,  1.]])
>>> np.percentile(a, 50)
np.float64(nan)
>>> np.nanpercentile(a, 50)
3.0
>>> np.nanpercentile(a, 50, axis=0)
array([6.5, 2. , 2.5])
>>> np.nanpercentile(a, 50, axis=1, keepdims=True)
array([[7.],
       [2.]])
>>> m = np.nanpercentile(a, 50, axis=0)
>>> out = np.zeros_like(m)
>>> np.nanpercentile(a, 50, axis=0, out=out)
array([6.5, 2. , 2.5])
>>> m
array([6.5,  2. ,  2.5])
```

```
>>> b = a.copy()
>>> np.nanpercentile(b, 50, axis=1, overwrite_input=True)
array([7., 2.])
>>> assert not np.all(a==b)
```

numpy.**quantile**(*a*, *q*, *axis=None*, *out=None*, *overwrite_input=False*, *method='linear'*, *keepdims=False*, ***, *weights=None*, *interpolation=None*)

Compute the q-th quantile of the data along the specified axis.

Parameters

a
: [array_like of real numbers] Input array or object that can be converted to an array.

q
: [array_like of float] Probability or sequence of probabilities of the quantiles to compute. Values must be between 0 and 1 inclusive.

axis
: [{int, tuple of int, None}, optional] Axis or axes along which the quantiles are computed. The default is to compute the quantile(s) along a flattened version of the array.

out
: [ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output, but the type (of the output) will be cast if necessary.

overwrite_input
: [bool, optional] If True, then allow the input array *a* to be modified by intermediate calculations, to save memory. In this case, the contents of the input *a* after this function completes is undefined.

method
: [str, optional] This parameter specifies the method to use for estimating the quantile. There are many different methods, some unique to NumPy. The recommended options, numbered as they appear in [1], are:

  1. 'inverted_cdf'
  2. 'averaged_inverted_cdf'
  3. 'closest_observation'
  4. 'interpolated_inverted_cdf'
  5. 'hazen'
  6. 'weibull'
  7. 'linear' (default)
  8. 'median_unbiased'
  9. 'normal_unbiased'

  The first three methods are discontinuous. For backward compatibility with previous versions of NumPy, the following discontinuous variations of the default 'linear' (7.) option are available:

  - 'lower'
  - 'higher',
  - 'midpoint'
  - 'nearest'

  See Notes for details.

  Changed in version 1.22.0: This argument was previously called "interpolation" and only offered the "linear" default and last four options.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original array *a*.

weights
: [array_like, optional] An array of weights associated with the values in *a*. Each value in *a* contributes to the quantile according to its associated weight. The weights array can either be 1-D (in which case its length must be the size of *a* along the given axis) or of the same shape as *a*. If *weights=None*, then all data in *a* are assumed to have a weight equal to one. Only *method="inverted_cdf"* supports weights. See the notes for more details.

  New in version 2.0.0.

interpolation
[str, optional] Deprecated name for the method keyword argument.

Deprecated since version 1.22.0.

Returns

quantile
[scalar or ndarray] If *q* is a single probability and *axis=None*, then the result is a scalar. If multiple probability levels are given, first axis of the result corresponds to the quantiles. The other axes are the axes that remain after the reduction of *a*. If the input contains integers or floats smaller than `float64`, the output data-type is `float64`. Otherwise, the output data-type is the same as that of the input. If *out* is specified, that array is returned instead.

See also:

mean

percentile
equivalent to quantile, but with q in the range [0, 100].

median
equivalent to `quantile(..., 0.5)`

nanquantile

Notes

Given a sample *a* from an underlying distribution, *quantile* provides a nonparametric estimate of the inverse cumulative distribution function.

By default, this is done by interpolating between adjacent elements in `y`, a sorted copy of *a*:

```
(1-g)*y[j] + g*y[j+1]
```

where the index `j` and coefficient `g` are the integral and fractional components of `q * (n-1)`, and `n` is the number of elements in the sample.

This is a special case of Equation 1 of H&F [1]. More generally,

- `j = (q*n + m - 1) // 1`, and
- `g = (q*n + m - 1) % 1`,

where `m` may be defined according to several different conventions. The preferred convention may be selected using the `method` parameter:

`method`	number in H&F	`m`
`interpolated_inverted_cdf`	4	`0`
`hazen`	5	`1/2`
`weibull`	6	`q`
`linear` (default)	7	`1 - q`
`median_unbiased`	8	`q/3 + 1/3`
`normal_unbiased`	9	`q/4 + 3/8`

Note that indices `j` and `j + 1` are clipped to the range `0` to `n - 1` when the results of the formula would be outside the allowed range of non-negative indices. The `- 1` in the formulas for `j` and `g` accounts for Python's 0-based indexing.

The table above includes only the estimators from H&F that are continuous functions of probability q (estimators 4-9). NumPy also provides the three discontinuous estimators from H&F (estimators 1-3), where `j` is defined as above, `m` is defined as follows, and `g` is a function of the real-valued `index = q*n + m - 1` and `j`.

1. `inverted_cdf`: `m = 0` and `g = int(index - j > 0)`
2. `averaged_inverted_cdf`: `m = 0` and `g = (1 + int(index - j > 0)) / 2`
3. `closest_observation`: `m = -1/2` and `g = 1 - int((index == j) & (j%2 == 1))`

For backward compatibility with previous versions of NumPy, *quantile* provides four additional discontinuous estimators. Like `method='linear'`, all have `m = 1 - q` so that `j = q*(n-1) // 1`, but `g` is defined as follows.

- `lower`: `g = 0`
- `midpoint`: `g = 0.5`
- `higher`: `g = 1`
- `nearest`: `g = (q*(n-1) % 1) > 0.5`

Weighted quantiles: More formally, the quantile at probability level q of a cumulative distribution function $F(y) = P(Y \leq y)$ with probability measure P is defined as any number x that fulfills the *coverage conditions*

$$P(Y < x) \leq q \quad \text{and} \quad P(Y \leq x) \geq q$$

with random variable $Y \sim P$. Sample quantiles, the result of *quantile*, provide nonparametric estimation of the underlying population counterparts, represented by the unknown F, given a data vector a of length `n`.

Some of the estimators above arise when one considers F as the empirical distribution function of the data, i.e. $F(y) = \frac{1}{n} \sum_i 1_{a_i \leq y}$. Then, different methods correspond to different choices of x that fulfill the above coverage conditions. Methods that follow this approach are `inverted_cdf` and `averaged_inverted_cdf`.

For weighted quantiles, the coverage conditions still hold. The empirical cumulative distribution is simply replaced by its weighted version, i.e. $P(Y \leq t) = \frac{1}{\sum_i w_i} \sum_i w_i 1_{x_i \leq t}$. Only `method="inverted_cdf"` supports weights.

References

[1]

Examples

```
>>> import numpy as np
>>> a = np.array([[10, 7, 4], [3, 2, 1]])
>>> a
array([[10,  7,  4],
       [ 3,  2,  1]])
>>> np.quantile(a, 0.5)
3.5
>>> np.quantile(a, 0.5, axis=0)
array([6.5, 4.5, 2.5])
>>> np.quantile(a, 0.5, axis=1)
array([7.,  2.])
>>> np.quantile(a, 0.5, axis=1, keepdims=True)
array([[7.],
       [2.]])
```

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```
>>> m = np.quantile(a, 0.5, axis=0)
>>> out = np.zeros_like(m)
>>> np.quantile(a, 0.5, axis=0, out=out)
array([6.5, 4.5, 2.5])
>>> m
array([6.5, 4.5, 2.5])
>>> b = a.copy()
>>> np.quantile(b, 0.5, axis=1, overwrite_input=True)
array([7.,  2.])
>>> assert not np.all(a == b)
```

See also *numpy.percentile* for a visualization of most methods.

numpy.**nanquantile**(*a*, *q*, *axis=None*, *out=None*, *overwrite_input=False*, *method='linear'*, *keepdims=<no value>*, ***, *weights=None*, *interpolation=None*)

Compute the qth quantile of the data along the specified axis, while ignoring nan values. Returns the qth quantile(s) of the array elements.

Parameters

a
: [array_like] Input array or object that can be converted to an array, containing nan values to be ignored

q
: [array_like of float] Probability or sequence of probabilities for the quantiles to compute. Values must be between 0 and 1 inclusive.

axis
: [{int, tuple of int, None}, optional] Axis or axes along which the quantiles are computed. The default is to compute the quantile(s) along a flattened version of the array.

out
: [ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output, but the type (of the output) will be cast if necessary.

overwrite_input
: [bool, optional] If True, then allow the input array *a* to be modified by intermediate calculations, to save memory. In this case, the contents of the input *a* after this function completes is undefined.

method
: [str, optional] This parameter specifies the method to use for estimating the quantile. There are many different methods, some unique to NumPy. See the notes for explanation. The options sorted by their R type as summarized in the H&F paper [1] are:

  1. 'inverted_cdf'
  2. 'averaged_inverted_cdf'
  3. 'closest_observation'
  4. 'interpolated_inverted_cdf'
  5. 'hazen'
  6. 'weibull'
  7. 'linear' (default)

8. 'median_unbiased'
9. 'normal_unbiased'

The first three methods are discontinuous. NumPy further defines the following discontinuous variations of the default 'linear' (7.) option:

- 'lower'
- 'higher',
- 'midpoint'
- 'nearest'

Changed in version 1.22.0: This argument was previously called "interpolation" and only offered the "linear" default and last four options.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original array *a*.

If this is anything but the default value it will be passed through (in the special case of an empty array) to the `mean` function of the underlying array. If the array is a sub-class and `mean` does not have the kwarg *keepdims* this will raise a RuntimeError.

weights
[array_like, optional] An array of weights associated with the values in *a*. Each value in *a* contributes to the quantile according to its associated weight. The weights array can either be 1-D (in which case its length must be the size of *a* along the given axis) or of the same shape as *a*. If *weights=None*, then all data in *a* are assumed to have a weight equal to one. Only *method="inverted_cdf"* supports weights.

New in version 2.0.0.

interpolation
[str, optional] Deprecated name for the method keyword argument.

Deprecated since version 1.22.0.

Returns

quantile
[scalar or ndarray] If *q* is a single probability and *axis=None*, then the result is a scalar. If multiple probability levels are given, first axis of the result corresponds to the quantiles. The other axes are the axes that remain after the reduction of *a*. If the input contains integers or floats smaller than `float64`, the output data-type is `float64`. Otherwise, the output data-type is the same as that of the input. If *out* is specified, that array is returned instead.

See also:

quantile
nanmean*, *nanmedian
nanmedian
equivalent to `nanquantile(..., 0.5)`

nanpercentile
same as nanquantile, but with q in the range [0, 100].

Notes

The behavior of *numpy.nanquantile* is the same as that of *numpy.quantile* (ignoring nan values). For more information, please see *numpy.quantile*.

References

[1]

Examples

```
>>> import numpy as np
>>> a = np.array([[10., 7., 4.], [3., 2., 1.]])
>>> a[0][1] = np.nan
>>> a
array([[10.,  nan,  4.],
       [ 3.,  2.,  1.]])
>>> np.quantile(a, 0.5)
np.float64(nan)
>>> np.nanquantile(a, 0.5)
3.0
>>> np.nanquantile(a, 0.5, axis=0)
array([6.5, 2. , 2.5])
>>> np.nanquantile(a, 0.5, axis=1, keepdims=True)
array([[7.],
       [2.]])
>>> m = np.nanquantile(a, 0.5, axis=0)
>>> out = np.zeros_like(m)
>>> np.nanquantile(a, 0.5, axis=0, out=out)
array([6.5, 2. , 2.5])
>>> m
array([6.5,  2. ,  2.5])
>>> b = a.copy()
>>> np.nanquantile(b, 0.5, axis=1, overwrite_input=True)
array([7., 2.])
>>> assert not np.all(a==b)
```

Averages and variances

median(a[, axis, out, overwrite_input, keepdims])	Compute the median along the specified axis.
average(a[, axis, weights, returned, keepdims])	Compute the weighted average along the specified axis.
mean(a[, axis, dtype, out, keepdims, where])	Compute the arithmetic mean along the specified axis.
std(a[, axis, dtype, out, ddof, keepdims, ...])	Compute the standard deviation along the specified axis.
var(a[, axis, dtype, out, ddof, keepdims, ...])	Compute the variance along the specified axis.
nanmedian(a[, axis, out, overwrite_input, ...])	Compute the median along the specified axis, while ignoring NaNs.
nanmean(a[, axis, dtype, out, keepdims, where])	Compute the arithmetic mean along the specified axis, ignoring NaNs.
nanstd(a[, axis, dtype, out, ddof, ...])	Compute the standard deviation along the specified axis, while ignoring NaNs.
nanvar(a[, axis, dtype, out, ddof, ...])	Compute the variance along the specified axis, while ignoring NaNs.

numpy.**median**(*a*, *axis=None*, *out=None*, *overwrite_input=False*, *keepdims=False*)

Compute the median along the specified axis.

Returns the median of the array elements.

Parameters

a
[array_like] Input array or object that can be converted to an array.

axis
[{int, sequence of int, None}, optional] Axis or axes along which the medians are computed. The default, axis=None, will compute the median along a flattened version of the array. If a sequence of axes, the array is first flattened along the given axes, then the median is computed along the resulting flattened axis.

out
[ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output, but the type (of the output) will be cast if necessary.

overwrite_input
[bool, optional] If True, then allow use of memory of input array *a* for calculations. The input array will be modified by the call to *median*. This will save memory when you do not need to preserve the contents of the input array. Treat the input as undefined, but it will probably be fully or partially sorted. Default is False. If *overwrite_input* is `True` and *a* is not already an *ndarray*, an error will be raised.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *arr*.

Returns

median
[ndarray] A new array holding the result. If the input contains integers or floats smaller than `float64`, then the output data-type is `np.float64`. Otherwise, the data-type of the output is the same as that of the input. If *out* is specified, that array is returned instead.

See also:

mean*, *percentile

Notes

Given a vector `V` of length `N`, the median of `V` is the middle value of a sorted copy of `V`, `V_sorted` - i e., `V_sorted[(N-1)/2]`, when `N` is odd, and the average of the two middle values of `V_sorted` when `N` is even.

Examples

```
>>> import numpy as np
>>> a = np.array([[10, 7, 4], [3, 2, 1]])
>>> a
array([[10,  7,  4],
       [ 3,  2,  1]])
>>> np.median(a)
np.float64(3.5)
>>> np.median(a, axis=0)
array([6.5, 4.5, 2.5])
>>> np.median(a, axis=1)
array([7.,  2.])
>>> np.median(a, axis=(0, 1))
np.float64(3.5)
>>> m = np.median(a, axis=0)
>>> out = np.zeros_like(m)
>>> np.median(a, axis=0, out=m)
array([6.5,  4.5,  2.5])
>>> m
array([6.5,  4.5,  2.5])
>>> b = a.copy()
>>> np.median(b, axis=1, overwrite_input=True)
array([7.,  2.])
>>> assert not np.all(a==b)
>>> b = a.copy()
>>> np.median(b, axis=None, overwrite_input=True)
np.float64(3.5)
>>> assert not np.all(a==b)
```

numpy.**average**(*a*, *axis=None*, *weights=None*, *returned=False*, *, *keepdims=<no value>*)

Compute the weighted average along the specified axis.

Parameters

a

[array_like] Array containing data to be averaged. If *a* is not an array, a conversion is attempted.

axis

[None or int or tuple of ints, optional] Axis or axes along which to average *a*. The default, *axis=None*, will average over all of the elements of the input array. If axis is negative it counts from the last to the first axis. If axis is a tuple of ints, averaging is performed on all of the axes specified in the tuple instead of a single axis or all the axes as before.

weights

[array_like, optional] An array of weights associated with the values in *a*. Each value in *a* contributes to the average according to its associated weight. The array of weights must be the same shape as *a* if no axis is specified, otherwise the weights must have dimensions and shape consistent with *a* along the specified axis. If *weights=None*, then all data in *a* are assumed to have a weight equal to one. The calculation is:

```
avg = sum(a * weights) / sum(weights)
```

where the sum is over all included elements. The only constraint on the values of *weights* is that *sum(weights)* must not be 0.

returned

[bool, optional] Default is *False*. If *True*, the tuple (`average`, *sum_of_weights*) is returned,

otherwise only the average is returned. If *weights=None*, *sum_of_weights* is equivalent to the number of elements over which the average is taken.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*. *Note: keepdims* will not work with instances of `numpy.matrix` or other classes whose methods do not support *keepdims*.

New in version 1.23.0.

Returns

retval, [sum_of_weights]
[array_type or double] Return the average along the specified axis. When *returned* is *True*, return a tuple with the average as the first element and the sum of the weights as the second element. *sum_of_weights* is of the same type as *retval*. The result dtype follows a general pattern. If *weights* is None, the result dtype will be that of *a* , or `float64` if *a* is integral. Otherwise, if *weights* is not None and *a* is non- integral, the result type will be the type of lowest precision capable of representing values of both *a* and *weights*. If *a* happens to be integral, the previous rules still applies but the result dtype will at least be `float64`.

Raises

ZeroDivisionError
When all weights along axis are zero. See `numpy.ma.average` for a version robust to this type of error.

TypeError
When *weights* does not have the same shape as *a*, and *axis=None*.

ValueError
When *weights* does not have dimensions and shape consistent with *a* along specified *axis*.

See also:

mean
ma.average
average for masked arrays – useful if your data contains "missing" values

numpy.result_type
Returns the type that results from applying the numpy type promotion rules to the arguments.

Examples

```
>>> import numpy as np
>>> data = np.arange(1, 5)
>>> data
array([1, 2, 3, 4])
>>> np.average(data)
2.5
>>> np.average(np.arange(1, 11), weights=np.arange(10, 0, -1))
4.0
```

```
>>> data = np.arange(6).reshape((3, 2))
>>> data
array([[0, 1],
       [2, 3],
```

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```
       [4, 5]])
>>> np.average(data, axis=1, weights=[1./4, 3./4])
array([0.75, 2.75, 4.75])
>>> np.average(data, weights=[1./4, 3./4])
Traceback (most recent call last):
    ...
TypeError: Axis must be specified when shapes of a and weights differ.
```

With `keepdims=True`, the following result has shape (3, 1).

```
>>> np.average(data, axis=1, keepdims=True)
array([[0.5],
       [2.5],
       [4.5]])
```

```
>>> data = np.arange(8).reshape((2, 2, 2))
>>> data
array([[[0, 1],
        [2, 3]],
       [[4, 5],
        [6, 7]]])
>>> np.average(data, axis=(0, 1), weights=[[1./4, 3./4], [1., 1./2]])
array([3.4, 4.4])
>>> np.average(data, axis=0, weights=[[1./4, 3./4], [1., 1./2]])
Traceback (most recent call last):
    ...
ValueError: Shape of weights must be consistent
with shape of a along specified axis.
```

numpy.**mean**(*a*, *axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*, ***, *where=<no value>*)

Compute the arithmetic mean along the specified axis.

Returns the average of the array elements. The average is taken over the flattened array by default, otherwise over the specified axis. *float64* intermediate and return values are used for integer inputs.

Parameters

a

[array_like] Array containing numbers whose mean is desired. If *a* is not an array, a conversion is attempted.

axis

[None or int or tuple of ints, optional] Axis or axes along which the means are computed. The default is to compute the mean of the flattened array.

If this is a tuple of ints, a mean is performed over multiple axes, instead of a single axis or all the axes as before.

dtype

[data-type, optional] Type to use in computing the mean. For integer inputs, the default is *float64*; for floating point inputs, it is the same as the input dtype.

out

[ndarray, optional] Alternate output array in which to place the result. The default is `None`; if provided, it must have the same shape as the expected output, but the type will be cast if necessary. See ufuncs-output-type for more details. See ufuncs-output-type for more details.

keepdims

[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

If the default value is passed, then *keepdims* will not be passed through to the *mean* method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

where
[array_like of bool, optional] Elements to include in the mean. See *reduce* for details.

New in version 1.20.0.

Returns

m
[ndarray, see dtype parameter above] If *out*=*None*, returns a new array containing the mean values, otherwise a reference to the output array is returned.

See also:

average
Weighted average

std, ***var***, ***nanmean***, ***nanstd***, ***nanvar***

Notes

The arithmetic mean is the sum of the elements along the axis divided by the number of elements.

Note that for floating-point input, the mean is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for *float32* (see example below). Specifying a higher-precision accumulator using the *dtype* keyword can alleviate this issue.

By default, *float16* results are computed using *float32* intermediates for extra precision.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> np.mean(a)
2.5
>>> np.mean(a, axis=0)
array([2., 3.])
>>> np.mean(a, axis=1)
array([1.5, 3.5])
```

In single precision, *mean* can be inaccurate:

```
>>> a = np.zeros((2, 512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.mean(a)
np.float32(0.54999924)
```

Computing the mean in float64 is more accurate:

```
>>> np.mean(a, dtype=np.float64)
0.55000000074505806 # may vary
```

Computing the mean in timedelta64 is available:

```
>>> b = np.array([1, 3], dtype="timedelta64[D]")
>>> np.mean(b)
np.timedelta64(2,'D')
```

Specifying a where argument:

```
>>> a = np.array([[5, 9, 13], [14, 10, 12], [11, 15, 19]])
>>> np.mean(a)
12.0
>>> np.mean(a, where=[[True], [False], [False]])
9.0
```

numpy.**std**(*a*, *axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=<no value>*, ***, *where=<no value>*, *mean=<no value>*, *correction=<no value>*)

Compute the standard deviation along the specified axis.

Returns the standard deviation, a measure of the spread of a distribution, of the array elements. The standard deviation is computed for the flattened array by default, otherwise over the specified axis.

Parameters

a
: [array_like] Calculate the standard deviation of these values.

axis
: [None or int or tuple of ints, optional] Axis or axes along which the standard deviation is computed. The default is to compute the standard deviation of the flattened array. If this is a tuple of ints, a standard deviation is performed over multiple axes, instead of a single axis or all the axes as before.

dtype
: [dtype, optional] Type to use in computing the standard deviation. For arrays of integer type the default is float64, for arrays of float types it is the same as the array type.

out
: [ndarray, optional] Alternative output array in which to place the result. It must have the same shape as the expected output but the type (of the calculated values) will be cast if necessary. See ufuncs-output-type for more details.

ddof
: [{int, float}, optional] Means Delta Degrees of Freedom. The divisor used in calculations is `N - ddof`, where `N` represents the number of elements. By default *ddof* is zero. See Notes for details about use of *ddof*.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

  If the default value is passed, then *keepdims* will not be passed through to the *std* method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

where
[array_like of bool, optional] Elements to include in the standard deviation. See *reduce* for details.

New in version 1.20.0.

mean
[array_like, optional] Provide the mean to prevent its recalculation. The mean should have a shape as if it was calculated with `keepdims=True`. The axis for the calculation of the mean should be the same as used in the call to this std function.

New in version 2.0.0.

correction
[{int, float}, optional] Array API compatible name for the `ddof` parameter. Only one of them can be provided at the same time.

New in version 2.0.0.

Returns

standard_deviation
[ndarray, see dtype parameter above.] If *out* is None, return a new array containing the standard deviation, otherwise return a reference to the output array.

See also:

var*, *mean*, *nanmean*, *nanstd*, *nanvar
ufuncs-output-type

Notes

There are several common variants of the array standard deviation calculation. Assuming the input *a* is a one-dimensional NumPy array and `mean` is either provided as an argument or computed as `a.mean()`, NumPy computes the standard deviation of an array as:

```
N = len(a)
d2 = abs(a - mean)**2  # abs is for complex `a`
var = d2.sum() / (N - ddof)  # note use of `ddof`
std = var**0.5
```

Different values of the argument *ddof* are useful in different contexts. NumPy's default `ddof=0` corresponds with the expression:

$$\sqrt{\frac{\sum_i |a_i - \bar{a}|^2}{N}}$$

which is sometimes called the "population standard deviation" in the field of statistics because it applies the definition of standard deviation to *a* as if *a* were a complete population of possible observations.

Many other libraries define the standard deviation of an array differently, e.g.:

$$\sqrt{\frac{\sum_i |a_i - \bar{a}|^2}{N - 1}}$$

In statistics, the resulting quantity is sometimes called the "sample standard deviation" because if *a* is a random sample from a larger population, this calculation provides the square root of an unbiased estimate of the variance of the population. The use of $N - 1$ in the denominator is often called "Bessel's correction" because it corrects for bias (toward lower values) in the variance estimate introduced when the sample mean of *a* is used in place of the

true mean of the population. The resulting estimate of the standard deviation is still biased, but less than it would have been without the correction. For this quantity, use `ddof=1`.

Note that, for complex numbers, *std* takes the absolute value before squaring, so that the result is always real and nonnegative.

For floating-point input, the standard deviation is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the *dtype* keyword can alleviate this issue.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> np.std(a)
1.1180339887498949 # may vary
>>> np.std(a, axis=0)
array([1.,  1.])
>>> np.std(a, axis=1)
array([0.5,  0.5])
```

In single precision, std() can be inaccurate:

```
>>> a = np.zeros((2, 512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.std(a)
np.float32(0.45000005)
```

Computing the standard deviation in float64 is more accurate:

```
>>> np.std(a, dtype=np.float64)
0.44999999925494177 # may vary
```

Specifying a where argument:

```
>>> a = np.array([[14, 8, 11, 10], [7, 9, 10, 11], [10, 15, 5, 10]])
>>> np.std(a)
2.614064523559687 # may vary
>>> np.std(a, where=[[True], [True], [False]])
2.0
```

Using the mean keyword to save computation time:

```
>>> import numpy as np
>>> from timeit import timeit
>>> a = np.array([[14, 8, 11, 10], [7, 9, 10, 11], [10, 15, 5, 10]])
>>> mean = np.mean(a, axis=1, keepdims=True)
>>>
>>> g = globals()
>>> n = 10000
>>> t1 = timeit("std = np.std(a, axis=1, mean=mean)", globals=g, number=n)
>>> t2 = timeit("std = np.std(a, axis=1)", globals=g, number=n)
>>> print(f'Percentage execution time saved {100*(t2-t1)/t2:.0f}%')

Percentage execution time saved 30%
```

numpy.**var**(*a*, *axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=<no value>*, ***, *where=<no value>*, *mean=<no value>*, *correction=<no value>*)

Compute the variance along the specified axis.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed for the flattened array by default, otherwise over the specified axis.

Parameters

a
[array_like] Array containing numbers whose variance is desired. If *a* is not an array, a conversion is attempted.

axis
[None or int or tuple of ints, optional] Axis or axes along which the variance is computed. The default is to compute the variance of the flattened array. If this is a tuple of ints, a variance is performed over multiple axes, instead of a single axis or all the axes as before.

dtype
[data-type, optional] Type to use in computing the variance. For arrays of integer type the default is *float64*; for arrays of float types it is the same as the array type.

out
[ndarray, optional] Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

ddof
[{int, float}, optional] "Delta Degrees of Freedom": the divisor used in the calculation is `N - ddof`, where `N` represents the number of elements. By default *ddof* is zero. See notes for details about use of *ddof*.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the input array.

If the default value is passed, then *keepdims* will not be passed through to the *var* method of sub-classes of *ndarray*, however any non-default value will be. If the sub-class' method does not implement *keepdims* any exceptions will be raised.

where
[array_like of bool, optional] Elements to include in the variance. See *reduce* for details.

New in version 1.20.0.

mean
[array like, optional] Provide the mean to prevent its recalculation. The mean should have a shape as if it was calculated with `keepdims=True`. The axis for the calculation of the mean should be the same as used in the call to this var function.

New in version 2.0.0.

correction
[{int, float}, optional] Array API compatible name for the `ddof` parameter. Only one of them can be provided at the same time.

New in version 2.0.0.

Returns

variance
: [ndarray, see dtype parameter above] If `out=None`, returns a new array containing the variance; otherwise, a reference to the output array is returned.

See also:

std*, *mean*, *nanmean*, *nanstd*, *nanvar
ufuncs-output-type

Notes

There are several common variants of the array variance calculation. Assuming the input *a* is a one-dimensional NumPy array and `mean` is either provided as an argument or computed as `a.mean()`, NumPy computes the variance of an array as:

```
N = len(a)
d2 = abs(a - mean)**2  # abs is for complex `a`
var = d2.sum() / (N - ddof)  # note use of `ddof`
```

Different values of the argument *ddof* are useful in different contexts. NumPy's default `ddof=0` corresponds with the expression:

$$\frac{\sum_i |a_i - \bar{a}|^2}{N}$$

which is sometimes called the "population variance" in the field of statistics because it applies the definition of variance to *a* as if *a* were a complete population of possible observations.

Many other libraries define the variance of an array differently, e.g.:

$$\frac{\sum_i |a_i - \bar{a}|^2}{N - 1}$$

In statistics, the resulting quantity is sometimes called the "sample variance" because if *a* is a random sample from a larger population, this calculation provides an unbiased estimate of the variance of the population. The use of $N - 1$ in the denominator is often called "Bessel's correction" because it corrects for bias (toward lower values) in the variance estimate introduced when the sample mean of *a* is used in place of the true mean of the population. For this quantity, use `ddof=1`.

Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.

For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for *float32* (see example below). Specifying a higher-accuracy accumulator using the `dtype` keyword can alleviate this issue.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, 2], [3, 4]])
>>> np.var(a)
1.25
>>> np.var(a, axis=0)
array([1.,  1.])
>>> np.var(a, axis=1)
array([0.25,  0.25])
```

In single precision, var() can be inaccurate:

```
>>> a = np.zeros((2, 512*512), dtype=np.float32)
>>> a[0, :] = 1.0
>>> a[1, :] = 0.1
>>> np.var(a)
np.float32(0.20250003)
```

Computing the variance in float64 is more accurate:

```
>>> np.var(a, dtype=np.float64)
0.20249999932944759 # may vary
>>> ((1-0.55)**2 + (0.1-0.55)**2)/2
0.2025
```

Specifying a where argument:

```
>>> a = np.array([[14, 8, 11, 10], [7, 9, 10, 11], [10, 15, 5, 10]])
>>> np.var(a)
6.833333333333333 # may vary
>>> np.var(a, where=[[True], [True], [False]])
4.0
```

Using the mean keyword to save computation time:

```
>>> import numpy as np
>>> from timeit import timeit
>>>
>>> a = np.array([[14, 8, 11, 10], [7, 9, 10, 11], [10, 15, 5, 10]])
>>> mean = np.mean(a, axis=1, keepdims=True)
>>>
>>> g = globals()
>>> n = 10000
>>> t1 = timeit("var = np.var(a, axis=1, mean=mean)", globals=g, number=n)
>>> t2 = timeit("var = np.var(a, axis=1)", globals=g, number=n)
>>> print(f'Percentage execution time saved {100*(t2-t1)/t2:.0f}%')

Percentage execution time saved 32%
```

numpy.**nanmedian**(*a*, *axis=None*, *out=None*, *overwrite_input=False*, *keepdims=<no value>*)

Compute the median along the specified axis, while ignoring NaNs.

Returns the median of the array elements.

Parameters

a
[array_like] Input array or object that can be converted to an array.

axis
[{int, sequence of int, None}, optional] Axis or axes along which the medians are computed. The default is to compute the median along a flattened version of the array. A sequence of axes is supported since version 1.9.0.

out
[ndarray, optional] Alternative output array in which to place the result. It must have the same shape and buffer length as the expected output, but the type (of the output) will be cast if necessary.

overwrite_input
: [bool, optional] If True, then allow use of memory of input array *a* for calculations. The input array will be modified by the call to *median*. This will save memory when you do not need to preserve the contents of the input array. Treat the input as undefined, but it will probably be fully or partially sorted. Default is False. If *overwrite_input* is `True` and *a* is not already an *ndarray*, an error will be raised.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*.

  If this is anything but the default value it will be passed through (in the special case of an empty array) to the *mean* function of the underlying array. If the array is a sub-class and *mean* does not have the kwarg *keepdims* this will raise a RuntimeError.

Returns

median
: [ndarray] A new array holding the result. If the input contains integers or floats smaller than `float64`, then the output data-type is `np.float64`. Otherwise, the data-type of the output is the same as that of the input. If *out* is specified, that array is returned instead.

See also:

mean*, *median*, *percentile

Notes

Given a vector `V` of length `N`, the median of `V` is the middle value of a sorted copy of `V`, `V_sorted` - i.e., `V_sorted[(N-1)/2]`, when `N` is odd and the average of the two middle values of `V_sorted` when `N` is even.

Examples

```
>>> import numpy as np
>>> a = np.array([[10.0, 7, 4], [3, 2, 1]])
>>> a[0, 1] = np.nan
>>> a
array([[10., nan,  4.],
       [ 3.,  2.,  1.]])
>>> np.median(a)
np.float64(nan)
>>> np.nanmedian(a)
3.0
>>> np.nanmedian(a, axis=0)
array([6.5, 2. , 2.5])
>>> np.median(a, axis=1)
array([nan,  2.])
>>> b = a.copy()
>>> np.nanmedian(b, axis=1, overwrite_input=True)
array([7.,  2.])
>>> assert not np.all(a==b)
>>> b = a.copy()
>>> np.nanmedian(b, axis=None, overwrite_input=True)
3.0
>>> assert not np.all(a==b)
```

numpy.**nanmean**(*a*, *axis=None*, *dtype=None*, *out=None*, *keepdims=<no value>*, ***, *where=<no value>*)

Compute the arithmetic mean along the specified axis, ignoring NaNs.

Returns the average of the array elements. The average is taken over the flattened array by default, otherwise over the specified axis. *float64* intermediate and return values are used for integer inputs.

For all-NaN slices, NaN is returned and a *RuntimeWarning* is raised.

Parameters

a
[array_like] Array containing numbers whose mean is desired. If *a* is not an array, a conversion is attempted.

axis
[{int, tuple of int, None}, optional] Axis or axes along which the means are computed. The default is to compute the mean of the flattened array.

dtype
[data-type, optional] Type to use in computing the mean. For integer inputs, the default is *float64*; for inexact inputs, it is the same as the input dtype.

out
[ndarray, optional] Alternate output array in which to place the result. The default is `None`; if provided, it must have the same shape as the expected output, but the type will be cast if necessary. See ufuncs-output-type for more details.

keepdims
[bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*.

If the value is anything but the default, then *keepdims* will be passed through to the *mean* or *sum* methods of sub-classes of *ndarray*. If the sub-classes methods does not implement *keepdims* any exceptions will be raised.

where
[array_like of bool, optional] Elements to include in the mean. See *reduce* for details.

New in version 1.22.0.

Returns

m
[ndarray, see dtype parameter above] If *out=None*, returns a new array containing the mean values, otherwise a reference to the output array is returned. Nan is returned for slices that contain only NaNs.

See also:

average
Weighted average

mean
Arithmetic mean taken while not ignoring NaNs

var*, *nanvar

Notes

The arithmetic mean is the sum of the non-NaN elements along the axis divided by the number of non-NaN elements.

Note that for floating-point input, the mean is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for *float32*. Specifying a higher-precision accumulator using the *dtype* keyword can alleviate this issue.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, np.nan], [3, 4]])
>>> np.nanmean(a)
2.6666666666666665
>>> np.nanmean(a, axis=0)
array([2.,  4.])
>>> np.nanmean(a, axis=1)
array([1.,  3.5]) # may vary
```

numpy.**nanstd**(*a*, *axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=<no value>*, ***, *where=<no value>*, *mean=<no value>*, *correction=<no value>*)

Compute the standard deviation along the specified axis, while ignoring NaNs.

Returns the standard deviation, a measure of the spread of a distribution, of the non-NaN array elements. The standard deviation is computed for the flattened array by default, otherwise over the specified axis.

For all-NaN slices or slices with zero degrees of freedom, NaN is returned and a *RuntimeWarning* is raised.

Parameters

a
: [array_like] Calculate the standard deviation of the non-NaN values.

axis
: [{int, tuple of int, None}, optional] Axis or axes along which the standard deviation is computed. The default is to compute the standard deviation of the flattened array.

dtype
: [dtype, optional] Type to use in computing the standard deviation. For arrays of integer type the default is float64, for arrays of float types it is the same as the array type.

out
: [ndarray, optional] Alternative output array in which to place the result. It must have the same shape as the expected output but the type (of the calculated values) will be cast if necessary.

ddof
: [{int, float}, optional] Means Delta Degrees of Freedom. The divisor used in calculations is `N - ddof`, where `N` represents the number of non-NaN elements. By default *ddof* is zero.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*.

  If this value is anything but the default it is passed through as-is to the relevant functions of the sub-classes. If these functions do not have a *keepdims* kwarg, a RuntimeError will be raised.

where
[array_like of bool, optional] Elements to include in the standard deviation. See *reduce* for details.

New in version 1.22.0.

mean
[array_like, optional] Provide the mean to prevent its recalculation. The mean should have a shape as if it was calculated with `keepdims=True`. The axis for the calculation of the mean should be the same as used in the call to this std function.

New in version 2.0.0.

correction
[{int, float}, optional] Array API compatible name for the `ddof` parameter. Only one of them can be provided at the same time.

New in version 2.0.0.

Returns

standard_deviation
[ndarray, see dtype parameter above.] If *out* is None, return a new array containing the standard deviation, otherwise return a reference to the output array. If ddof is >= the number of non-NaN elements in a slice or the slice contains only NaNs, then the result for that slice is NaN.

See also:

var*, *mean*, *std
nanvar*, *nanmean
ufuncs-output-type

Notes

The standard deviation is the square root of the average of the squared deviations from the mean: `std = sqrt(mean(abs(x - x.mean())**2))`.

The average squared deviation is normally calculated as `x.sum() / N`, where `N = len(x)`. If, however, *ddof* is specified, the divisor `N - ddof` is used instead. In standard statistical practice, `ddof=1` provides an unbiased estimator of the variance of the infinite population. `ddof=0` provides a maximum likelihood estimate of the variance for normally distributed variables. The standard deviation computed in this function is the square root of the estimated variance, so even with `ddof=1`, it will not be an unbiased estimate of the standard deviation per se.

Note that, for complex numbers, *std* takes the absolute value before squaring, so that the result is always real and nonnegative.

For floating-point input, the *std* is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for float32 (see example below). Specifying a higher-accuracy accumulator using the *dtype* keyword can alleviate this issue.

Examples

```
>>> import numpy as np
>>> a = np.array([[1, np.nan], [3, 4]])
>>> np.nanstd(a)
1.247219128924647
>>> np.nanstd(a, axis=0)
array([1., 0.])
>>> np.nanstd(a, axis=1)
array([0.,  0.5]) # may vary
```

numpy.**nanvar**(*a*, *axis=None*, *dtype=None*, *out=None*, *ddof=0*, *keepdims=<no value>*, ***, *where=<no value>*, *mean=<no value>*, *correction=<no value>*)

Compute the variance along the specified axis, while ignoring NaNs.

Returns the variance of the array elements, a measure of the spread of a distribution. The variance is computed for the flattened array by default, otherwise over the specified axis.

For all-NaN slices or slices with zero degrees of freedom, NaN is returned and a *RuntimeWarning* is raised.

Parameters

a
: [array_like] Array containing numbers whose variance is desired. If *a* is not an array, a conversion is attempted.

axis
: [{int, tuple of int, None}, optional] Axis or axes along which the variance is computed. The default is to compute the variance of the flattened array.

dtype
: [data-type, optional] Type to use in computing the variance. For arrays of integer type the default is *float64*; for arrays of float types it is the same as the array type.

out
: [ndarray, optional] Alternate output array in which to place the result. It must have the same shape as the expected output, but the type is cast if necessary.

ddof
: [{int, float}, optional] "Delta Degrees of Freedom": the divisor used in the calculation is `N - ddof`, where `N` represents the number of non-NaN elements. By default *ddof* is zero.

keepdims
: [bool, optional] If this is set to True, the axes which are reduced are left in the result as dimensions with size one. With this option, the result will broadcast correctly against the original *a*.

where
: [array_like of bool, optional] Elements to include in the variance. See *reduce* for details.

  New in version 1.22.0.

mean
: [array_like, optional] Provide the mean to prevent its recalculation. The mean should have a shape as if it was calculated with `keepdims=True`. The axis for the calculation of the mean should be the same as used in the call to this var function.

  New in version 2.0.0.

correction
[{int, float}, optional] Array API compatible name for the `ddof` parameter. Only one of them can be provided at the same time.

New in version 2.0.0.

Returns

variance
[ndarray, see dtype parameter above] If *out* is None, return a new array containing the variance, otherwise return a reference to the output array. If ddof is >= the number of non-NaN elements in a slice or the slice contains only NaNs, then the result for that slice is NaN.

See also:

std
Standard deviation

mean
Average

var
Variance while not ignoring NaNs

nanstd, ***nanmean***
ufuncs-output-type

Notes

The variance is the average of the squared deviations from the mean, i.e., `var = mean(abs(x - x.mean())**2)`.

The mean is normally calculated as `x.sum() / N`, where `N = len(x)`. If, however, *ddof* is specified, the divisor `N - ddof` is used instead. In standard statistical practice, `ddof=1` provides an unbiased estimator of the variance of a hypothetical infinite population. `ddof=0` provides a maximum likelihood estimate of the variance for normally distributed variables.

Note that for complex numbers, the absolute value is taken before squaring, so that the result is always real and nonnegative.

For floating-point input, the variance is computed using the same precision the input has. Depending on the input data, this can cause the results to be inaccurate, especially for *`float32`* (see example below). Specifying a higher-accuracy accumulator using the `dtype` keyword can alleviate this issue.

For this function to work on sub-classes of ndarray, they must define *`sum`* with the kwarg *keepdims*

Examples

```
>>> import numpy as np
>>> a = np.array([[1, np.nan], [3, 4]])
>>> np.nanvar(a)
1.5555555555555554
>>> np.nanvar(a, axis=0)
array([1.,  0.])
>>> np.nanvar(a, axis=1)
array([0.,  0.25])  # may vary
```

Correlating

corrcoef(x[, y, rowvar, bias, ddof, dtype])	Return Pearson product-moment correlation coefficients.
correlate(a, v[, mode])	Cross-correlation of two 1-dimensional sequences.
cov(m[, y, rowvar, bias, ddof, fweights, ...])	Estimate a covariance matrix, given data and weights.

numpy.**corrcoef**(*x*, *y=None*, *rowvar=True*, *bias=<no value>*, *ddof=<no value>*, ***, *dtype=None*)

Return Pearson product-moment correlation coefficients.

Please refer to the documentation for *cov* for more detail. The relationship between the correlation coefficient matrix, *R*, and the covariance matrix, *C*, is

$$R_{ij} = \frac{C_{ij}}{\sqrt{C_{ii}C_{jj}}}$$

The values of *R* are between -1 and 1, inclusive.

Parameters

x
: [array_like] A 1-D or 2-D array containing multiple variables and observations. Each row of *x* represents a variable, and each column a single observation of all those variables. Also see *rowvar* below.

y
: [array_like, optional] An additional set of variables and observations. *y* has the same shape as *x*.

rowvar
: [bool, optional] If *rowvar* is True (default), then each row represents a variable, with observations in the columns. Otherwise, the relationship is transposed: each column represents a variable, while the rows contain observations.

bias
: [_NoValue, optional] Has no effect, do not use.

  Deprecated since version 1.10.0.

ddof
: [_NoValue, optional] Has no effect, do not use.

  Deprecated since version 1.10.0.

dtype
: [data-type, optional] Data-type of the result. By default, the return data-type will have at least *numpy.float64* precision.

  New in version 1.20.

Returns

R
: [ndarray] The correlation coefficient matrix of the variables.

See also:

cov
: Covariance matrix

Notes

Due to floating point rounding the resulting array may not be Hermitian, the diagonal elements may not be 1, and the elements may not satisfy the inequality abs(a) <= 1. The real and imaginary parts are clipped to the interval [-1, 1] in an attempt to improve on that situation but is not much help in the complex case.

This function accepts but discards arguments *bias* and *ddof*. This is for backwards compatibility with previous versions of this function. These arguments had no effect on the return values of the function and can be safely ignored in this and previous versions of numpy.

Examples

```
>>> import numpy as np
```

In this example we generate two random arrays, `xarr` and `yarr`, and compute the row-wise and column-wise Pearson correlation coefficients, `R`. Since `rowvar` is true by default, we first find the row-wise Pearson correlation coefficients between the variables of `xarr`.

```
>>> import numpy as np
>>> rng = np.random.default_rng(seed=42)
>>> xarr = rng.random((3, 3))
>>> xarr
array([[0.77395605, 0.43887844, 0.85859792],
       [0.69736803, 0.09417735, 0.97562235],
       [0.7611397 , 0.78606431, 0.12811363]])
>>> R1 = np.corrcoef(xarr)
>>> R1
array([[ 1.        ,  0.99256089, -0.68080986],
       [ 0.99256089,  1.        , -0.76492172],
       [-0.68080986, -0.76492172,  1.        ]])
```

If we add another set of variables and observations `yarr`, we can compute the row-wise Pearson correlation coefficients between the variables in `xarr` and `yarr`.

```
>>> yarr = rng.random((3, 3))
>>> yarr
array([[0.45038594, 0.37079802, 0.92676499],
       [0.64386512, 0.82276161, 0.4434142 ],
       [0.22723872, 0.55458479, 0.06381726]])
>>> R2 = np.corrcoef(xarr, yarr)
>>> R2
array([[ 1.        ,  0.99256089, -0.68080986,  0.75008178, -0.934284  ,
        -0.99004057],
       [ 0.99256089,  1.        , -0.76492172,  0.82502011, -0.97074098,
        -0.99981569],
       [-0.68080986, -0.76492172,  1.        , -0.99507202,  0.89721355,
         0.77714685],
       [ 0.75008178,  0.82502011, -0.99507202,  1.        , -0.93657855,
        -0.83571711],
       [-0.934284  , -0.97074098,  0.89721355, -0.93657855,  1.        ,
         0.97517215],
       [-0.99004057, -0.99981569,  0.77714685, -0.83571711,  0.97517215,
         1.        ]])
```

Finally if we use the option `rowvar=False`, the columns are now being treated as the variables and we will find the column-wise Pearson correlation coefficients between variables in `xarr` and `yarr`.

```
>>> R3 = np.corrcoef(xarr, yarr, rowvar=False)
>>> R3
array([[ 1.        ,  0.77598074, -0.47458546, -0.75078643, -0.9665554 ,
         0.22423734],
       [ 0.77598074,  1.        , -0.92346708, -0.99923895, -0.58826587,
        -0.44069024],
       [-0.47458546, -0.92346708,  1.        ,  0.93773029,  0.23297648,
         0.75137473],
       [-0.75078643, -0.99923895,  0.93773029,  1.        ,  0.55627469,
         0.47536961],
       [-0.9665554 , -0.58826587,  0.23297648,  0.55627469,  1.        ,
        -0.46666491],
       [ 0.22423734, -0.44069024,  0.75137473,  0.47536961, -0.46666491,
         1.        ]])
```

numpy.**correlate**(*a*, *v*, *mode='valid'*)

Cross-correlation of two 1-dimensional sequences.

This function computes the correlation as generally defined in signal processing texts [1]:

$$c_k = \sum_n a_{n+k} \cdot \overline{v}_n$$

with a and v sequences being zero-padded where necessary and $\overline{v}$ denoting complex conjugation.

Parameters

a, v
[array_like] Input sequences.

mode
[{'valid', 'same', 'full'}, optional] Refer to the *convolve* docstring. Note that the default is 'valid', unlike *convolve*, which uses 'full'.

Returns

out
[ndarray] Discrete cross-correlation of *a* and *v*.

See also:

convolve
Discrete, linear convolution of two one-dimensional sequences.

scipy.signal.correlate
uses FFT which has superior performance on large arrays.

Notes

The definition of correlation above is not unique and sometimes correlation may be defined differently. Another common definition is [1]:

$$c'_k = \sum_n a_n \cdot \overline{v_{n+k}}$$

which is related to c_k by $c'_k = c_{-k}$.

numpy.correlate may perform slowly in large arrays (i.e. n = 1e5) because it does not use the FFT to compute the convolution; in that case, scipy.signal.correlate might be preferable.

References

[1]

Examples

```
>>> import numpy as np
>>> np.correlate([1, 2, 3], [0, 1, 0.5])
array([3.5])
>>> np.correlate([1, 2, 3], [0, 1, 0.5], "same")
array([2. ,  3.5,  3. ])
>>> np.correlate([1, 2, 3], [0, 1, 0.5], "full")
array([0.5,  2. ,  3.5,  3. ,  0. ])
```

Using complex sequences:

```
>>> np.correlate([1+1j, 2, 3-1j], [0, 1, 0.5j], 'full')
array([ 0.5-0.5j,  1.0+0.j ,  1.5-1.5j,  3.0-1.j ,  0.0+0.j ])
```

Note that you get the time reversed, complex conjugated result ($\overline{c_{-k}}$) when the two input sequences a and v change places:

```
>>> np.correlate([0, 1, 0.5j], [1+1j, 2, 3-1j], 'full')
array([ 0.0+0.j ,  3.0+1.j ,  1.5+1.5j,  1.0+0.j ,  0.5+0.5j])
```

numpy.**cov**(*m*, *y=None*, *rowvar=True*, *bias=False*, *ddof=None*, *fweights=None*, *aweights=None*, *, *dtype=None*)

Estimate a covariance matrix, given data and weights.

Covariance indicates the level to which two variables vary together. If we examine N-dimensional samples, $X = [x_1, x_2, ...x_N]^T$, then the covariance matrix element C_{ij} is the covariance of x_i and x_j. The element C_{ii} is the variance of x_i.

See the notes for an outline of the algorithm.

Parameters

m
: [array_like] A 1-D or 2-D array containing multiple variables and observations. Each row of *m* represents a variable, and each column a single observation of all those variables. Also see *rowvar* below.

y
: [array_like, optional] An additional set of variables and observations. *y* has the same form as that of *m*.

rowvar
: [bool, optional] If *rowvar* is True (default), then each row represents a variable, with observations in the columns. Otherwise, the relationship is transposed: each column represents a variable, while the rows contain observations.

bias
: [bool, optional] Default normalization (False) is by `(N - 1)`, where `N` is the number of observations given (unbiased estimate). If *bias* is True, then normalization is by `N`. These values can be overridden by using the keyword `ddof` in numpy versions >= 1.5.

ddof
: [int, optional] If not `None` the default value implied by *bias* is overridden. Note that `ddof=1`

will return the unbiased estimate, even if both *fweights* and *aweights* are specified, and `ddof=0` will return the simple average. See the notes for the details. The default value is `None`.

fweights
: [array_like, int, optional] 1-D array of integer frequency weights; the number of times each observation vector should be repeated.

aweights
: [array_like, optional] 1-D array of observation vector weights. These relative weights are typically large for observations considered "important" and smaller for observations considered less "important". If `ddof=0` the array of weights can be used to assign probabilities to observation vectors.

dtype
: [data-type, optional] Data-type of the result. By default, the return data-type will have at least *numpy.float64* precision.

  New in version 1.20.

Returns

out
: [ndarray] The covariance matrix of the variables.

See also:

corrcoef
: Normalized covariance matrix

Notes

Assume that the observations are in the columns of the observation array *m* and let `f = fweights` and `a = aweights` for brevity. The steps to compute the weighted covariance are as follows:

```
>>> m = np.arange(10, dtype=np.float64)
>>> f = np.arange(10) * 2
>>> a = np.arange(10) ** 2.
>>> ddof = 1
>>> w = f * a
>>> v1 = np.sum(w)
>>> v2 = np.sum(w * a)
>>> m -= np.sum(m * w, axis=None, keepdims=True) / v1
>>> cov = np.dot(m * w, m.T) * v1 / (v1**2 - ddof * v2)
```

Note that when `a == 1`, the normalization factor `v1 / (v1**2 - ddof * v2)` goes over to `1 / (np.sum(f) - ddof)` as it should.

Examples

```
>>> import numpy as np
```

Consider two variables, x_0 and x_1, which correlate perfectly, but in opposite directions:

```
>>> x = np.array([[0, 2], [1, 1], [2, 0]]).T
>>> x
array([[0, 1, 2],
       [2, 1, 0]])
```

Note how x_0 increases while x_1 decreases. The covariance matrix shows this clearly:

```
>>> np.cov(x)
array([[ 1., -1.],
       [-1.,  1.]])
```

Note that element $C_{0,1}$, which shows the correlation between x_0 and x_1, is negative.

Further, note how *x* and *y* are combined:

```
>>> x = [-2.1, -1,  4.3]
>>> y = [3,  1.1,  0.12]
>>> X = np.stack((x, y), axis=0)
>>> np.cov(X)
array([[11.71      , -4.286     ], # may vary
       [-4.286     ,  2.144133]])
>>> np.cov(x, y)
array([[11.71      , -4.286     ], # may vary
       [-4.286     ,  2.144133]])
>>> np.cov(x)
array(11.71)
```

Histograms

histogram(a[, bins, range, density, weights])	Compute the histogram of a dataset.
histogram2d(x, y[, bins, range, density, ...])	Compute the bi-dimensional histogram of two data samples.
histogramdd(sample[, bins, range, density, ...])	Compute the multidimensional histogram of some data.
bincount(x, /[, weights, minlength])	Count number of occurrences of each value in array of non-negative ints.
histogram_bin_edges(a[, bins, range, weights])	Function to calculate only the edges of the bins used by the *histogram* function.
digitize(x, bins[, right])	Return the indices of the bins to which each value in input array belongs.

numpy.**histogram**(*a*, *bins=10*, *range=None*, *density=None*, *weights=None*)

Compute the histogram of a dataset.

Parameters

a
[array_like] Input data. The histogram is computed over the flattened array.

bins
[int or sequence of scalars or str, optional] If *bins* is an int, it defines the number of equal-width bins in the given range (10, by default). If *bins* is a sequence, it defines a monotonically increasing array of bin edges, including the rightmost edge, allowing for non-uniform bin widths.

If *bins* is a string, it defines the method used to calculate the optimal bin width, as defined by *histogram_bin_edges*.

range
[(float, float), optional] The lower and upper range of the bins. If not provided, range is simply `(a.min(), a.max())`. Values outside the range are ignored. The first element of the range must be less than or equal to the second. *range* affects the automatic bin computation

as well. While bin width is computed to be optimal based on the actual data within *range*, the bin count will fill the entire range including portions containing no data.

weights
: [array_like, optional] An array of weights, of the same shape as *a*. Each value in *a* only contributes its associated weight towards the bin count (instead of 1). If *density* is True, the weights are normalized, so that the integral of the density over the range remains 1. Please note that the `dtype` of *weights* will also become the `dtype` of the returned accumulator (*hist*), so it must be large enough to hold accumulated values as well.

density
: [bool, optional] If `False`, the result will contain the number of samples in each bin. If `True`, the result is the value of the probability *density* function at the bin, normalized such that the *integral* over the range is 1. Note that the sum of the histogram values will not be equal to 1 unless bins of unity width are chosen; it is not a probability *mass* function.

Returns

hist
: [array] The values of the histogram. See *density* and *weights* for a description of the possible semantics. If *weights* are given, `hist.dtype` will be taken from *weights*.

bin_edges
: [array of dtype float] Return the bin edges `(length(hist)+1)`.

See also:

histogramdd*, *bincount*, *searchsorted*, *digitize*, *histogram_bin_edges

Notes

All but the last (righthand-most) bin is half-open. In other words, if *bins* is:

```
[1, 2, 3, 4]
```

then the first bin is `[1, 2)` (including 1, but excluding 2) and the second `[2, 3)`. The last bin, however, is `[3, 4]`, which *includes* 4.

Examples

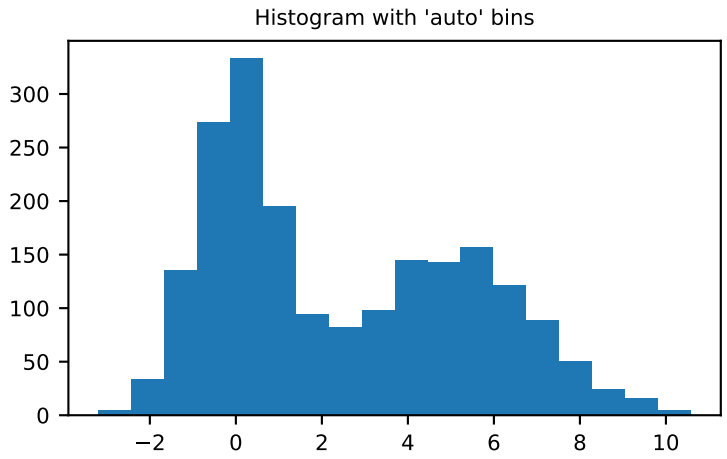
```
>>> import numpy as np
>>> np.histogram([1, 2, 1], bins=[0, 1, 2, 3])
(array([0, 2, 1]), array([0, 1, 2, 3]))
>>> np.histogram(np.arange(4), bins=np.arange(5), density=True)
(array([0.25, 0.25, 0.25, 0.25]), array([0, 1, 2, 3, 4]))
>>> np.histogram([[1, 2, 1], [1, 0, 1]], bins=[0,1,2,3])
(array([1, 4, 1]), array([0, 1, 2, 3]))
```

```
>>> a = np.arange(5)
>>> hist, bin_edges = np.histogram(a, density=True)
>>> hist
array([0.5, 0. , 0.5, 0. , 0. , 0.5, 0. , 0.5, 0. , 0.5])
>>> hist.sum()
2.4999999999999996
>>> np.sum(hist * np.diff(bin_edges))
1.0
```

Automated Bin Selection Methods example, using 2 peak random data with 2000 points.

```
import matplotlib.pyplot as plt
import numpy as np

rng = np.random.RandomState(10)  # deterministic random data
a = np.hstack((rng.normal(size=1000),
               rng.normal(loc=5, scale=2, size=1000)))
plt.hist(a, bins='auto')  # arguments are passed to np.histogram
plt.title("Histogram with 'auto' bins")
plt.show()
```



numpy.**histogram2d**(*x*, *y*, *bins=10*, *range=None*, *density=None*, *weights=None*)

Compute the bi-dimensional histogram of two data samples.

Parameters

x

[array_like, shape (N,)] An array containing the x coordinates of the points to be histogrammed.

y

[array_like, shape (N,)] An array containing the y coordinates of the points to be histogrammed.

bins

[int or array_like or [int, int] or [array, array], optional] The bin specification:

- If int, the number of bins for the two dimensions (nx=ny=bins).
- If array_like, the bin edges for the two dimensions (x_edges=y_edges=bins).
- If [int, int], the number of bins in each dimension (nx, ny = bins).
- If [array, array], the bin edges in each dimension (x_edges, y_edges = bins).
- A combination [int, array] or [array, int], where int is the number of bins and array is the bin edges.

range
: [array_like, shape(2,2), optional] The leftmost and rightmost edges of the bins along each dimension (if not specified explicitly in the *bins* parameters): `[[xmin, xmax], [ymin, ymax]]`. All values outside of this range will be considered outliers and not tallied in the histogram.

density
: [bool, optional] If False, the default, returns the number of samples in each bin. If True, returns the probability *density* function at the bin, `bin_count / sample_count / bin_area`.

weights
: [array_like, shape(N,), optional] An array of values `w_i` weighing each sample `(x_i, y_i)`. Weights are normalized to 1 if *density* is True. If *density* is False, the values of the returned histogram are equal to the sum of the weights belonging to the samples falling into each bin.

Returns

H
: [ndarray, shape(nx, ny)] The bi-dimensional histogram of samples *x* and *y*. Values in *x* are histogrammed along the first dimension and values in *y* are histogrammed along the second dimension.

xedges
: [ndarray, shape(nx+1,)] The bin edges along the first dimension.

yedges
: [ndarray, shape(ny+1,)] The bin edges along the second dimension.

See also:

histogram
: 1D histogram

histogramdd
: Multidimensional histogram

Notes

When *density* is True, then the returned histogram is the sample density, defined such that the sum over bins of the product `bin_value * bin_area` is 1.

Please note that the histogram does not follow the Cartesian convention where *x* values are on the abscissa and *y* values on the ordinate axis. Rather, *x* is histogrammed along the first dimension of the array (vertical), and *y* along the second dimension of the array (horizontal). This ensures compatibility with *histogramdd*.

Examples

```
>>> import numpy as np
>>> from matplotlib.image import NonUniformImage
>>> import matplotlib.pyplot as plt
```

Construct a 2-D histogram with variable bin width. First define the bin edges:

```
>>> xedges = [0, 1, 3, 5]
>>> yedges = [0, 2, 3, 4, 6]
```

Next we create a histogram H with random bin content:

```
>>> x = np.random.normal(2, 1, 100)
>>> y = np.random.normal(1, 1, 100)
>>> H, xedges, yedges = np.histogram2d(x, y, bins=(xedges, yedges))
>>> # Histogram does not follow Cartesian convention (see Notes),
>>> # therefore transpose H for visualization purposes.
>>> H = H.T
```

`imshow` can only display square bins:

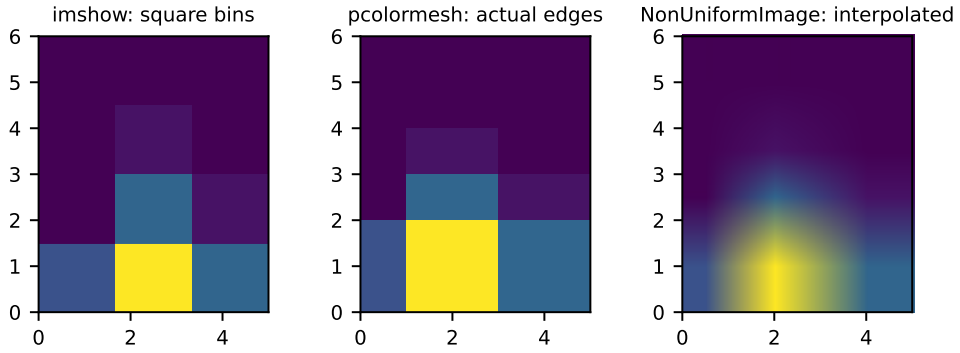
```
>>> fig = plt.figure(figsize=(7, 3))
>>> ax = fig.add_subplot(131, title='imshow: square bins')
>>> plt.imshow(H, interpolation='nearest', origin='lower',
...         extent=[xedges[0], xedges[-1], yedges[0], yedges[-1]])
<matplotlib.image.AxesImage object at 0x...>
```

`pcolormesh` can display actual edges:

```
>>> ax = fig.add_subplot(132, title='pcolormesh: actual edges',
...         aspect='equal')
>>> X, Y = np.meshgrid(xedges, yedges)
>>> ax.pcolormesh(X, Y, H)
<matplotlib.collections.QuadMesh object at 0x...>
```

`NonUniformImage` can be used to display actual bin edges with interpolation:

```
>>> ax = fig.add_subplot(133, title='NonUniformImage: interpolated',
...         aspect='equal', xlim=xedges[[0, -1]], ylim=yedges[[0, -1]])
>>> im = NonUniformImage(ax, interpolation='bilinear')
>>> xcenters = (xedges[:-1] + xedges[1:]) / 2
>>> ycenters = (yedges[:-1] + yedges[1:]) / 2
>>> im.set_data(xcenters, ycenters, H)
>>> ax.add_image(im)
>>> plt.show()
```



It is also possible to construct a 2-D histogram without specifying bin edges:

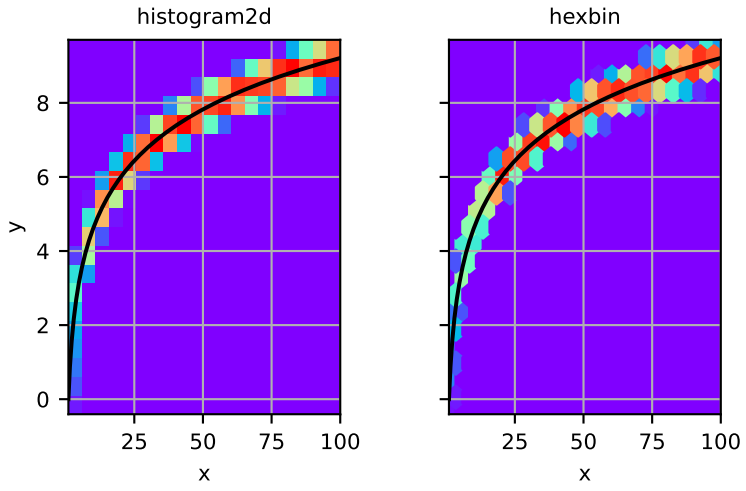
```
>>> # Generate non-symmetric test data
>>> n = 10000
>>> x = np.linspace(1, 100, n)
>>> y = 2*np.log(x) + np.random.rand(n) - 0.5
>>> # Compute 2d histogram. Note the order of x/y and xedges/yedges
>>> H, yedges, xedges = np.histogram2d(y, x, bins=20)
```

Now we can plot the histogram using `pcolormesh`, and a `hexbin` for comparison.

```
>>> # Plot histogram using pcolormesh
>>> fig, (ax1, ax2) = plt.subplots(ncols=2, sharey=True)
>>> ax1.pcolormesh(xedges, yedges, H, cmap='rainbow')
>>> ax1.plot(x, 2*np.log(x), 'k-')
>>> ax1.set_xlim(x.min(), x.max())
>>> ax1.set_ylim(y.min(), y.max())
>>> ax1.set_xlabel('x')
>>> ax1.set_ylabel('y')
>>> ax1.set_title('histogram2d')
>>> ax1.grid()
```

```
>>> # Create hexbin plot for comparison
>>> ax2.hexbin(x, y, gridsize=20, cmap='rainbow')
>>> ax2.plot(x, 2*np.log(x), 'k-')
>>> ax2.set_title('hexbin')
>>> ax2.set_xlim(x.min(), x.max())
>>> ax2.set_xlabel('x')
>>> ax2.grid()
```

```
>>> plt.show()
```



numpy.**histogramdd**(*sample*, *bins=10*, *range=None*, *density=None*, *weights=None*)

Compute the multidimensional histogram of some data.

Parameters

sample

[(N, D) array, or (N, D) array_like] The data to be histogrammed.

Note the unusual interpretation of sample when an array_like:

- When an array, each row is a coordinate in a D-dimensional space - such as `histogramdd(np.array([p1, p2, p3]))`.
- When an array_like, each element is the list of values for single coordinate - such as `histogramdd((X, Y, Z))`.

The first form should be preferred.

bins
[sequence or int, optional] The bin specification:

- A sequence of arrays describing the monotonically increasing bin edges along each dimension.
- The number of bins for each dimension (nx, ny, … =bins)
- The number of bins for all dimensions (nx=ny=…=bins).

range
[sequence, optional] A sequence of length D, each an optional (lower, upper) tuple giving the outer bin edges to be used if the edges are not given explicitly in *bins*. An entry of None in the sequence results in the minimum and maximum values being used for the corresponding dimension. The default, None, is equivalent to passing a tuple of D None values.

density
[bool, optional] If False, the default, returns the number of samples in each bin. If True, returns the probability *density* function at the bin, `bin_count / sample_count / bin_volume`.

weights
[(N,) array_like, optional] An array of values *w_i* weighing each sample *(x_i, y_i, z_i, …)*. Weights are normalized to 1 if density is True. If density is False, the values of the returned histogram are equal to the sum of the weights belonging to the samples falling into each bin.

Returns

H
[ndarray] The multidimensional histogram of sample x. See density and weights for the different possible semantics.

edges
[tuple of ndarrays] A tuple of D arrays describing the bin edges for each dimension.

See also:

histogram
1-D histogram

histogram2d
2-D histogram

Examples

```
>>> import numpy as np
>>> rng = np.random.default_rng()
>>> r = rng.normal(size=(100,3))
>>> H, edges = np.histogramdd(r, bins = (5, 8, 4))
>>> H.shape, edges[0].size, edges[1].size, edges[2].size
((5, 8, 4), 6, 9, 5)
```

numpy.**bincount**(*x*, */*, *weights=None*, *minlength=0*)

Count number of occurrences of each value in array of non-negative ints.

The number of bins (of size 1) is one larger than the largest value in *x*. If *minlength* is specified, there will be at least this number of bins in the output array (though it will be longer if necessary, depending on the contents of *x*). Each bin gives the number of occurrences of its index value in *x*. If *weights* is specified the input array is weighted by it, i.e. if a value `n` is found at position `i`, `out[n] += weight[i]` instead of `out[n] += 1`.

Parameters

x
: [array_like, 1 dimension, nonnegative ints] Input array.

weights
: [array_like, optional] Weights, array of the same shape as *x*.

minlength
: [int, optional] A minimum number of bins for the output array.

Returns

out
: [ndarray of ints] The result of binning the input array. The length of *out* is equal to `np.amax(x)+1`.

Raises

ValueError
: If the input is not 1-dimensional, or contains elements with negative values, or if *minlength* is negative.

TypeError
: If the type of the input is float or complex.

See also:

histogram, ***digitize***, ***unique***

Examples

```
>>> import numpy as np
>>> np.bincount(np.arange(5))
array([1, 1, 1, 1, 1])
>>> np.bincount(np.array([0, 1, 1, 3, 2, 1, 7]))
array([1, 3, 1, 1, 0, 0, 0, 1])
```

```
>>> x = np.array([0, 1, 1, 3, 2, 1, 7, 23])
>>> np.bincount(x).size == np.amax(x)+1
True
```

The input array needs to be of integer dtype, otherwise a TypeError is raised:

```
>>> np.bincount(np.arange(5, dtype=float))
Traceback (most recent call last):
  ...
TypeError: Cannot cast array data from dtype('float64') to dtype('int64')
according to the rule 'safe'
```

A possible use of `bincount` is to perform sums over variable-size chunks of an array, using the `weights` keyword.

```
>>> w = np.array([0.3, 0.5, 0.2, 0.7, 1., -0.6]) # weights
>>> x = np.array([0, 1, 1, 2, 2, 2])
>>> np.bincount(x,  weights=w)
array([ 0.3,  0.7,  1.1])
```

numpy.**histogram_bin_edges**(*a*, *bins=10*, *range=None*, *weights=None*)

Function to calculate only the edges of the bins used by the *histogram* function.

Parameters

a
[array_like] Input data. The histogram is computed over the flattened array.

bins
[int or sequence of scalars or str, optional] If *bins* is an int, it defines the number of equal-width bins in the given range (10, by default). If *bins* is a sequence, it defines the bin edges, including the rightmost edge, allowing for non-uniform bin widths.

If *bins* is a string from the list below, *histogram_bin_edges* will use the method chosen to calculate the optimal bin width and consequently the number of bins (see the Notes section for more detail on the estimators) from the data that falls within the requested range. While the bin width will be optimal for the actual data in the range, the number of bins will be computed to fill the entire range, including the empty portions. For visualisation, using the 'auto' option is suggested. Weighted data is not supported for automated bin size selection.

'auto'
Minimum bin width between the 'sturges' and 'fd' estimators. Provides good all-around performance.

'fd' (Freedman Diaconis Estimator)
Robust (resilient to outliers) estimator that takes into account data variability and data size.

'doane'
An improved version of Sturges' estimator that works better with non-normal datasets.

'scott'
Less robust estimator that takes into account data variability and data size.

'stone'
Estimator based on leave-one-out cross-validation estimate of the integrated squared error. Can be regarded as a generalization of Scott's rule.

'rice'
Estimator does not take variability into account, only data size. Commonly overestimates number of bins required.

'sturges'
R's default method, only accounts for data size. Only optimal for gaussian data and underestimates number of bins for large non-gaussian datasets.

'sqrt'
Square root (of data size) estimator, used by Excel and other programs for its speed and simplicity.

range
[(float, float), optional] The lower and upper range of the bins. If not provided, range is simply `(a.min(), a.max())`. Values outside the range are ignored. The first element of the range must be less than or equal to the second. *range* affects the automatic bin computation as well. While bin width is computed to be optimal based on the actual data within *range*, the bin count will fill the entire range including portions containing no data.

weights
[array_like, optional] An array of weights, of the same shape as a. Each value in a only contributes its associated weight towards the bin count (instead of 1). This is currently not used by any of the bin estimators, but may be in the future.

Returns

bin_edges
[array of dtype float] The edges to pass into *histogram*

See also:

histogram

Notes

The methods to estimate the optimal number of bins are well founded in literature, and are inspired by the choices R provides for histogram visualisation. Note that having the number of bins proportional to $n^{1/3}$ is asymptotically optimal, which is why it appears in most estimators. These are simply plug-in methods that give good starting points for number of bins. In the equations below, h is the binwidth and n_h is the number of bins. All estimators that compute bin counts are recast to bin width using the *ptp* of the data. The final bin count is obtained from `np.round(np.ceil(range / h))`. The final bin width is often less than what is returned by the estimators below.

'auto' (minimum bin width of the 'sturges' and 'fd' estimators)
A compromise to get a good value. For small datasets the Sturges value will usually be chosen, while larger datasets will usually default to FD. Avoids the overly conservative behaviour of FD and Sturges for small and large datasets respectively. Switchover point is usually $a.size \approx 1000$.

'fd' (Freedman Diaconis Estimator)

$$h = 2\frac{IQR}{n^{1/3}}$$

The binwidth is proportional to the interquartile range (IQR) and inversely proportional to cube root of a.size. Can be too conservative for small datasets, but is quite good for large datasets. The IQR is very robust to outliers.

'scott'

$$h = \sigma\sqrt[3]{\frac{24\sqrt{\pi}}{n}}$$

The binwidth is proportional to the standard deviation of the data and inversely proportional to cube root of `x.size`. Can be too conservative for small datasets, but is quite good for large datasets. The standard deviation is not very robust to outliers. Values are very similar to the Freedman-Diaconis estimator in the absence of outliers.

'rice'

$$n_h = 2n^{1/3}$$

The number of bins is only proportional to cube root of `a.size`. It tends to overestimate the number of bins and it does not take into account data variability.

'sturges'

$$n_h = \log_2(n) + 1$$

The number of bins is the base 2 log of `a.size`. This estimator assumes normality of data and is too conservative for larger, non-normal datasets. This is the default method in R's `hist` method.

'doane'

$$n_h = 1 + \log_2(n) + \log_2\left(1 + \frac{|g_1|}{\sigma_{g_1}}\right)$$

$$g_1 = mean\left[\left(\frac{x - \mu}{\sigma}\right)^3\right]$$

$$\sigma_{g_1} = \sqrt{\frac{6(n-2)}{(n+1)(n+3)}}$$

An improved version of Sturges' formula that produces better estimates for non-normal datasets. This estimator attempts to account for the skew of the data.

'sqrt'

$$n_h = \sqrt{n}$$

The simplest and fastest estimator. Only takes into account the data size.

Additionally, if the data is of integer dtype, then the binwidth will never be less than 1.

Examples

```
>>> import numpy as np
>>> arr = np.array([0, 0, 0, 1, 2, 3, 3, 4, 5])
>>> np.histogram_bin_edges(arr, bins='auto', range=(0, 1))
array([0.  , 0.25, 0.5 , 0.75, 1.  ])
>>> np.histogram_bin_edges(arr, bins=2)
array([0. , 2.5, 5. ])
```

For consistency with histogram, an array of pre-computed bins is passed through unmodified:

```
>>> np.histogram_bin_edges(arr, [1, 2])
array([1, 2])
```

This function allows one set of bins to be computed, and reused across multiple histograms:

```
>>> shared_bins = np.histogram_bin_edges(arr, bins='auto')
>>> shared_bins
array([0., 1., 2., 3., 4., 5.])
```

```
>>> group_id = np.array([0, 1, 1, 0, 1, 1, 0, 1, 1])
>>> hist_0, _ = np.histogram(arr[group_id == 0], bins=shared_bins)
>>> hist_1, _ = np.histogram(arr[group_id == 1], bins=shared_bins)
```

```
>>> hist_0; hist_1
array([1, 1, 0, 1, 0])
array([2, 0, 1, 1, 2])
```

Which gives more easily comparable results than using separate bins for each histogram:

```
>>> hist_0, bins_0 = np.histogram(arr[group_id == 0], bins='auto')
>>> hist_1, bins_1 = np.histogram(arr[group_id == 1], bins='auto')
>>> hist_0; hist_1
array([1, 1, 1])
array([2, 1, 1, 2])
>>> bins_0; bins_1
array([0., 1., 2., 3.])
array([0.  , 1.25, 2.5 , 3.75, 5.  ])
```

`numpy.`**`digitize`**(*x*, *bins*, *right=False*)

Return the indices of the bins to which each value in input array belongs.

right	order of bins	returned index *i* satisfies
`False`	increasing	`bins[i-1] <= x < bins[i]`
`True`	increasing	`bins[i-1] < x <= bins[i]`
`False`	decreasing	`bins[i-1] > x >= bins[i]`
`True`	decreasing	`bins[i-1] >= x > bins[i]`

If values in *x* are beyond the bounds of *bins*, 0 or `len(bins)` is returned as appropriate.

Parameters

x
[array_like] Input array to be binned. Prior to NumPy 1.10.0, this array had to be 1-dimensional, but can now have any shape.

bins
[array_like] Array of bins. It has to be 1-dimensional and monotonic.

right
[bool, optional] Indicating whether the intervals include the right or the left bin edge. Default behavior is (right==False) indicating that the interval does not include the right edge. The left bin end is open in this case, i.e., bins[i-1] <= x < bins[i] is the default behavior for monotonically increasing bins.

Returns

indices
[ndarray of ints] Output array of indices, of same shape as *x*.

Raises

ValueError
If *bins* is not monotonic.

TypeError
If the type of the input is complex.

See also:

bincount, *histogram*, *unique*, *searchsorted*

Notes

If values in *x* are such that they fall outside the bin range, attempting to index *bins* with the indices that *digitize* returns will result in an IndexError.

New in version 1.10.0.

numpy.digitize is implemented in terms of *numpy.searchsorted*. This means that a binary search is used to bin the values, which scales much better for larger number of bins than the previous linear search. It also removes the requirement for the input array to be 1-dimensional.

For monotonically *increasing bins*, the following are equivalent:

```
np.digitize(x, bins, right=True)
np.searchsorted(bins, x, side='left')
```

Note that as the order of the arguments are reversed, the side must be too. The *searchsorted* call is marginally faster, as it does not do any monotonicity checks. Perhaps more importantly, it supports all dtypes.

Examples

```
>>> import numpy as np
>>> x = np.array([0.2, 6.4, 3.0, 1.6])
>>> bins = np.array([0.0, 1.0, 2.5, 4.0, 10.0])
>>> inds = np.digitize(x, bins)
>>> inds
array([1, 4, 3, 2])
>>> for n in range(x.size):
...   print(bins[inds[n]-1], "<=", x[n], "<", bins[inds[n]])
...
0.0 <= 0.2 < 1.0
4.0 <= 6.4 < 10.0
2.5 <= 3.0 < 4.0
1.0 <= 1.6 < 2.5
```

```
>>> x = np.array([1.2, 10.0, 12.4, 15.5, 20.])
>>> bins = np.array([0, 5, 10, 15, 20])
>>> np.digitize(x,bins,right=True)
array([1, 2, 3, 4, 4])
>>> np.digitize(x,bins,right=False)
array([1, 3, 3, 4, 5])
```

1.4.18 Window functions

Various windows

bartlett(M)	Return the Bartlett window.
blackman(M)	Return the Blackman window.
hamming(M)	Return the Hamming window.
hanning(M)	Return the Hanning window.
kaiser(M, beta)	Return the Kaiser window.

numpy.**bartlett**(*M*)

Return the Bartlett window.

The Bartlett window is very similar to a triangular window, except that the end points are at zero. It is often used in signal processing for tapering a signal, without generating too much ripple in the frequency domain.

Parameters

M

[int] Number of points in the output window. If zero or less, an empty array is returned.

Returns

out

[array] The triangular window, with the maximum value normalized to one (the value one appears only if the number of samples is odd), with the first and last samples equal to zero.

See also:

blackman, ***hamming***, ***hanning***, ***kaiser***

Notes

The Bartlett window is defined as

$$w(n) = \frac{2}{M-1}\left(\frac{M-1}{2} - \left|n - \frac{M-1}{2}\right|\right)$$

Most references to the Bartlett window come from the signal processing literature, where it is used as one of many windowing functions for smoothing values. Note that convolution with this window produces linear interpolation. It is also known as an apodization (which means "removing the foot", i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function. The Fourier transform of the Bartlett window is the product of two sinc functions. Note the excellent discussion in Kanasewich [2].

References

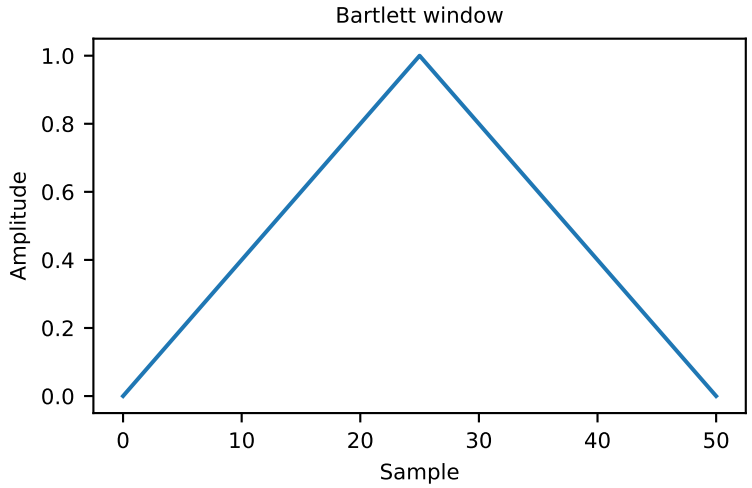
[1], [2], [3], [4], [5]

Examples

```
>>> import numpy as np
>>> import matplotlib.pyplot as plt
>>> np.bartlett(12)
array([ 0.        ,  0.18181818,  0.36363636,  0.54545455,  0.72727273, # may vary
        0.90909091,  0.90909091,  0.72727273,  0.54545455,  0.36363636,
        0.18181818,  0.        ])
```

Plot the window and its frequency response (requires SciPy and matplotlib).

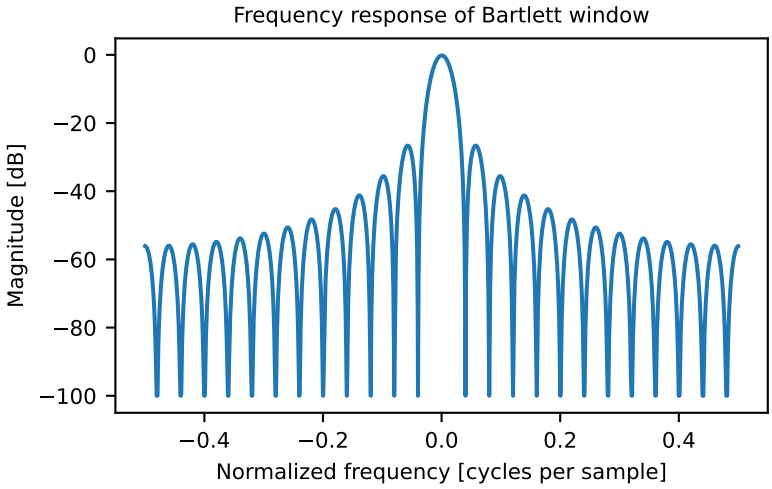
```
import matplotlib.pyplot as plt
from numpy.fft import fft, fftshift
window = np.bartlett(51)
plt.plot(window)
plt.title("Bartlett window")
plt.ylabel("Amplitude")
plt.xlabel("Sample")
plt.show()
```




```
plt.figure()
A = fft(window, 2048) / 25.5
mag = np.abs(fftshift(A))
freq = np.linspace(-0.5, 0.5, len(A))
with np.errstate(divide='ignore', invalid='ignore'):
    response = 20 * np.log10(mag)
response = np.clip(response, -100, 100)
plt.plot(freq, response)
plt.title("Frequency response of Bartlett window")
plt.ylabel("Magnitude [dB]")
plt.xlabel("Normalized frequency [cycles per sample]")
plt.axis('tight')
plt.show()
```

numpy.**blackman**(*M*)

Return the Blackman window.



The Blackman window is a taper formed by using the first three terms of a summation of cosines. It was designed to have close to the minimal leakage possible. It is close to optimal, only slightly worse than a Kaiser window.

Parameters

M
[int] Number of points in the output window. If zero or less, an empty array is returned.

Returns

out
[ndarray] The window, with the maximum value normalized to one (the value one appears only if the number of samples is odd).

See also:

bartlett, ***hamming***, ***hanning***, ***kaiser***

Notes

The Blackman window is defined as

$$w(n) = 0.42 - 0.5\cos(2\pi n/M) + 0.08\cos(4\pi n/M)$$

Most references to the Blackman window come from the signal processing literature, where it is used as one of many windowing functions for smoothing values. It is also known as an apodization (which means "removing the foot", i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function. It is known as a "near optimal" tapering function, almost as good (by some measures) as the kaiser window.

References

Blackman, R.B. and Tukey, J.W., (1958) The measurement of power spectra, Dover Publications, New York.

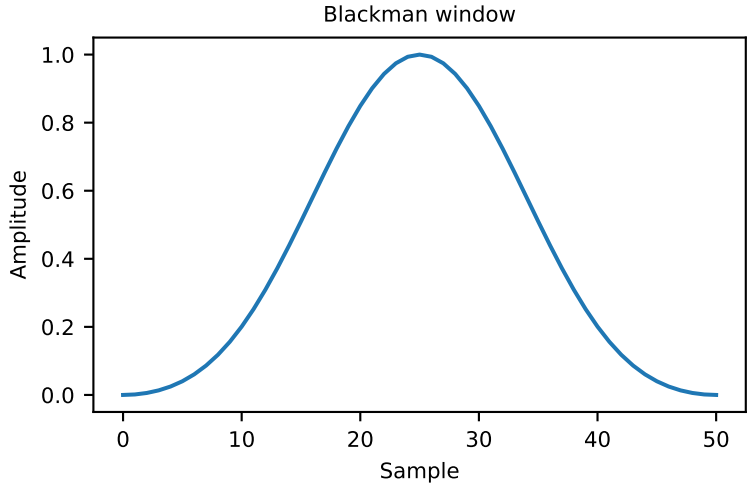
Oppenheim, A.V., and R.W. Schafer. Discrete-Time Signal Processing. Upper Saddle River, NJ: Prentice-Hall, 1999, pp. 468-471.

Examples

```
>>> import numpy as np
>>> import matplotlib.pyplot as plt
>>> np.blackman(12)
array([-1.38777878e-17,   3.26064346e-02,   1.59903635e-01, # may vary
        4.14397981e-01,   7.36045180e-01,   9.67046769e-01,
        9.67046769e-01,   7.36045180e-01,   4.14397981e-01,
        1.59903635e-01,   3.26064346e-02,  -1.38777878e-17])
```

Plot the window and the frequency response.

```
import matplotlib.pyplot as plt
from numpy.fft import fft, fftshift
window = np.blackman(51)
plt.plot(window)
plt.title("Blackman window")
plt.ylabel("Amplitude")
plt.xlabel("Sample")
plt.show()  # doctest: +SKIP
```




```
plt.figure()
A = fft(window, 2048) / 25.5
mag = np.abs(fftshift(A))
freq = np.linspace(-0.5, 0.5, len(A))
with np.errstate(divide='ignore', invalid='ignore'):
    response = 20 * np.log10(mag)
response = np.clip(response, -100, 100)
```

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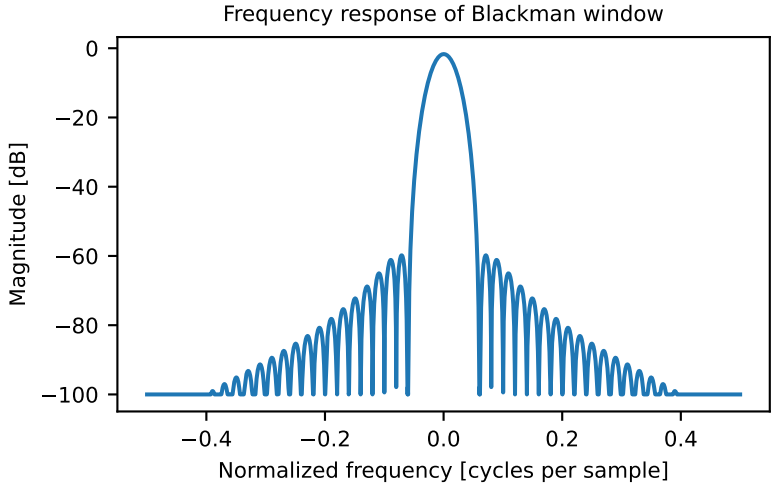
```
plt.plot(freq, response)
plt.title("Frequency response of Blackman window")
plt.ylabel("Magnitude [dB]")
plt.xlabel("Normalized frequency [cycles per sample]")
plt.axis('tight')
plt.show()
```



numpy.**hamming**(*M*)

Return the Hamming window.

The Hamming window is a taper formed by using a weighted cosine.

Parameters

M

[int] Number of points in the output window. If zero or less, an empty array is returned.

Returns

out

[ndarray] The window, with the maximum value normalized to one (the value one appears only if the number of samples is odd).

See also:

bartlett, ***blackman***, ***hanning***, ***kaiser***

Notes

The Hamming window is defined as

$$w(n) = 0.54 - 0.46\cos\left(\frac{2\pi n}{M-1}\right) \qquad 0 \leq n \leq M-1$$

The Hamming was named for R. W. Hamming, an associate of J. W. Tukey and is described in Blackman and Tukey. It was recommended for smoothing the truncated autocovariance function in the time domain. Most references to the Hamming window come from the signal processing literature, where it is used as one of many windowing functions for smoothing values. It is also known as an apodization (which means "removing the foot", i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function.

References

[1], [2], [3], [4]

Examples

```
>>> import numpy as np
>>> np.hamming(12)
array([ 0.08      ,  0.15302337,  0.34890909,  0.60546483,  0.84123594, # may vary
        0.98136677,  0.98136677,  0.84123594,  0.60546483,  0.34890909,
        0.15302337,  0.08      ])
```

Plot the window and the frequency response.

```
import matplotlib.pyplot as plt
from numpy.fft import fft, fftshift
window = np.hamming(51)
plt.plot(window)
plt.title("Hamming window")
plt.ylabel("Amplitude")
plt.xlabel("Sample")
plt.show()
```

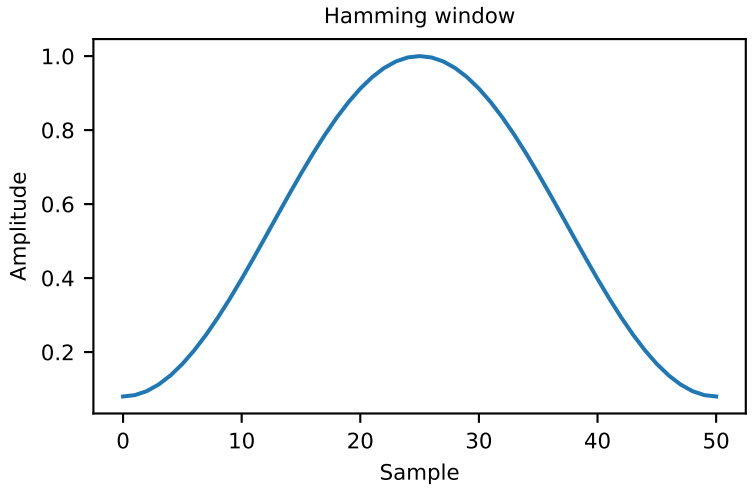
```
plt.figure()
A = fft(window, 2048) / 25.5
mag = np.abs(fftshift(A))
freq = np.linspace(-0.5, 0.5, len(A))
response = 20 * np.log10(mag)
response = np.clip(response, -100, 100)
plt.plot(freq, response)
plt.title("Frequency response of Hamming window")
plt.ylabel("Magnitude [dB]")
plt.xlabel("Normalized frequency [cycles per sample]")
plt.axis('tight')
plt.show()
```

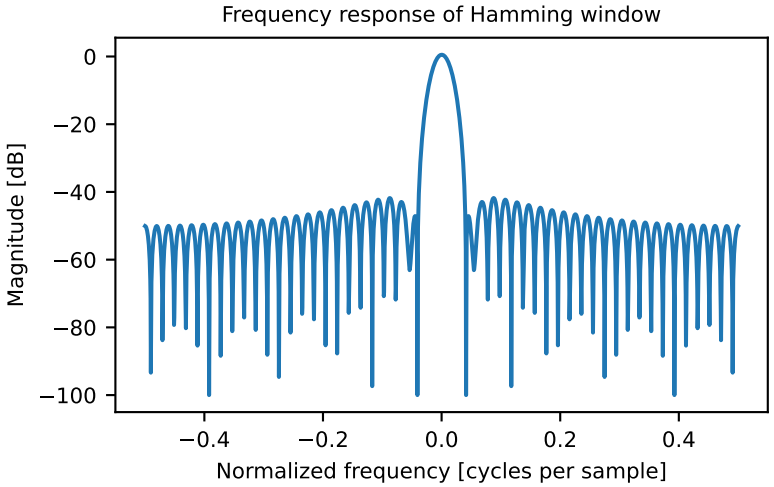
numpy.**hanning**(*M*)

Return the Hanning window.

The Hanning window is a taper formed by using a weighted cosine.

Parameters


Hamming window
Amplitude
Sample
1.0
0.8
0.6
0.4
0.2
0
10
20
30
40
50


Frequency response of Hamming window
Magnitude [dB]
Normalized frequency [cycles per sample]
0
−20
−40
−60
−80
−100
−0.4
−0.2
0.0
0.2
0.4

M
[int] Number of points in the output window. If zero or less, an empty array is returned.

Returns

out
[ndarray, shape(M,)] The window, with the maximum value normalized to one (the value one appears only if *M* is odd).

See also:

bartlett, ***blackman***, ***hamming***, ***kaiser***

Notes

The Hanning window is defined as

$$w(n) = 0.5 - 0.5\cos\left(\frac{2\pi n}{M-1}\right) \qquad 0 \leq n \leq M-1$$

The Hanning was named for Julius von Hann, an Austrian meteorologist. It is also known as the Cosine Bell. Some authors prefer that it be called a Hann window, to help avoid confusion with the very similar Hamming window.

Most references to the Hanning window come from the signal processing literature, where it is used as one of many windowing functions for smoothing values. It is also known as an apodization (which means "removing the foot", i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function.

References

[1], [2], [3], [4]

Examples

```
>>> import numpy as np
>>> np.hanning(12)
array([0.        , 0.07937323, 0.29229249, 0.57115742, 0.82743037,
       0.97974649, 0.97974649, 0.82743037, 0.57115742, 0.29229249,
       0.07937323, 0.        ])
```

Plot the window and its frequency response.

```
import matplotlib.pyplot as plt
from numpy.fft import fft, fftshift
window = np.hanning(51)
plt.plot(window)
plt.title("Hann window")
plt.ylabel("Amplitude")
plt.xlabel("Sample")
plt.show()
```

```
plt.figure()
A = fft(window, 2048) / 25.5
mag = np.abs(fftshift(A))
freq = np.linspace(-0.5, 0.5, len(A))
```

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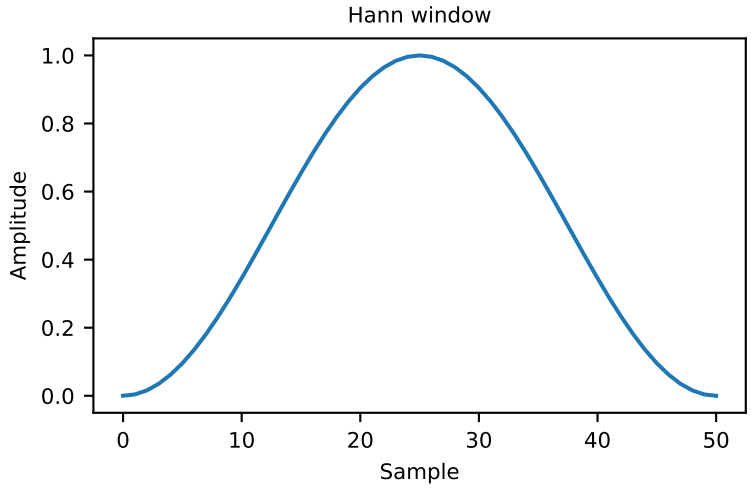

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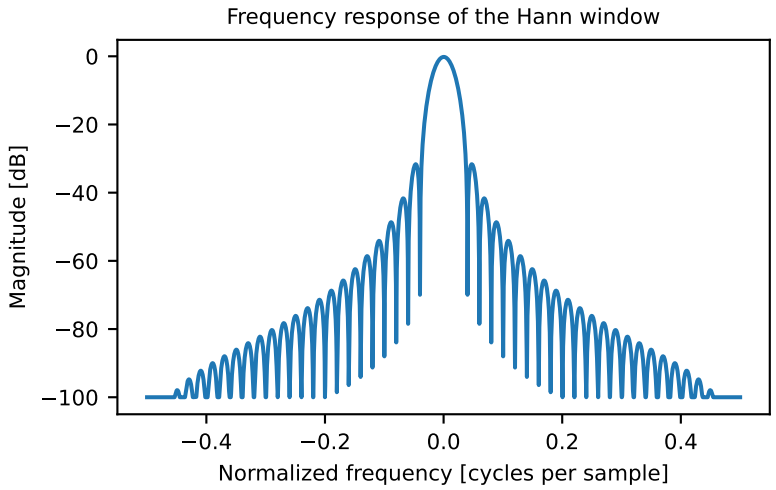
```
with np.errstate(divide='ignore', invalid='ignore'):
    response = 20 * np.log10(mag)
response = np.clip(response, -100, 100)
plt.plot(freq, response)
plt.title("Frequency response of the Hann window")
plt.ylabel("Magnitude [dB]")
plt.xlabel("Normalized frequency [cycles per sample]")
plt.axis('tight')
plt.show()
```



numpy.**kaiser**(*M*, *beta*)

Return the Kaiser window.

The Kaiser window is a taper formed by using a Bessel function.

Parameters

M
[int] Number of points in the output window. If zero or less, an empty array is returned.

beta
[float] Shape parameter for window.

Returns

out
[array] The window, with the maximum value normalized to one (the value one appears only if the number of samples is odd).

See also:

`bartlett`, `blackman`, `hamming`, `hanning`

Notes

The Kaiser window is defined as

$$w(n) = I_0\left(\beta\sqrt{1-\frac{4n^2}{(M-1)^2}}\right)/I_0(\beta)$$

with

$$-\frac{M-1}{2} \leq n \leq \frac{M-1}{2},$$

where I_0 is the modified zeroth-order Bessel function.

The Kaiser was named for Jim Kaiser, who discovered a simple approximation to the DPSS window based on Bessel functions. The Kaiser window is a very good approximation to the Digital Prolate Spheroidal Sequence, or Slepian window, which is the transform which maximizes the energy in the main lobe of the window relative to total energy.

The Kaiser can approximate many other windows by varying the beta parameter.

beta	Window shape
0	Rectangular
5	Similar to a Hamming
6	Similar to a Hanning
8.6	Similar to a Blackman

A beta value of 14 is probably a good starting point. Note that as beta gets large, the window narrows, and so the number of samples needs to be large enough to sample the increasingly narrow spike, otherwise NaNs will get returned.

Most references to the Kaiser window come from the signal processing literature, where it is used as one of many windowing functions for smoothing values. It is also known as an apodization (which means "removing the foot", i.e. smoothing discontinuities at the beginning and end of the sampled signal) or tapering function.

References

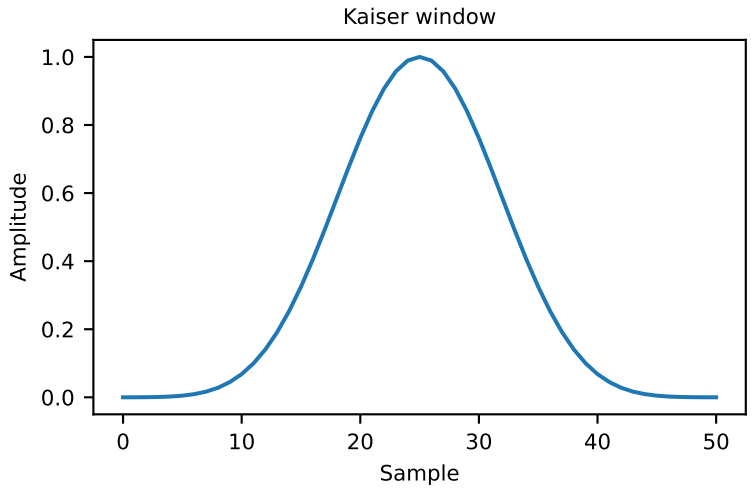
[1], [2], [3]

Examples

```
>>> import numpy as np
>>> import matplotlib.pyplot as plt
>>> np.kaiser(12, 14)
 array([7.72686684e-06, 3.46009194e-03, 4.65200189e-02, # may vary
        2.29737120e-01, 5.99885316e-01, 9.45674898e-01,
        9.45674898e-01, 5.99885316e-01, 2.29737120e-01,
        4.65200189e-02, 3.46009194e-03, 7.72686684e-06])
```

Plot the window and the frequency response.

```
import matplotlib.pyplot as plt
from numpy.fft import fft, fftshift
window = np.kaiser(51, 14)
plt.plot(window)
plt.title("Kaiser window")
plt.ylabel("Amplitude")
plt.xlabel("Sample")
plt.show()
```




```
plt.figure()
A = fft(window, 2048) / 25.5
mag = np.abs(fftshift(A))
freq = np.linspace(-0.5, 0.5, len(A))
response = 20 * np.log10(mag)
response = np.clip(response, -100, 100)
plt.plot(freq, response)
plt.title("Frequency response of Kaiser window")
plt.ylabel("Magnitude [dB]")
plt.xlabel("Normalized frequency [cycles per sample]")
```

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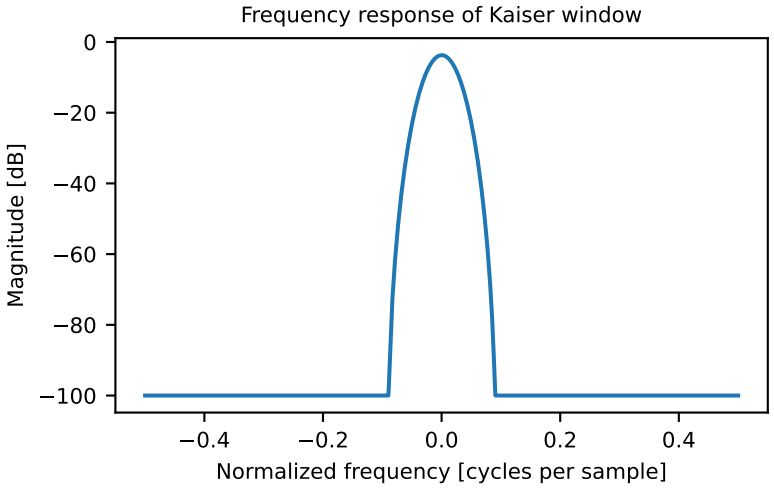
```
plt.axis('tight')
plt.show()
```



CHAPTER

TWO

C API

2.1 NumPy C-API

Beware of the man who won't be bothered with details.
— *William Feather, Sr.*

The truth is out there.
— *Chris Carter, The X Files*

NumPy provides a C-API to enable users to extend the system and get access to the array object for use in other routines. The best way to truly understand the C-API is to read the source code. If you are unfamiliar with (C) source code, however, this can be a daunting experience at first. Be assured that the task becomes easier with practice, and you may be surprised at how simple the C-code can be to understand. Even if you don't think you can write C-code from scratch, it is much easier to understand and modify already-written source code than create it *de novo*.

Python extensions are especially straightforward to understand because they all have a very similar structure. Admittedly, NumPy is not a trivial extension to Python, and may take a little more snooping to grasp. This is especially true because of the code-generation techniques, which simplify maintenance of very similar code, but can make the code a little less readable to beginners. Still, with a little persistence, the code can be opened to your understanding. It is my hope, that this guide to the C-API can assist in the process of becoming familiar with the compiled-level work that can be done with NumPy in order to squeeze that last bit of necessary speed out of your code.

2.1.1 Python types and C-structures

Several new types are defined in the C-code. Most of these are accessible from Python, but a few are not exposed due to their limited use. Every new Python type has an associated `PyObject*` with an internal structure that includes a pointer to a "method table" that defines how the new object behaves in Python. When you receive a Python object into C code, you always get a pointer to a `PyObject` structure. Because a `PyObject` structure is very generic and defines only `PyObject_HEAD`, by itself it is not very interesting. However, different objects contain more details after the `PyObject_HEAD` (but you have to cast to the correct type to access them — or use accessor functions or macros).

New Python types defined

Python types are the functional equivalent in C of classes in Python. By constructing a new Python type you make available a new object for Python. The ndarray object is an example of a new type defined in C. New types are defined in C by two basic steps:

1. creating a C-structure (usually named `Py{Name}Object`) that is binary- compatible with the `PyObject` structure itself but holds the additional information needed for that particular object;
2. populating the `PyTypeObject` table (pointed to by the ob_type member of the `PyObject` structure) with pointers to functions that implement the desired behavior for the type.

Instead of special method names which define behavior for Python classes, there are "function tables" which point to functions that implement the desired results. Since Python 2.2, the PyTypeObject itself has become dynamic which allows C types that can be "sub-typed "from other C-types in C, and sub-classed in Python. The children types inherit the attributes and methods from their parent(s).

There are two major new types: the ndarray (*PyArray_Type*) and the ufunc (*PyUFunc_Type*). Additional types play a supportive role: the *PyArrayIter_Type*, the *PyArrayMultiIter_Type*, and the *PyArrayDescr_Type* . The *PyArrayIter_Type* is the type for a flat iterator for an ndarray (the object that is returned when getting the flat attribute). The *PyArrayMultiIter_Type* is the type of the object returned when calling `broadcast`. It handles iteration and broadcasting over a collection of nested sequences. Also, the *PyArrayDescr_Type* is the data-type-descriptor type whose instances describe the data and *PyArray_DTypeMeta* is the metaclass for data-type descriptors. There are also new scalar-array types which are new Python scalars corresponding to each of the fundamental data types available for arrays. Additional types are placeholders that allow the array scalars to fit into a hierarchy of actual Python types. Finally, the *PyArray_DTypeMeta* instances corresponding to the NumPy built-in data types are also publicly visible.

PyArray_Type and PyArrayObject

PyTypeObject **PyArray_Type**

The Python type of the ndarray is *PyArray_Type*. In C, every ndarray is a pointer to a *PyArrayObject* structure. The ob_type member of this structure contains a pointer to the *PyArray_Type* typeobject.

type **PyArrayObject**

type **NPY_AO**

The *PyArrayObject* C-structure contains all of the required information for an array. All instances of an ndarray (and its subclasses) will have this structure. For future compatibility, these structure members should normally be accessed using the provided macros. If you need a shorter name, then you can make use of *NPY_AO* (deprecated) which is defined to be equivalent to *PyArrayObject*. Direct access to the struct fields are deprecated. Use the `PyArray_*(arr)` form instead. As of NumPy 1.20, the size of this struct is not considered part of the NumPy ABI (see note at the end of the member list).

```
typedef struct PyArrayObject {
    PyObject_HEAD
    char *data;
    int nd;
    npy_intp *dimensions;
    npy_intp *strides;
    PyObject *base;
    PyArray_Descr *descr;
    int flags;
    PyObject *weakreflist;
    /* version dependent private members */
} PyArrayObject;
```

PyObject_HEAD

This is needed by all Python objects. It consists of (at least) a reference count member (`ob_refcnt`) and a pointer to the typeobject (`ob_type`). (Other elements may also be present if Python was compiled with special options see Include/object.h in the Python source tree for more information). The ob_type member points to a Python type object.

char ***data**

Accessible via *PyArray_DATA*, this data member is a pointer to the first element of the array. This pointer can (and normally should) be recast to the data type of the array.

int **nd**

An integer providing the number of dimensions for this array. When nd is 0, the array is sometimes called a rank-0 array. Such arrays have undefined dimensions and strides and cannot be accessed. Macro *PyArray_NDIM* defined in `ndarraytypes.h` points to this data member. `NPY_MAXDIMS` is defined as a compile time constant limiting the number of dimensions. This number is 64 since NumPy 2 and was 32 before. However, we may wish to remove this limitations in the future so that it is best to explicitly check dimensionality for code that relies on such an upper bound.

npy_intp ***dimensions**

An array of integers providing the shape in each dimension as long as nd $\geq$ 1. The integer is always large enough to hold a pointer on the platform, so the dimension size is only limited by memory. *PyArray_DIMS* is the macro associated with this data member.

npy_intp ***strides**

An array of integers providing for each dimension the number of bytes that must be skipped to get to the next element in that dimension. Associated with macro *PyArray_STRIDES*.

PyObject ***base**

Pointed to by *PyArray_BASE*, this member is used to hold a pointer to another Python object that is related to this array. There are two use cases:

- If this array does not own its own memory, then base points to the Python object that owns it (perhaps another array object)
- If this array has the *NPY_ARRAY_WRITEBACKIFCOPY* flag set, then this array is a working copy of a "misbehaved" array.

When `PyArray_ResolveWritebackIfCopy` is called, the array pointed to by base will be updated with the contents of this array.

PyArray_Descr ***descr**

A pointer to a data-type descriptor object (see below). The data-type descriptor object is an instance of a new built-in type which allows a generic description of memory. There is a descriptor structure for each data type supported. This descriptor structure contains useful information about the type as well as a pointer to a table of function pointers to implement specific functionality. As the name suggests, it is associated with the macro *PyArray_DESCR*.

int **flags**

Pointed to by the macro *PyArray_FLAGS*, this data member represents the flags indicating how the memory pointed to by data is to be interpreted. Possible flags are *NPY_ARRAY_C_CONTIGUOUS*, *NPY_ARRAY_F_CONTIGUOUS*, *NPY_ARRAY_OWNDATA*, *NPY_ARRAY_ALIGNED*, *NPY_ARRAY_WRITEABLE*, *NPY_ARRAY_WRITEBACKIFCOPY*.

PyObject ***weakreflist**

This member allows array objects to have weak references (using the weakref module).

Note: Further members are considered private and version dependent. If the size of the struct is important for your code, special care must be taken. A possible use-case when this is relevant is subclassing in C. If your code relies on `sizeof(PyArrayObject)` to be constant, you must add the following check at import time:

```
if (sizeof(PyArrayObject) < PyArray_Type.tp_basicsize) {
    PyErr_SetString(PyExc_ImportError,
       "Binary incompatibility with NumPy, must recompile/update X.");
    return NULL;
}
```

To ensure that your code does not have to be compiled for a specific NumPy version, you may add a constant, leaving room for changes in NumPy. A solution guaranteed to be compatible with any future NumPy version requires the use of a runtime calculate offset and allocation size.

The *PyArray_Type* typeobject implements many of the features of `Python objects` including the `tp_as_number`, `tp_as_sequence`, `tp_as_mapping`, and `tp_as_buffer` interfaces. The `rich comparison`) is also used along with new-style attribute lookup for member (`tp_members`) and properties (`tp_getset`). The *PyArray_Type* can also be sub-typed.

Tip: The `tp_as_number` methods use a generic approach to call whatever function has been registered for handling the operation. When the `_multiarray_umath` module is imported, it sets the numeric operations for all arrays to the corresponding ufuncs. This choice can be changed with *PyUFunc_ReplaceLoopBySignature*.

PyGenericArrType_Type

PyTypeObject **PyGenericArrType_Type**

The *PyGenericArrType_Type* is the PyTypeObject definition which create the *numpy.generic* python type.

PyArrayDescr_Type and PyArray_Descr

PyTypeObject **PyArrayDescr_Type**

The *PyArrayDescr_Type* is the built-in type of the data-type-descriptor objects used to describe how the bytes comprising the array are to be interpreted. There are 21 statically-defined *PyArray_Descr* objects for the built-in data-types. While these participate in reference counting, their reference count should never reach zero. There is also a dynamic table of user-defined *PyArray_Descr* objects that is also maintained. Once a data-type-descriptor object is "registered" it should never be deallocated either. The function *PyArray_DescrFromType*(…) can be used to retrieve a *PyArray_Descr* object from an enumerated type-number (either built-in or user-defined).

type **PyArray_DescrProto**

Identical structure to *PyArray_Descr*. This struct is used for static definition of a prototype for registering a new legacy DType by *PyArray_RegisterDataType*.

See the note in *PyArray_RegisterDataType* for details.

type **PyArray_Descr**

The *PyArray_Descr* structure lies at the heart of the *PyArrayDescr_Type*. While it is described here for completeness, it should be considered internal to NumPy and manipulated via `PyArrayDescr_*` or `PyDataType*` functions and macros. The size of this structure is subject to change across versions of NumPy. To ensure compatibility:

- Never declare a non-pointer instance of the struct

- Never perform pointer arithmetic
- Never use `sizeof(PyArray_Descr)`

It has the following structure:

```
typedef struct {
    PyObject_HEAD
    PyTypeObject *typeobj;
    char kind;
    char type;
    char byteorder;
    char _former_flags;  // unused field
    int type_num;
    /*
     * Definitions after this one must be accessed through accessor
     * functions (see below) when compiling with NumPy 1.x support.
     */
    npy_uint64 flags;
    npy_intp elsize;
    npy_intp alignment;
    NpyAuxData *c_metadata;
    npy_hash_t hash;
    void *reserved_null[2];  // unused field, must be NULLed.
} PyArray_Descr;
```

Some dtypes have additional members which are accessible through *PyDataType_NAMES*, *PyDataType_FIELDS*, *PyDataType_SUBARRAY*, and in some cases (times) *PyDataType_C_METADATA*.

PyTypeObject ***typeobj**

Pointer to a typeobject that is the corresponding Python type for the elements of this array. For the builtin types, this points to the corresponding array scalar. For user-defined types, this should point to a user-defined typeobject. This typeobject can either inherit from array scalars or not. If it does not inherit from array scalars, then the *NPY_USE_GETITEM* and *NPY_USE_SETITEM* flags should be set in the `flags` member.

char **kind**

A character code indicating the kind of array (using the array interface typestring notation). A 'b' represents Boolean, a 'i' represents signed integer, a 'u' represents unsigned integer, 'f' represents floating point, 'c' represents complex floating point, 'S' represents 8-bit zero-terminated bytes, 'U' represents 32-bit/character unicode string, and 'V' represents arbitrary.

char **type**

A traditional character code indicating the data type.

char **byteorder**

A character indicating the byte-order: '>' (big-endian), '<' (little- endian), '=' (native), '|' (irrelevant, ignore). All builtin data- types have byteorder '='.

npy_uint64 **flags**

A data-type bit-flag that determines if the data-type exhibits object- array like behavior. Each bit in this member is a flag which are named as:

- *NPY_ITEM_REFCOUNT*
- *NPY_ITEM_HASOBJECT*
- *NPY_LIST_PICKLE*
- *NPY_ITEM_IS_POINTER*
- *NPY_NEEDS_INIT*

- *NPY_NEEDS_PYAPI*
- *NPY_USE_GETITEM*
- *NPY_USE_SETITEM*
- *NPY_FROM_FIELDS*
- *NPY_OBJECT_DTYPE_FLAGS*

int **type_num**

A number that uniquely identifies the data type. For new data-types, this number is assigned when the data-type is registered.

npy_intp **elsize**

For data types that are always the same size (such as long), this holds the size of the data type. For flexible data types where different arrays can have a different elementsize, this should be 0.

See *PyDataType_ELSIZE* and *PyDataType_SET_ELSIZE* for a way to access this field in a NumPy 1.x compatible way.

npy_intp **alignment**

A number providing alignment information for this data type. Specifically, it shows how far from the start of a 2-element structure (whose first element is a `char`), the compiler places an item of this type: `offsetof(struct {char c; type v;}, v)`

See *PyDataType_ALIGNMENT* for a way to access this field in a NumPy 1.x compatible way.

PyObject ***metadata**

Metadata about this dtype.

NpyAuxData ***c_metadata**

Metadata specific to the C implementation of the particular dtype. Added for NumPy 1.7.0.

type **npy_hash_t**

npy_hash_t ***hash**

Used for caching hash values.

NPY_ITEM_REFCOUNT

Indicates that items of this data-type must be reference counted (using `Py_INCREF` and `Py_DECREF`).

NPY_ITEM_HASOBJECT

Same as *NPY_ITEM_REFCOUNT*.

NPY_LIST_PICKLE

Indicates arrays of this data-type must be converted to a list before pickling.

NPY_ITEM_IS_POINTER

Indicates the item is a pointer to some other data-type

NPY_NEEDS_INIT

Indicates memory for this data-type must be initialized (set to 0) on creation.

NPY_NEEDS_PYAPI

Indicates this data-type requires the Python C-API during access (so don't give up the GIL if array access is going to be needed).

NPY_USE_GETITEM

On array access use the `f->getitem` function pointer instead of the standard conversion to an array scalar. Must use if you don't define an array scalar to go along with the data-type.

NPY_USE_SETITEM

When creating a 0-d array from an array scalar use `f->setitem` instead of the standard copy from an array scalar. Must use if you don't define an array scalar to go along with the data-type.

NPY_FROM_FIELDS

The bits that are inherited for the parent data-type if these bits are set in any field of the data-type. Currently (*NPY_NEEDS_INIT* | *NPY_LIST_PICKLE* | *NPY_ITEM_REFCOUNT* | *NPY_NEEDS_PYAPI*).

NPY_OBJECT_DTYPE_FLAGS

Bits set for the object data-type: (*NPY_LIST_PICKLE* | *NPY_USE_GETITEM* | *NPY_ITEM_IS_POINTER* | *NPY_ITEM_REFCOUNT* | *NPY_NEEDS_INIT* | *NPY_NEEDS_PYAPI*).

int **PyDataType_FLAGCHK**(*PyArray_Descr* *dtype, int flags)

Return true if all the given flags are set for the data-type object.

int **PyDataType_REFCHK**(*PyArray_Descr* *dtype)

Equivalent to *PyDataType_FLAGCHK* (*dtype*, *NPY_ITEM_REFCOUNT*).

PyArray_ArrFuncs

PyArray_ArrFuncs ***PyDataType_GetArrFuncs**(*PyArray_Descr* *dtype)

Fetch the legacy *PyArray_ArrFuncs* of the datatype (cannot fail).

New in version NumPy: 2.0 This function was added in a backwards compatible and backportable way in NumPy 2.0 (see `npy_2_compat.h`). Any code that previously accessed the `->f` slot of the `PyArray_Descr`, must now use this function and backport it to compile with 1.x. (The `npy_2_compat.h` header can be vendored for this purpose.)

type **PyArray_ArrFuncs**

Functions implementing internal features. Not all of these function pointers must be defined for a given type. The required members are `nonzero`, `copyswap`, `copyswapn`, `setitem`, `getitem`, and `cast`. These are assumed to be non- `NULL` and `NULL` entries will cause a program crash. The other functions may be `NULL` which will just mean reduced functionality for that data-type. (Also, the nonzero function will be filled in with a default function if it is `NULL` when you register a user-defined data-type).

```
typedef struct {
    PyArray_VectorUnaryFunc *cast[NPY_NTYPES_LEGACY];
    PyArray_GetItemFunc *getitem;
    PyArray_SetItemFunc *setitem;
    PyArray_CopySwapNFunc *copyswapn;
    PyArray_CopySwapFunc *copyswap;
    PyArray_CompareFunc *compare;
    PyArray_ArgFunc *argmax;
    PyArray_DotFunc *dotfunc;
    PyArray_ScanFunc *scanfunc;
    PyArray_FromStrFunc *fromstr;
    PyArray_NonzeroFunc *nonzero;
    PyArray_FillFunc *fill;
    PyArray_FillWithScalarFunc *fillwithscalar;
    PyArray_SortFunc *sort[NPY_NSORTS];
    PyArray_ArgSortFunc *argsort[NPY_NSORTS];
    PyObject *castdict;
    PyArray_ScalarKindFunc *scalarkind;
```

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```
    int **cancastscalarkindto;
    int *cancastto;
    void *_unused1;
    void *_unused2;
    void *_unused3;
    PyArray_ArgFunc *argmin;
} PyArray_ArrFuncs;
```

The concept of a behaved segment is used in the description of the function pointers. A behaved segment is one that is aligned and in native machine byte-order for the data-type. The `nonzero`, `copyswap`, `copyswapn`, `getitem`, and `setitem` functions can (and must) deal with mis-behaved arrays. The other functions require behaved memory segments.

Note: The functions are largely legacy API, however, some are still used. As of NumPy 2.x they are only available via *PyDataType_GetArrFuncs* (see the function for more details). Before using any function defined in the struct you should check whether it is `NULL`. In general, the functions `getitem`, `setitem`, `copyswap`, and `copyswapn` can be expected to be defined, but all functions are expected to be replaced with newer API. For example, `PyArray_Pack` is a more powerful version of `setitem` that for example correctly deals with casts.

---

void **cast**(void *from, void *to, *npy_intp* n, void *fromarr, void *toarr)

An array of function pointers to cast from the current type to all of the other builtin types. Each function casts a contiguous, aligned, and notswapped buffer pointed at by *from* to a contiguous, aligned, and notswapped buffer pointed at by *to* The number of items to cast is given by *n*, and the arguments *fromarr* and *toarr* are interpreted as PyArrayObjects for flexible arrays to get itemsize information.

PyObject ***getitem**(void *data, void *arr)

A pointer to a function that returns a standard Python object from a single element of the array object *arr* pointed to by *data*. This function must be able to deal with "misbehaved "(misaligned and/or swapped) arrays correctly.

int **setitem**(PyObject *item, void *data, void *arr)

A pointer to a function that sets the Python object *item* into the array, *arr*, at the position pointed to by *data* . This function deals with "misbehaved" arrays. If successful, a zero is returned, otherwise, a negative one is returned (and a Python error set).

void **copyswapn**(void *dest, *npy_intp* dstride, void *src, *npy_intp* sstride, *npy_intp* n, int swap, void *arr)

void **copyswap**(void *dest, void *src, int swap, void *arr)

These members are both pointers to functions to copy data from *src* to *dest* and *swap* if indicated. The value of arr is only used for flexible (*NPY_STRING*, *NPY_UNICODE*, and *NPY_VOID*) arrays (and is obtained from `arr->descr->elsize`). The second function copies a single value, while the first loops over n values with the provided strides. These functions can deal with misbehaved *src* data. If *src* is NULL then no copy is performed. If *swap* is 0, then no byteswapping occurs. It is assumed that *dest* and *src* do not overlap. If they overlap, then use `memmove` (...) first followed by `copyswap(n)` with NULL valued `src`.

int **compare**(const void *d1, const void *d2, void *arr)

A pointer to a function that compares two elements of the array, `arr`, pointed to by `d1` and `d2`. This function requires behaved (aligned and not swapped) arrays. The return value is 1 if * `d1` > * `d2`, 0 if * `d1` == * `d2`, and -1 if * `d1` < * `d2`. The array object `arr` is used to retrieve itemsize and field information for flexible arrays.

int **argmax**(void *data, *npy_intp* n, *npy_intp* *max_ind, void *arr)

A pointer to a function that retrieves the index of the largest of `n` elements in `arr` beginning at the element

pointed to by `data`. This function requires that the memory segment be contiguous and behaved. The return value is always 0. The index of the largest element is returned in `max_ind`.

void **dotfunc**(void *ip1, *npy_intp* is1, void *ip2, *npy_intp* is2, void *op, *npy_intp* n, void *arr)

A pointer to a function that multiplies two `n` -length sequences together, adds them, and places the result in element pointed to by `op` of `arr`. The start of the two sequences are pointed to by `ip1` and `ip2`. To get to the next element in each sequence requires a jump of `is1` and `is2` *bytes*, respectively. This function requires behaved (though not necessarily contiguous) memory.

int **scanfunc**(FILE *fd, void *ip, void *arr)

A pointer to a function that scans (scanf style) one element of the corresponding type from the file descriptor `fd` into the array memory pointed to by `ip`. The array is assumed to be behaved. The last argument `arr` is the array to be scanned into. Returns number of receiving arguments successfully assigned (which may be zero in case a matching failure occurred before the first receiving argument was assigned), or EOF if input failure occurs before the first receiving argument was assigned. This function should be called without holding the Python GIL, and has to grab it for error reporting.

int **fromstr**(char *str, void *ip, char **endptr, void *arr)

A pointer to a function that converts the string pointed to by `str` to one element of the corresponding type and places it in the memory location pointed to by `ip`. After the conversion is completed, `*endptr` points to the rest of the string. The last argument `arr` is the array into which ip points (needed for variable-size data- types). Returns 0 on success or -1 on failure. Requires a behaved array. This function should be called without holding the Python GIL, and has to grab it for error reporting.

npy_bool **nonzero**(void *data, void *arr)

A pointer to a function that returns TRUE if the item of `arr` pointed to by `data` is nonzero. This function can deal with misbehaved arrays.

void **fill**(void *data, *npy_intp* length, void *arr)

A pointer to a function that fills a contiguous array of given length with data. The first two elements of the array must already be filled- in. From these two values, a delta will be computed and the values from item 3 to the end will be computed by repeatedly adding this computed delta. The data buffer must be well-behaved.

void **fillwithscalar**(void *buffer, *npy_intp* length, void *value, void *arr)

A pointer to a function that fills a contiguous `buffer` of the given `length` with a single scalar `value` whose address is given. The final argument is the array which is needed to get the itemsize for variable-length arrays.

int **sort**(void *start, *npy_intp* length, void *arr)

An array of function pointers to a particular sorting algorithms. A particular sorting algorithm is obtained using a key (so far *NPY_QUICKSORT*, *NPY_HEAPSORT*, and *NPY_MERGESORT* are defined). These sorts are done in-place assuming contiguous and aligned data.

int **argsort**(void *start, *npy_intp* *result, *npy_intp* length, void *arr)

An array of function pointers to sorting algorithms for this data type. The same sorting algorithms as for sort are available. The indices producing the sort are returned in `result` (which must be initialized with indices 0 to `length-1` inclusive).

PyObject ***castdict**

Either `NULL` or a dictionary containing low-level casting functions for user- defined data-types. Each function is wrapped in a `PyCapsule*` and keyed by the data-type number.

NPY_SCALARKIND **scalarkind**(*PyArrayObject* *arr)

A function to determine how scalars of this type should be interpreted. The argument is `NULL` or a 0-dimensional array containing the data (if that is needed to determine the kind of scalar). The return value must be of type *NPY_SCALARKIND*.

int ****cancastscalarkindto**

Either `NULL` or an array of *`NPY_NSCALARKINDS`* pointers. These pointers should each be either `NULL` or a pointer to an array of integers (terminated by *`NPY_NOTYPE`*) indicating data-types that a scalar of this data-type of the specified kind can be cast to safely (this usually means without losing precision).

int ***cancastto**

Either `NULL` or an array of integers (terminated by *`NPY_NOTYPE`*) indicated data-types that this data-type can be cast to safely (this usually means without losing precision).

int **argmin**(void *data, *npy_intp* n, *npy_intp* *min_ind, void *arr)

A pointer to a function that retrieves the index of the smallest of `n` elements in `arr` beginning at the element pointed to by `data`. This function requires that the memory segment be contiguous and behaved. The return value is always 0. The index of the smallest element is returned in `min_ind`.

PyArrayMethod_Context and PyArrayMethod_Spec

type **PyArrayMethodObject_tag**

An opaque struct used to represent the method "self" in ArrayMethod loops.

type **PyArrayMethod_Context**

A struct that is passed in to ArrayMethod loops to provide context for the runtime usage of the loop.

```
typedef struct {
    PyObject *caller;
    struct PyArrayMethodObject_tag *method;
    PyArray_Descr *const *descriptors;
} PyArrayMethod_Context
```

PyObject ***caller**

The caller, which is typically the ufunc that called the loop. May be `NULL` when a call is not from a ufunc (e.g. casts).

struct *PyArrayMethodObject_tag* ***method**

The method "self". Currently this object is an opaque pointer.

PyArray_Descr ****descriptors**

An array of descriptors for the ufunc loop, filled in by `resolve_descriptors`. The length of the array is `nin` + `nout`.

type **PyArrayMethod_Spec**

A struct used to register an ArrayMethod with NumPy. We use the slots mechanism used by the Python limited API. See below for the slot definitions.

```
typedef struct {
   const char *name;
   int nin, nout;
   NPY_CASTING casting;
   NPY_ARRAYMETHOD_FLAGS flags;
   PyArray_DTypeMeta **dtypes;
   PyType_Slot *slots;
} PyArrayMethod_Spec;
```

const char ***name**

The name of the loop.

int **nin**

The number of input operands

int **nout**

The number of output operands.

NPY_CASTING **casting**

Used to indicate how minimally permissive a casting operation should be. For example, if a cast operation might in some circumstances be safe, but in others unsafe, then `NPY_UNSAFE_CASTING` should be set. Not used for ufunc loops but must still be set.

NPY_ARRAYMETHOD_FLAGS **flags**

The flags set for the method.

PyArray_DTypeMeta ****dtypes**

The DTypes for the loop. Must be `nin` + `nout` in length.

PyType_Slot ***slots**

An array of slots for the method. Slot IDs must be one of the values below.

PyArray_DTypeMeta and PyArrayDTypeMeta_Spec

PyTypeObject **PyArrayDTypeMeta_Type**

The python type object corresponding to *PyArray_DTypeMeta*.

type **PyArray_DTypeMeta**

A largely opaque struct representing DType classes. Each instance defines a metaclass for a single NumPy data type. Data types can either be non-parametric or parametric. For non-parametric types, the DType class has a one-to-one correspondence with the descriptor instance created from the DType class. Parametric types can correspond to many different dtype instances depending on the chosen parameters. This type is available in the public `numpy/dtype_api.h` header. Currently use of this struct is not supported in the limited CPython API, so if `Py_LIMITED_API` is set, this type is a typedef for `PyTypeObject`.

```
typedef struct {
     PyHeapTypeObject super;
     PyArray_Descr *singleton;
     int type_num;
     PyTypeObject *scalar_type;
     npy_uint64 flags;
     void *dt_slots;
     void *reserved[3];
} PyArray_DTypeMeta
```

PyHeapTypeObject **super**

The superclass, providing hooks into the python object API. Set members of this struct to fill in the functions implementing the `PyTypeObject` API (e.g. `tp_new`).

PyArray_Descr ***singleton**

A descriptor instance suitable for use as a singleton descriptor for the data type. This is useful for non-parametric types representing simple plain old data type where there is only one logical descriptor instance for all data of the type. Can be NULL if a singleton instance is not appropriate.

int **type_num**

Corresponds to the type number for legacy data types. Data types defined outside of NumPy and possibly future data types shipped with NumPy will have `type_num` set to -1, so this should not be relied on to discriminate between data types.

PyTypeObject ***scalar_type**

The type of scalar instances for this data type.

npy_uint64 **flags**

Flags can be set to indicate to NumPy that this data type has optional behavior. See *Flags* for a listing of allowed flag values.

void ***dt_slots**

An opaque pointer to a private struct containing implementations of functions in the DType API. This is filled in from the `slots` member of the `PyArrayDTypeMeta_Spec` instance used to initialize the DType.

type **PyArrayDTypeMeta_Spec**

A struct used to initialize a new DType with the `PyArrayInitDTypeMeta_FromSpec` function.

```
typedef struct {
    PyTypeObject *typeobj;
    int flags;
    PyArrayMethod_Spec **casts;
    PyType_Slot *slots;
    PyTypeObject *baseclass;
}
```

PyTypeObject ***typeobj**

Either `NULL` or the type of the python scalar associated with the DType. Scalar indexing into an array returns an item with this type.

int **flags**

Static flags for the DType class, indicating whether the DType is parametric, abstract, or represents numeric data. The latter is optional but is useful to set to indicate to downstream code if the DType represents data that are numbers (ints, floats, or other numeric data type) or something else (e.g. a string, unit, or date).

PyArrayMethod_Spec ****casts**;

A `NULL`-terminated array of ArrayMethod specifications for casts defined by the DType.

PyType_Slot ***slots**;

A `NULL`-terminated array of slot specifications for implementations of functions in the DType API. Slot IDs must be one of the DType slot IDs enumerated in *Slot IDs and API Function Typedefs*.

Exposed DTypes classes (`PyArray_DTypeMeta` objects)

For use with promoters, NumPy exposes a number of Dtypes following the pattern `PyArray_<Name>DType` corresponding to those found in *np.dtypes*.

Additionally, the three DTypes, `PyArray_PyLongDType`, `PyArray_PyFloatDType`, `PyArray_PyComplexDType` correspond to the Python scalar values. These cannot be used in all places, but do allow for example the common dtype operation and implementing promotion with them may be necessary.

Further, the following abstract DTypes are defined which cover both the builtin NumPy ones and the python ones, and users can in principle subclass from them (this does not inherit any DType specific functionality): * `PyArray_IntAbstractDType` * `PyArray_FloatAbstractDType` * `PyArray_ComplexAbstractDType`

Warning: As of NumPy 2.0, the *only* valid use for these DTypes is registering a promoter conveniently to e.g. match "any integers" (and subclass checks). Because of this, they are not exposed to Python.

PyUFunc_Type and PyUFuncObject

PyTypeObject **PyUFunc_Type**

The ufunc object is implemented by creation of the *PyUFunc_Type*. It is a very simple type that implements only basic getattribute behavior, printing behavior, and has call behavior which allows these objects to act like functions. The basic idea behind the ufunc is to hold a reference to fast 1-dimensional (vector) loops for each data type that supports the operation. These one-dimensional loops all have the same signature and are the key to creating a new ufunc. They are called by the generic looping code as appropriate to implement the N-dimensional function. There are also some generic 1-d loops defined for floating and complexfloating arrays that allow you to define a ufunc using a single scalar function (*e.g.* atanh).

type **PyUFuncObject**

The core of the ufunc is the *PyUFuncObject* which contains all the information needed to call the underlying C-code loops that perform the actual work. While it is described here for completeness, it should be considered internal to NumPy and manipulated via `PyUFunc_*` functions. The size of this structure is subject to change across versions of NumPy. To ensure compatibility:

- Never declare a non-pointer instance of the struct
- Never perform pointer arithmetic
- Never use `sizeof(PyUFuncObject)`

It has the following structure:

```
typedef struct {
    PyObject_HEAD
    int nin;
    int nout;
    int nargs;
    int identity;
    PyUFuncGenericFunction *functions;
    void **data;
    int ntypes;
    int reserved1;
    const char *name;
    char *types;
    const char *doc;
    void *ptr;
    PyObject *obj;
    PyObject *userloops;
    int core_enabled;
    int core_num_dim_ix;
    int *core_num_dims;
    int *core_dim_ixs;
    int *core_offsets;
    char *core_signature;
    PyUFunc_TypeResolutionFunc *type_resolver;
    void *reserved2;
    void *reserved3;
    npy_uint32 *op_flags;
    npy_uint32 *iter_flags;
    /* new in API version 0x0000000D */
    npy_intp *core_dim_sizes;
    npy_uint32 *core_dim_flags;
    PyObject *identity_value;
    /* Further private slots (size depends on the NumPy version) */
} PyUFuncObject;
```

int **nin**

The number of input arguments.

int **nout**

The number of output arguments.

int **nargs**

The total number of arguments (*nin* + *nout*). This must be less than *NPY_MAXARGS*.

int **identity**

Either *PyUFunc_One*, *PyUFunc_Zero*, *PyUFunc_MinusOne*, *PyUFunc_None*, *PyUFunc_ReorderableNone*, or *PyUFunc_IdentityValue* to indicate the identity for this operation. It is only used for a reduce-like call on an empty array.

void **functions**(char **args, *npy_intp* *dims, *npy_intp* *steps, void *extradata)

An array of function pointers — one for each data type supported by the ufunc. This is the vector loop that is called to implement the underlying function *dims* [0] times. The first argument, *args*, is an array of *nargs* pointers to behaved memory. Pointers to the data for the input arguments are first, followed by the pointers to the data for the output arguments. How many bytes must be skipped to get to the next element in the sequence is specified by the corresponding entry in the *steps* array. The last argument allows the loop to receive extra information. This is commonly used so that a single, generic vector loop can be used for multiple functions. In this case, the actual scalar function to call is passed in as *extradata*. The size of this function pointer array is ntypes.

void ***data**

Extra data to be passed to the 1-d vector loops or `NULL` if no extra-data is needed. This C-array must be the same size (*i.e.* ntypes) as the functions array. `NULL` is used if extra_data is not needed. Several C-API calls for UFuncs are just 1-d vector loops that make use of this extra data to receive a pointer to the actual function to call.

int **ntypes**

The number of supported data types for the ufunc. This number specifies how many different 1-d loops (of the builtin data types) are available.

char ***name**

A string name for the ufunc. This is used dynamically to build the __doc__ attribute of ufuncs.

char ***types**

An array of $nargs \times ntypes$ 8-bit type_numbers which contains the type signature for the function for each of the supported (builtin) data types. For each of the *ntypes* functions, the corresponding set of type numbers in this array shows how the *args* argument should be interpreted in the 1-d vector loop. These type numbers do not have to be the same type and mixed-type ufuncs are supported.

char ***doc**

Documentation for the ufunc. Should not contain the function signature as this is generated dynamically when __doc__ is retrieved.

void ***ptr**

Any dynamically allocated memory. Currently, this is used for dynamic ufuncs created from a python function to store room for the types, data, and name members.

PyObject ***obj**

For ufuncs dynamically created from python functions, this member holds a reference to the underlying Python function.

PyObject ***userloops**

A dictionary of user-defined 1-d vector loops (stored as CObject ptrs) for user-defined types. A loop may be registered by the user for any user-defined type. It is retrieved by type number. User defined type numbers are always larger than *NPY_USERDEF*.

int **core_enabled**

0 for scalar ufuncs; 1 for generalized ufuncs

int **core_num_dim_ix**

Number of distinct core dimension names in the signature

int ***core_num_dims**

Number of core dimensions of each argument

int ***core_dim_ixs**

Dimension indices in a flattened form; indices of argument `k` are stored in `core_dim_ixs[core_offsets[k] : core_offsets[k] + core_numdims[k]]`

int ***core_offsets**

Position of 1st core dimension of each argument in `core_dim_ixs`, equivalent to cumsum(`core_num_dims`)

char ***core_signature**

Core signature string

PyUFunc_TypeResolutionFunc ***type_resolver**

A function which resolves the types and fills an array with the dtypes for the inputs and outputs

type **PyUFunc_TypeResolutionFunc**

The function pointer type for *type_resolver*

npy_uint32 **op_flags**

Override the default operand flags for each ufunc operand.

npy_uint32 **iter_flags**

Override the default nditer flags for the ufunc.

Added in API version 0x0000000D

npy_intp ***core_dim_sizes**

For each distinct core dimension, the possible *frozen* size if *UFUNC_CORE_DIM_SIZE_INFERRED* is `0`

npy_uint32 ***core_dim_flags**

For each distinct core dimension, a set of flags (*UFUNC_CORE_DIM_CAN_IGNORE* and *UFUNC_CORE_DIM_SIZE_INFERRED*)

PyObject ***identity_value**

Identity for reduction, when *PyUFuncObject.identity* is equal to *PyUFunc_IdentityValue*.

UFUNC_CORE_DIM_CAN_IGNORE

if the dim name ends in `?`

UFUNC_CORE_DIM_SIZE_INFERRED

if the dim size will be determined from the operands and not from a *frozen* signature

PyArrayIter_Type and PyArrayIterObject

PyTypeObject **PyArrayIter_Type**

This is an iterator object that makes it easy to loop over an N-dimensional array. It is the object returned from the flat attribute of an ndarray. It is also used extensively throughout the implementation internals to loop over an N-dimensional array. The tp_as_mapping interface is implemented so that the iterator object can be indexed (using 1-d indexing), and a few methods are implemented through the tp_methods table. This object implements the next method and can be used anywhere an iterator can be used in Python.

type **PyArrayIterObject**

The C-structure corresponding to an object of *PyArrayIter_Type* is the *PyArrayIterObject*. The *PyArrayIterObject* is used to keep track of a pointer into an N-dimensional array. It contains associated information used to quickly march through the array. The pointer can be adjusted in three basic ways: 1) advance to the "next" position in the array in a C-style contiguous fashion, 2) advance to an arbitrary N-dimensional coordinate in the array, and 3) advance to an arbitrary one-dimensional index into the array. The members of the *PyArrayIterObject* structure are used in these calculations. Iterator objects keep their own dimension and strides information about an array. This can be adjusted as needed for "broadcasting," or to loop over only specific dimensions.

```
typedef struct {
    PyObject_HEAD
    int   nd_m1;
    npy_intp  index;
    npy_intp  size;
    npy_intp  coordinates[NPY_MAXDIMS_LEGACY_ITERS];
    npy_intp  dims_m1[NPY_MAXDIMS_LEGACY_ITERS];
    npy_intp  strides[NPY_MAXDIMS_LEGACY_ITERS];
    npy_intp  backstrides[NPY_MAXDIMS_LEGACY_ITERS];
    npy_intp  factors[NPY_MAXDIMS_LEGACY_ITERS];
    PyArrayObject *ao;
    char  *dataptr;
    npy_bool  contiguous;
} PyArrayIterObject;
```

int **nd_m1**

$N-1$ where N is the number of dimensions in the underlying array.

npy_intp **index**

The current 1-d index into the array.

npy_intp **size**

The total size of the underlying array.

npy_intp ***coordinates**

An N -dimensional index into the array.

npy_intp ***dims_m1**

The size of the array minus 1 in each dimension.

npy_intp ***strides**

The strides of the array. How many bytes needed to jump to the next element in each dimension.

npy_intp ***backstrides**

How many bytes needed to jump from the end of a dimension back to its beginning. Note that `backstrides[k] == strides[k] * dims_m1[k]`, but it is stored here as an optimization.

npy_intp ***factors**

This array is used in computing an N-d index from a 1-d index. It contains needed products of the dimensions.

PyArrayObject ***ao**

A pointer to the underlying ndarray this iterator was created to represent.

char ***dataptr**

This member points to an element in the ndarray indicated by the index.

npy_bool **contiguous**

This flag is true if the underlying array is *NPY_ARRAY_C_CONTIGUOUS*. It is used to simplify calculations when possible.

How to use an array iterator on a C-level is explained more fully in later sections. Typically, you do not need to concern yourself with the internal structure of the iterator object, and merely interact with it through the use of the macros *PyArray_ITER_NEXT* (it), *PyArray_ITER_GOTO* (it, dest), or *PyArray_ITER_GOTO1D* (it, index). All of these macros require the argument *it* to be a *PyArrayIterObject**.

PyArrayMultiIter_Type and PyArrayMultiIterObject

PyTypeObject **PyArrayMultiIter_Type**

This type provides an iterator that encapsulates the concept of broadcasting. It allows N arrays to be broadcast together so that the loop progresses in C-style contiguous fashion over the broadcasted array. The corresponding C-structure is the *PyArrayMultiIterObject* whose memory layout must begin any object, *obj*, passed in to the *PyArray_Broadcast* (obj) function. Broadcasting is performed by adjusting array iterators so that each iterator represents the broadcasted shape and size, but has its strides adjusted so that the correct element from the array is used at each iteration.

type **PyArrayMultiIterObject**

```
typedef struct {
    PyObject_HEAD
    int numiter;
    npy_intp size;
    npy_intp index;
    int nd;
    npy_intp dimensions[NPY_MAXDIMS_LEGACY_ITERS];
    PyArrayIterObject *iters[];
} PyArrayMultiIterObject;
```

int **numiter**

The number of arrays that need to be broadcast to the same shape.

npy_intp **size**

The total broadcasted size.

npy_intp **index**

The current (1-d) index into the broadcasted result.

int **nd**

The number of dimensions in the broadcasted result.

npy_intp ***dimensions**

The shape of the broadcasted result (only `nd` slots are used).

PyArrayIterObject ****iters**

An array of iterator objects that holds the iterators for the arrays to be broadcast together. On return, the iterators are adjusted for broadcasting.

PyArrayNeighborhoodIter_Type and PyArrayNeighborhoodIterObject

PyTypeObject **PyArrayNeighborhoodIter_Type**

This is an iterator object that makes it easy to loop over an N-dimensional neighborhood.

type **PyArrayNeighborhoodIterObject**

The C-structure corresponding to an object of *PyArrayNeighborhoodIter_Type* is the *PyArrayNeighborhoodIterObject*.

```
typedef struct {
    PyObject_HEAD
    int nd_m1;
    npy_intp index, size;
    npy_intp coordinates[NPY_MAXDIMS_LEGACY_ITERS]
    npy_intp dims_m1[NPY_MAXDIMS_LEGACY_ITERS];
    npy_intp strides[NPY_MAXDIMS_LEGACY_ITERS];
    npy_intp backstrides[NPY_MAXDIMS_LEGACY_ITERS];
    npy_intp factors[NPY_MAXDIMS_LEGACY_ITERS];
    PyArrayObject *ao;
    char *dataptr;
    npy_bool contiguous;
    npy_intp bounds[NPY_MAXDIMS_LEGACY_ITERS][2];
    npy_intp limits[NPY_MAXDIMS_LEGACY_ITERS][2];
    npy_intp limits_sizes[NPY_MAXDIMS_LEGACY_ITERS];
    npy_iter_get_dataptr_t translate;
    npy_intp nd;
    npy_intp dimensions[NPY_MAXDIMS_LEGACY_ITERS];
    PyArrayIterObject* _internal_iter;
    char* constant;
    int mode;
} PyArrayNeighborhoodIterObject;
```

ScalarArrayTypes

There is a Python type for each of the different built-in data types that can be present in the array. Most of these are simple wrappers around the corresponding data type in C. The C-names for these types are `Py{TYPE}ArrType_Type` where `{TYPE}` can be

> **Bool**, **Byte**, **Short**, **Int**, **Long**, **LongLong**, **UByte**, **UShort**, **UInt**, **ULong**, **ULongLong**, **Half**, **Float**, **Double**, **LongDouble**, **CFloat**, **CDouble**, **CLongDouble**, **String**, **Unicode**, **Void**, **Datetime**, **Timedelta**, and **Object**.

These type names are part of the C-API and can therefore be created in extension C-code. There is also a `PyIntpArrType_Type` and a `PyUIntpArrType_Type` that are simple substitutes for one of the integer types that can hold a pointer on the platform. The structure of these scalar objects is not exposed to C-code. The function *PyArray_ScalarAsCtype* (..) can be used to extract the C-type value from the array scalar and the function *PyArray_Scalar* (…) can be used to construct an array scalar from a C-value.

Other C-structures

A few new C-structures were found to be useful in the development of NumPy. These C-structures are used in at least one C-API call and are therefore documented here. The main reason these structures were defined is to make it easy to use the Python ParseTuple C-API to convert from Python objects to a useful C-Object.

PyArray_Dims

type **PyArray_Dims**

This structure is very useful when shape and/or strides information is supposed to be interpreted. The structure is:

```
typedef struct {
    npy_intp *ptr;
    int len;
} PyArray_Dims;
```

The members of this structure are

npy_intp ***ptr**

A pointer to a list of (*npy_intp*) integers which usually represent array shape or array strides.

int **len**

The length of the list of integers. It is assumed safe to access *ptr* [0] to *ptr* [len-1].

PyArray_Chunk

type **PyArray_Chunk**

This is equivalent to the buffer object structure in Python up to the ptr member. On 32-bit platforms (*i.e.* if *NPY_SIZEOF_INT* == *NPY_SIZEOF_INTP*), the len member also matches an equivalent member of the buffer object. It is useful to represent a generic single-segment chunk of memory.

```
typedef struct {
    PyObject_HEAD
    PyObject *base;
    void *ptr;
    npy_intp len;
    int flags;
} PyArray_Chunk;
```

The members are

PyObject ***base**

The Python object this chunk of memory comes from. Needed so that memory can be accounted for properly.

void ***ptr**

A pointer to the start of the single-segment chunk of memory.

npy_intp **len**

The length of the segment in bytes.

int **flags**

Any data flags (*e.g.* *NPY_ARRAY_WRITEABLE*) that should be used to interpret the memory.

PyArrayInterface

See also:

The array interface protocol

type **PyArrayInterface**

The *PyArrayInterface* structure is defined so that NumPy and other extension modules can use the rapid array interface protocol. The *__array_struct__* method of an object that supports the rapid array interface protocol should return a PyCapsule that contains a pointer to a *PyArrayInterface* structure with the relevant details of the array. After the new array is created, the attribute should be DECREF'd which will free the *PyArrayInterface* structure. Remember to INCREF the object (whose *__array_struct__* attribute was retrieved) and point the base member of the new *PyArrayObject* to this same object. In this way the memory for the array will be managed correctly.

```
typedef struct {
    int two;
    int nd;
    char typekind;
    int itemsize;
    int flags;
    npy_intp *shape;
    npy_intp *strides;
    void *data;
    PyObject *descr;
} PyArrayInterface;
```

int **two**

the integer 2 as a sanity check.

int **nd**

the number of dimensions in the array.

char **typekind**

A character indicating what kind of array is present according to the typestring convention with 't' -> bitfield, 'b' -> Boolean, 'i' -> signed integer, 'u' -> unsigned integer, 'f' -> floating point, 'c' -> complex floating point, 'O' -> object, 'S' -> (byte-)string, 'U' -> unicode, 'V' -> void.

int **itemsize**

The number of bytes each item in the array requires.

int **flags**

Any of the bits *NPY_ARRAY_C_CONTIGUOUS* (1), *NPY_ARRAY_F_CONTIGUOUS* (2), *NPY_ARRAY_ALIGNED* (0x100), *NPY_ARRAY_NOTSWAPPED* (0x200), or *NPY_ARRAY_WRITEABLE* (0x400) to indicate something about the data. The *NPY_ARRAY_ALIGNED*, *NPY_ARRAY_C_CONTIGUOUS*, and *NPY_ARRAY_F_CONTIGUOUS* flags can actually be determined from the other parameters. The flag *NPY_ARR_HAS_DESCR* (0x800) can also be set to indicate to objects consuming the version 3 array interface that the descr member of the structure is present (it will be ignored by objects consuming version 2 of the array interface).

npy_intp ***shape**

An array containing the size of the array in each dimension.

npy_intp ***strides**

An array containing the number of bytes to jump to get to the next element in each dimension.

void ***data**

A pointer *to* the first element of the array.

PyObject ***descr**

A Python object describing the data-type in more detail (same as the *descr* key in *__array_interface__*). This can be `NULL` if *typekind* and *itemsize* provide enough information. This field is also ignored unless *NPY_ARR_HAS_DESCR* flag is on in *flags*.

Internally used structures

Internally, the code uses some additional Python objects primarily for memory management. These types are not accessible directly from Python, and are not exposed to the C-API. They are included here only for completeness and assistance in understanding the code.

type **PyUFunc_Loop1d**

A simple linked-list of C-structures containing the information needed to define a 1-d loop for a ufunc for every defined signature of a user-defined data-type.

PyTypeObject **PyArrayMapIter_Type**

Advanced indexing is handled with this Python type. It is simply a loose wrapper around the C-structure containing the variables needed for advanced array indexing.

type **PyArrayMapIterObject**

The C-structure associated with *PyArrayMapIter_Type*. This structure is useful if you are trying to understand the advanced-index mapping code. It is defined in the `arrayobject.h` header. This type is not exposed to Python and could be replaced with a C-structure. As a Python type it takes advantage of reference- counted memory management.

NumPy C-API and C complex

When you use the NumPy C-API, you will have access to complex real declarations `npy_cdouble` and `npy_cfloat`, which are declared in terms of the C standard types from `complex.h`. Unfortunately, `complex.h` contains *#define I ...`* (where the actual definition depends on the compiler), which means that any downstream user that does `#include <numpy/arrayobject.h>` could get `I` defined, and using something like declaring `double I;` in their code will result in an obscure compiler error like

This error can be avoided by adding:

```
#undef I
```

to your code.

Changed in version 2.0: The inclusion of `complex.h` was new in NumPy 2, so that code defining a different `I` may not have required the `#undef I` on older versions. NumPy 2.0.1 briefly included the `#under I`

2.1.2 System configuration

When NumPy is built, information about system configuration is recorded, and is made available for extension modules using NumPy's C API. These are mostly defined in `numpyconfig.h` (included in `ndarrayobject.h`). The public symbols are prefixed by `NPY_*`. NumPy also offers some functions for querying information about the platform in use.

For private use, NumPy also constructs a `config.h` in the NumPy include directory, which is not exported by NumPy (that is a python extension which use the numpy C API will not see those symbols), to avoid namespace pollution.

Data type sizes

The `NPY_SIZEOF_{CTYPE}` constants are defined so that sizeof information is available to the pre-processor.

NPY_SIZEOF_SHORT
: sizeof(short)

NPY_SIZEOF_INT
: sizeof(int)

NPY_SIZEOF_LONG
: sizeof(long)

NPY_SIZEOF_LONGLONG
: sizeof(longlong) where longlong is defined appropriately on the platform.

NPY_SIZEOF_PY_LONG_LONG

NPY_SIZEOF_FLOAT
: sizeof(float)

NPY_SIZEOF_DOUBLE
: sizeof(double)

NPY_SIZEOF_LONG_DOUBLE

NPY_SIZEOF_LONGDOUBLE
: sizeof(longdouble)

NPY_SIZEOF_PY_INTPTR_T
: Size of a pointer `void *` and `intptr_t`/`Py_intptr_t`.

NPY_SIZEOF_INTP
: Size of a `size_t` on this platform (`sizeof(size_t)`)

Platform information

NPY_CPU_X86

NPY_CPU_AMD64

NPY_CPU_IA64

NPY_CPU_PPC

NPY_CPU_PPC64

NPY_CPU_SPARC

NPY_CPU_SPARC64

NPY_CPU_S390

NPY_CPU_PARISC
: CPU architecture of the platform; only one of the above is defined.

  Defined in `numpy/npy_cpu.h`

NPY_LITTLE_ENDIAN

NPY_BIG_ENDIAN

NPY_BYTE_ORDER

Portable alternatives to the `endian.h` macros of GNU Libc. If big endian, *NPY_BYTE_ORDER* == *NPY_BIG_ENDIAN*, and similarly for little endian architectures.

Defined in `numpy/npy_endian.h`.

int **PyArray_GetEndianness**()

Returns the endianness of the current platform. One of *NPY_CPU_BIG*, *NPY_CPU_LITTLE*, or *NPY_CPU_UNKNOWN_ENDIAN*.

NPY_CPU_BIG

NPY_CPU_LITTLE

NPY_CPU_UNKNOWN_ENDIAN

Compiler directives

NPY_LIKELY

NPY_UNLIKELY

NPY_UNUSED

2.1.3 Data type API

The standard array can have 25 different data types (and has some support for adding your own types). These data types all have an enumerated type, an enumerated type-character, and a corresponding array scalar Python type object (placed in a hierarchy). There are also standard C typedefs to make it easier to manipulate elements of the given data type. For the numeric types, there are also bit-width equivalent C typedefs and named typenumbers that make it easier to select the precision desired.

Warning: The names for the types in c code follows c naming conventions more closely. The Python names for these types follow Python conventions. Thus, *NPY_FLOAT* picks up a 32-bit float in C, but *numpy.float64* in Python corresponds to a 64-bit double. The bit-width names can be used in both Python and C for clarity.

Enumerated types

enum **NPY_TYPES**

There is a list of enumerated types defined providing the basic 25 data types plus some useful generic names. Whenever the code requires a type number, one of these enumerated types is requested. The types are all called `NPY_{NAME}`:

enumerator **NPY_BOOL**

The enumeration value for the boolean type, stored as one byte. It may only be set to the values 0 and 1.

enumerator **NPY_BYTE**

enumerator **NPY_INT8**

The enumeration value for an 8-bit/1-byte signed integer.

enumerator **NPY_SHORT**

enumerator **NPY_INT16**

The enumeration value for a 16-bit/2-byte signed integer.

enumerator **NPY_INT**

enumerator **NPY_INT32**

The enumeration value for a 32-bit/4-byte signed integer.

enumerator **NPY_LONG**

Equivalent to either NPY_INT or NPY_LONGLONG, depending on the platform.

enumerator **NPY_LONGLONG**

enumerator **NPY_INT64**

The enumeration value for a 64-bit/8-byte signed integer.

enumerator **NPY_UBYTE**

enumerator **NPY_UINT8**

The enumeration value for an 8-bit/1-byte unsigned integer.

enumerator **NPY_USHORT**

enumerator **NPY_UINT16**

The enumeration value for a 16-bit/2-byte unsigned integer.

enumerator **NPY_UINT**

enumerator **NPY_UINT32**

The enumeration value for a 32-bit/4-byte unsigned integer.

enumerator **NPY_ULONG**

Equivalent to either NPY_UINT or NPY_ULONGLONG, depending on the platform.

enumerator **NPY_ULONGLONG**

enumerator **NPY_UINT64**

The enumeration value for a 64-bit/8-byte unsigned integer.

enumerator **NPY_HALF**

enumerator **NPY_FLOAT16**

The enumeration value for a 16-bit/2-byte IEEE 754-2008 compatible floating point type.

enumerator **NPY_FLOAT**

enumerator **NPY_FLOAT32**

The enumeration value for a 32-bit/4-byte IEEE 754 compatible floating point type.

enumerator **NPY_DOUBLE**

enumerator **NPY_FLOAT64**

The enumeration value for a 64-bit/8-byte IEEE 754 compatible floating point type.

enumerator **NPY_LONGDOUBLE**

The enumeration value for a platform-specific floating point type which is at least as large as NPY_DOUBLE, but larger on many platforms.

enumerator **NPY_CFLOAT**

enumerator **NPY_COMPLEX64**

The enumeration value for a 64-bit/8-byte complex type made up of two NPY_FLOAT values.

enumerator **NPY_CDOUBLE**

enumerator **NPY_COMPLEX128**

The enumeration value for a 128-bit/16-byte complex type made up of two NPY_DOUBLE values.

enumerator **NPY_CLONGDOUBLE**

The enumeration value for a platform-specific complex floating point type which is made up of two NPY_LONGDOUBLE values.

enumerator **NPY_DATETIME**

The enumeration value for a data type which holds dates or datetimes with a precision based on selectable date or time units.

enumerator **NPY_TIMEDELTA**

The enumeration value for a data type which holds lengths of times in integers of selectable date or time units.

enumerator **NPY_STRING**

The enumeration value for null-padded byte strings of a selectable size. The strings have a fixed maximum size within a given array.

enumerator **NPY_UNICODE**

The enumeration value for UCS4 strings of a selectable size. The strings have a fixed maximum size within a given array.

enumerator **NPY_VSTRING**

The enumeration value for UTF-8 variable-width strings. Note that this dtype holds an array of references, with string data stored outside of the array buffer. Use the C API for working with numpy variable-width static strings to access the string data in each array entry.

Note: This DType is new-style and is not included in `NPY_NTYPES_LEGACY`.

---

enumerator **NPY_OBJECT**

The enumeration value for references to arbitrary Python objects.

enumerator **NPY_VOID**

Primarily used to hold struct dtypes, but can contain arbitrary binary data.

Some useful aliases of the above types are

enumerator **NPY_INTP**

The enumeration value for a signed integer of type `Py_ssize_t` (same as `ssize_t` if defined). This is the type used by all arrays of indices.

Changed in version 2.0: Previously, this was the same as `intptr_t` (same size as a pointer). In practice, this is identical except on very niche platforms. You can use the `'p'` character code for the pointer meaning.

enumerator **NPY_UINTP**

The enumeration value for an unsigned integer type that is identical to a `size_t`.

Changed in version 2.0: Previously, this was the same as `uintptr_t` (same size as a pointer). In practice, this is identical except on very niche platforms. You can use the `'P'` character code for the pointer meaning.

enumerator **NPY_MASK**

The enumeration value of the type used for masks, such as with the *NPY_ITER_ARRAYMASK* iterator flag. This is equivalent to *NPY_UINT8*.

enumerator **NPY_DEFAULT_TYPE**

The default type to use when no dtype is explicitly specified, for example when calling np.zero(shape). This is equivalent to *NPY_DOUBLE*.

Other useful related constants are

NPY_NTYPES_LEGACY

The number of built-in NumPy types written using the legacy DType system. New NumPy dtypes will be written using the new DType API and may not function in the same manner as legacy DTypes. Use this macro if you want to handle legacy DTypes using different code paths or if you do not want to update code that uses `NPY_NTYPES_LEGACY` and does not work correctly with new DTypes.

Note: Newly added DTypes such as `NPY_VSTRING` will not be counted in `NPY_NTYPES_LEGACY`.

NPY_NOTYPE

A signal value guaranteed not to be a valid type enumeration number.

NPY_USERDEF

The start of type numbers used for legacy Custom Data types. New-style user DTypes currently are currently *not* assigned a type-number.

Note: The total number of user dtypes is limited to below `NPY_VSTRING`. Higher numbers are reserved to future new-style DType use.

The various character codes indicating certain types are also part of an enumerated list. References to type characters (should they be needed at all) should always use these enumerations. The form of them is `NPY_{NAME}LTR` where `{NAME}` can be

BOOL, **BYTE**, **UBYTE**, **SHORT**, **USHORT**, **INT**, **UINT**, **LONG**, **ULONG**, **LONGLONG**, **ULONGLONG**, **HALF**, **FLOAT**, **DOUBLE**, **LONGDOUBLE**, **CFLOAT**, **CDOUBLE**, **CLONGDOUBLE**, **DATETIME**, **TIMEDELTA**, **OBJECT**, **STRING**, **UNICODE**, **VSTRING**, **VOID**

INTP, **UINTP**

GENBOOL, **SIGNED**, **UNSIGNED**, **FLOATING**, **COMPLEX**

The latter group of `{NAME}s` corresponds to letters used in the array interface typestring specification.

Defines

Max and min values for integers

NPY_MAX_INT{bits}, NPY_MAX_UINT{bits}, NPY_MIN_INT{bits}
: These are defined for `{bits}` = 8, 16, 32, 64, 128, and 256 and provide the maximum (minimum) value of the corresponding (unsigned) integer type. Note: the actual integer type may not be available on all platforms (i.e. 128-bit and 256-bit integers are rare).

NPY_MIN_{type}
: This is defined for `{type}` = **BYTE**, **SHORT**, **INT**, **LONG**, **LONGLONG**, **INTP**

NPY_MAX_{type}
: This is defined for all defined for `{type}` = **BYTE**, **UBYTE**, **SHORT**, **USHORT**, **INT**, **UINT**, **LONG**, **ULONG**, **LONGLONG**, **ULONGLONG**, **INTP**, **UINTP**

Number of bits in data types

All `NPY_SIZEOF_{CTYPE}` constants have corresponding `NPY_BITSOF_{CTYPE}` constants defined. The `NPY_BITSOF_{CTYPE}` constants provide the number of bits in the data type. Specifically, the available `{CTYPE}s` are

BOOL, **CHAR**, **SHORT**, **INT**, **LONG**, **LONGLONG**, **FLOAT**, **DOUBLE**, **LONGDOUBLE**

Bit-width references to enumerated typenums

All of the numeric data types (integer, floating point, and complex) have constants that are defined to be a specific enumerated type number. Exactly which enumerated type a bit-width type refers to is platform dependent. In particular, the constants available are `PyArray_{NAME}{BITS}` where `{NAME}` is **INT**, **UINT**, **FLOAT**, **COMPLEX** and `{BITS}` can be 8, 16, 32, 64, 80, 96, 128, 160, 192, 256, and 512. Obviously not all bit-widths are available on all platforms for all the kinds of numeric types. Commonly 8-, 16-, 32-, 64-bit integers; 32-, 64-bit floats; and 64-, 128-bit complex types are available.

Further integer aliases

The constants **NPY_INTP** and **NPY_UINTP** refer to an `Py_ssize_t` and `size_t`. Although in practice normally true, these types are strictly speaking not pointer sized and the character codes `'p'` and `'P'` can be used for pointer sized integers. (Before NumPy 2, `intp` was pointer size, but this almost never matched the actual use, which is the reason for the name.)

Since NumPy 2, **NPY_DEFAULT_INT** is additionally defined. The value of the macro is runtime dependent: Since NumPy 2, it maps to `NPY_INTP` while on earlier versions it maps to `NPY_LONG`.

C-type names

There are standard variable types for each of the numeric data types and the bool data type. Some of these are already available in the C-specification. You can create variables in extension code with these types.

Boolean

type **npy_bool**
: unsigned char; The constants *NPY_FALSE* and *NPY_TRUE* are also defined.

(Un)Signed Integer

Unsigned versions of the integers can be defined by prepending a 'u' to the front of the integer name.

type **npy_byte**
: char

type **npy_ubyte**
: unsigned char

type **npy_short**
: short

type **npy_ushort**
: unsigned short

type **npy_int**
: int

type **npy_uint**
: unsigned int

type **npy_int16**
: 16-bit integer

type **npy_uint16**
: 16-bit unsigned integer

type **npy_int32**
: 32-bit integer

type **npy_uint32**
: 32-bit unsigned integer

type **npy_int64**
: 64-bit integer

type **npy_uint64**
: 64-bit unsigned integer

type **npy_long**
: long int

type **npy_ulong**
: unsigned long int

type **npy_longlong**
: long long int

type **npy_ulonglong**
: unsigned long long int

type **npy_intp**

`Py_ssize_t` (a signed integer with the same size as the C `size_t`). This is the correct integer for lengths or indexing. In practice this is normally the size of a pointer, but this is not guaranteed.

Note: Before NumPy 2.0, this was the same as `Py_intptr_t`. While a better match, this did not match actual usage in practice. On the Python side, we still support `np.dtype('p')` to fetch a dtype compatible with storing pointers, while `n` is the correct character for the `ssize_t`.

---

type **npy_uintp**

The C `size_t`/`Py_size_t`.

(Complex) Floating point

type **npy_half**

16-bit float

type **npy_float**

32-bit float

type **npy_cfloat**

32-bit complex float

type **npy_double**

64-bit double

type **npy_cdouble**

64-bit complex double

type **npy_longdouble**

long double

type **npy_clongdouble**

long complex double

complex types are structures with **.real** and **.imag** members (in that order).

Bit-width names

There are also typedefs for signed integers, unsigned integers, floating point, and complex floating point types of specific bit- widths. The available type names are

`npy_int{bits}`, `npy_uint{bits}`, `npy_float{bits}`, and `npy_complex{bits}`

where `{bits}` is the number of bits in the type and can be **8**, **16**, **32**, **64**, 128, and 256 for integer types; 16, **32** , **64**, 80, 96, 128, and 256 for floating-point types; and 32, **64**, **128**, 160, 192, and 512 for complex-valued types. Which bit-widths are available is platform dependent. The bolded bit-widths are usually available on all platforms.

Time and timedelta

type **npy_datetime**

date or datetime (alias of *npy_int64*)

type **npy_timedelta**

length of time (alias of *npy_int64*)

Printf formatting

For help in printing, the following strings are defined as the correct format specifier in printf and related commands.

NPY_LONGLONG_FMT

NPY_ULONGLONG_FMT

NPY_INTP_FMT

NPY_UINTP_FMT

NPY_LONGDOUBLE_FMT

2.1.4 Array API

The test of a first-rate intelligence is the ability to hold two
opposed ideas in the mind at the same time, and still retain the
ability to function.
— *F. Scott Fitzgerald*

For a successful technology, reality must take precedence over public
relations, for Nature cannot be fooled.
— *Richard P. Feynman*

Array structure and data access

These macros access the *PyArrayObject* structure members and are defined in `ndarraytypes.h`. The input argument, *arr*, can be any `PyObject*` that is directly interpretable as a *PyArrayObject** (any instance of the *PyArray_Type* and its sub-types).

int **PyArray_NDIM**(*PyArrayObject* *arr)

The number of dimensions in the array.

int **PyArray_FLAGS**(*PyArrayObject* *arr)

Returns an integer representing the *array-flags*.

int **PyArray_TYPE**(*PyArrayObject* *arr)

Return the (builtin) typenumber for the elements of this array.

int **PyArray_Pack**(const *PyArray_Descr* *descr, void *item, const PyObject *value)

New in version 2.0.

Sets the memory location `item` of dtype `descr` to `value`.

The function is equivalent to setting a single array element with a Python assignment. Returns 0 on success and -1 with an error set on failure.

Note: If the `descr` has the *NPY_NEEDS_INIT* flag set, the data must be valid or the memory zeroed.

int **PyArray_SETITEM**(*PyArrayObject* *arr, void *itemptr, PyObject *obj)

Convert obj and place it in the ndarray, *arr*, at the place pointed to by itemptr. Return -1 if an error occurs or 0 on success.

Note: In general, prefer the use of `PyArray_Pack` when handling arbitrary Python objects. Setitem is for example not able to handle arbitrary casts between different dtypes.

---

void **PyArray_ENABLEFLAGS**(*PyArrayObject* *arr, int flags)

Enables the specified array flags. This function does no validation, and assumes that you know what you're doing.

void **PyArray_CLEARFLAGS**(*PyArrayObject* *arr, int flags)

Clears the specified array flags. This function does no validation, and assumes that you know what you're doing.

void *__PyArray_DATA__(*PyArrayObject* *arr)

char *__PyArray_BYTES__(*PyArrayObject* *arr)

These two macros are similar and obtain the pointer to the data-buffer for the array. The first macro can (and should be) assigned to a particular pointer where the second is for generic processing. If you have not guaranteed a contiguous and/or aligned array then be sure you understand how to access the data in the array to avoid memory and/or alignment problems.

npy_intp *__PyArray_DIMS__(*PyArrayObject* *arr)

Returns a pointer to the dimensions/shape of the array. The number of elements matches the number of dimensions of the array. Can return `NULL` for 0-dimensional arrays.

npy_intp *__PyArray_SHAPE__(*PyArrayObject* *arr)

A synonym for `PyArray_DIMS`, named to be consistent with the `shape` usage within Python.

npy_intp *__PyArray_STRIDES__(*PyArrayObject* *arr)

Returns a pointer to the strides of the array. The number of elements matches the number of dimensions of the array.

npy_intp **PyArray_DIM**(*PyArrayObject* *arr, int n)

Return the shape in the n^{th} dimension.

npy_intp **PyArray_STRIDE**(*PyArrayObject* *arr, int n)

Return the stride in the n^{th} dimension.

npy_intp **PyArray_ITEMSIZE**(*PyArrayObject* *arr)

Return the itemsize for the elements of this array.

Note that, in the old API that was deprecated in version 1.7, this function had the return type `int`.

npy_intp **PyArray_SIZE**(*PyArrayObject* *arr)

Returns the total size (in number of elements) of the array.

npy_intp **PyArray_Size**(*PyArrayObject* *obj)

Returns 0 if *obj* is not a sub-class of ndarray. Otherwise, returns the total number of elements in the array. Safer version of `PyArray_SIZE` (*obj*).

npy_intp **PyArray_NBYTES**(*PyArrayObject* *arr)

Returns the total number of bytes consumed by the array.

PyObject ***PyArray_BASE**(*PyArrayObject* *arr)

This returns the base object of the array. In most cases, this means the object which owns the memory the array is pointing at.

If you are constructing an array using the C API, and specifying your own memory, you should use the function *PyArray_SetBaseObject* to set the base to an object which owns the memory.

If the *NPY_ARRAY_WRITEBACKIFCOPY* flag is set, it has a different meaning, namely base is the array into which the current array will be copied upon copy resolution. This overloading of the base property for two functions is likely to change in a future version of NumPy.

PyArray_Descr ***PyArray_DESCR**(*PyArrayObject* *arr)

Returns a borrowed reference to the dtype property of the array.

PyArray_Descr ***PyArray_DTYPE**(*PyArrayObject* *arr)

A synonym for PyArray_DESCR, named to be consistent with the 'dtype' usage within Python.

PyObject ***PyArray_GETITEM**(*PyArrayObject* *arr, void *itemptr)

Get a Python object of a builtin type from the ndarray, *arr*, at the location pointed to by itemptr. Return `NULL` on failure.

numpy.ndarray.item is identical to PyArray_GETITEM.

int **PyArray_FinalizeFunc**(*PyArrayObject* *arr, PyObject *obj)

The function pointed to by the `PyCapsule` *__array_finalize__*. The first argument is the newly created sub-type. The second argument (if not NULL) is the "parent" array (if the array was created using slicing or some other operation where a clearly-distinguishable parent is present). This routine can do anything it wants to. It should return a -1 on error and 0 otherwise.

Data access

These functions and macros provide easy access to elements of the ndarray from C. These work for all arrays. You may need to take care when accessing the data in the array, however, if it is not in machine byte-order, misaligned, or not writeable. In other words, be sure to respect the state of the flags unless you know what you are doing, or have previously guaranteed an array that is writeable, aligned, and in machine byte-order using *PyArray_FromAny*. If you wish to handle all types of arrays, the copyswap function for each type is useful for handling misbehaved arrays. Some platforms (e.g. Solaris) do not like misaligned data and will crash if you de-reference a misaligned pointer. Other platforms (e.g. x86 Linux) will just work more slowly with misaligned data.

void ***PyArray_GetPtr**(*PyArrayObject* *aobj, *npy_intp* *ind)

Return a pointer to the data of the ndarray, *aobj*, at the N-dimensional index given by the c-array, *ind*, (which must be at least *aobj* ->nd in size). You may want to typecast the returned pointer to the data type of the ndarray.

void ***PyArray_GETPTR1**(*PyArrayObject* *obj, *npy_intp* i)

void ***PyArray_GETPTR2**(*PyArrayObject* *obj, *npy_intp* i, *npy_intp* j)

void ***PyArray_GETPTR3**(*PyArrayObject* *obj, *npy_intp* i, *npy_intp* j, *npy_intp* k)

void ***PyArray_GETPTR4**(*PyArrayObject* *obj, *npy_intp* i, *npy_intp* j, *npy_intp* k, *npy_intp* l)

Quick, inline access to the element at the given coordinates in the ndarray, *obj*, which must have respectively 1, 2, 3, or 4 dimensions (this is not checked). The corresponding *i*, *j*, *k*, and *l* coordinates can be any integer but will be interpreted as `npy_intp`. You may want to typecast the returned pointer to the data type of the ndarray.

Creating arrays

From scratch

PyObject ***PyArray_NewFromDescr**(PyTypeObject *subtype, *PyArray_Descr* *descr, int nd, *npy_intp* const *dims, *npy_intp* const *strides, void *data, int flags, PyObject *obj)

This function steals a reference to *descr*. The easiest way to get one is using `PyArray_DescrFromType`.

This is the main array creation function. Most new arrays are created with this flexible function.

The returned object is an object of Python-type *subtype*, which must be a subtype of `PyArray_Type`. The array has *nd* dimensions, described by *dims*. The data-type descriptor of the new array is *descr*.

If *subtype* is of an array subclass instead of the base `&PyArray_Type`, then *obj* is the object to pass to the `__array_finalize__` method of the subclass.

If *data* is `NULL`, then new unitinialized memory will be allocated and *flags* can be non-zero to indicate a Fortran-style contiguous array. Use `PyArray_FILLWBYTE` to initialize the memory.

If *data* is not `NULL`, then it is assumed to point to the memory to be used for the array and the *flags* argument is used as the new flags for the array (except the state of `NPY_ARRAY_OWNDATA`, `NPY_ARRAY_WRITEBACKIFCOPY` flag of the new array will be reset).

In addition, if *data* is non-NULL, then *strides* can also be provided. If *strides* is `NULL`, then the array strides are computed as C-style contiguous (default) or Fortran-style contiguous (*flags* is nonzero for *data* = `NULL` or *flags* & `NPY_ARRAY_F_CONTIGUOUS` is nonzero non-NULL *data*). Any provided *dims* and *strides* are copied into newly allocated dimension and strides arrays for the new array object.

`PyArray_CheckStrides` can help verify non- `NULL` stride information.

If `data` is provided, it must stay alive for the life of the array. One way to manage this is through `PyArray_SetBaseObject`

PyObject ***PyArray_NewLikeArray**(*PyArrayObject* *prototype, *NPY_ORDER* order, *PyArray_Descr* *descr, int subok)

This function steals a reference to *descr* if it is not NULL. This array creation routine allows for the convenient creation of a new array matching an existing array's shapes and memory layout, possibly changing the layout and/or data type.

When *order* is `NPY_ANYORDER`, the result order is `NPY_FORTRANORDER` if *prototype* is a fortran array, `NPY_CORDER` otherwise. When *order* is `NPY_KEEPORDER`, the result order matches that of *prototype*, even when the axes of *prototype* aren't in C or Fortran order.

If *descr* is NULL, the data type of *prototype* is used.

If *subok* is 1, the newly created array will use the sub-type of *prototype* to create the new array, otherwise it will create a base-class array.

PyObject ***PyArray_New**(PyTypeObject *subtype, int nd, *npy_intp* const *dims, int type_num, *npy_intp* const *strides, void *data, int itemsize, int flags, PyObject *obj)

This is similar to `PyArray_NewFromDescr` (…) except you specify the data-type descriptor with *type_num* and *itemsize*, where *type_num* corresponds to a builtin (or user-defined) type. If the type always has the same number of bytes, then itemsize is ignored. Otherwise, itemsize specifies the particular size of this array.

Warning: If data is passed to `PyArray_NewFromDescr` or `PyArray_New`, this memory must not be deallocated until the new array is deleted. If this data came from another Python object, this can be accomplished using `Py_INCREF` on that object and setting the base member of the new array to point to that object. If strides are passed in they must be consistent with the dimensions, the itemsize, and the data of the array.

PyObject ***PyArray_SimpleNew**(int nd, *npy_intp* const *dims, int typenum)

Create a new uninitialized array of type, *typenum*, whose size in each of *nd* dimensions is given by the integer array, *dims*.The memory for the array is uninitialized (unless typenum is `NPY_OBJECT` in which case each element in the array is set to NULL). The *typenum* argument allows specification of any of the builtin data-types such as `NPY_FLOAT` or `NPY_LONG`. The memory for the array can be set to zero if desired using `PyArray_FILLWBYTE` (return_object, 0).This function cannot be used to create a flexible-type array (no itemsize given).

PyObject ***PyArray_SimpleNewFromData**(int nd, *npy_intp* const *dims, int typenum, void *data)

Create an array wrapper around *data* pointed to by the given pointer. The array flags will have a default that the data area is well-behaved and C-style contiguous. The shape of the array is given by the *dims* c-array of length *nd*. The data-type of the array is indicated by *typenum*. If data comes from another reference-counted Python object, the reference count on this object should be increased after the pointer is passed in, and the base member of the returned ndarray should point to the Python object that owns the data. This will ensure that the provided memory is not freed while the returned array is in existence.

PyObject ***PyArray_SimpleNewFromDescr**(int nd, *npy_int* const *dims, *PyArray_Descr* *descr)

This function steals a reference to *descr*.

Create a new array with the provided data-type descriptor, *descr*, of the shape determined by *nd* and *dims*.

void **PyArray_FILLWBYTE**(PyObject *obj, int val)

Fill the array pointed to by *obj* —which must be a (subclass of) ndarray—with the contents of *val* (evaluated as a byte). This macro calls memset, so obj must be contiguous.

PyObject ***PyArray_Zeros**(int nd, *npy_intp* const *dims, *PyArray_Descr* *dtype, int fortran)

Construct a new *nd* -dimensional array with shape given by *dims* and data type given by *dtype*. If *fortran* is non-zero, then a Fortran-order array is created, otherwise a C-order array is created. Fill the memory with zeros (or the 0 object if *dtype* corresponds to `NPY_OBJECT`).

PyObject ***PyArray_ZEROS**(int nd, *npy_intp* const *dims, int type_num, int fortran)

Macro form of `PyArray_Zeros` which takes a type-number instead of a data-type object.

PyObject ***PyArray_Empty**(int nd, *npy_intp* const *dims, *PyArray_Descr* *dtype, int fortran)

Construct a new *nd* -dimensional array with shape given by *dims* and data type given by *dtype*. If *fortran* is non-zero, then a Fortran-order array is created, otherwise a C-order array is created. The array is uninitialized unless the data type corresponds to `NPY_OBJECT` in which case the array is filled with `Py_None`.

PyObject ***PyArray_EMPTY**(int nd, *npy_intp* const *dims, int typenum, int fortran)

Macro form of `PyArray_Empty` which takes a type-number, *typenum*, instead of a data-type object.

PyObject ***PyArray_Arange**(double start, double stop, double step, int typenum)

Construct a new 1-dimensional array of data-type, *typenum*, that ranges from *start* to *stop* (exclusive) in increments of *step* . Equivalent to **arange** (*start*, *stop*, *step*, dtype).

PyObject ***PyArray_ArangeObj**(PyObject *start, PyObject *stop, PyObject *step, *PyArray_Descr* *descr)

Construct a new 1-dimensional array of data-type determined by `descr`, that ranges from `start` to `stop` (exclusive) in increments of `step`. Equivalent to arange(`start`, `stop`, `step`, `typenum`).

int **PyArray_SetBaseObject**(*PyArrayObject* *arr, PyObject *obj)

This function **steals a reference** to `obj` and sets it as the base property of `arr`.

If you construct an array by passing in your own memory buffer as a parameter, you need to set the array's *base* property to ensure the lifetime of the memory buffer is appropriate.

The return value is 0 on success, -1 on failure.

If the object provided is an array, this function traverses the chain of *base* pointers so that each array points to the owner of the memory directly. Once the base is set, it may not be changed to another value.

From other objects

PyObject ***PyArray_FromAny**(PyObject *op, *PyArray_Descr* *dtype, int min_depth, int max_depth, int requirements, PyObject *context)

This is the main function used to obtain an array from any nested sequence, or object that exposes the array interface, *op*. The parameters allow specification of the required *dtype*, the minimum (*min_depth*) and maximum (*max_depth*) number of dimensions acceptable, and other *requirements* for the array. This function **steals a reference** to the dtype argument, which needs to be a `PyArray_Descr` structure indicating the desired data-type (including required byteorder). The *dtype* argument may be `NULL`, indicating that any data-type (and byteorder) is acceptable. Unless `NPY_ARRAY_FORCECAST` is present in `flags`, this call will generate an error if the data type cannot be safely obtained from the object. If you want to use `NULL` for the *dtype* and ensure the array is not swapped then use `PyArray_CheckFromAny`. A value of 0 for either of the depth parameters causes the parameter to be ignored. Any of the following array flags can be added (*e.g.* using |) to get the *requirements* argument. If your code can handle general (*e.g.* strided, byte-swapped, or unaligned arrays) then *requirements* may be 0. Also, if *op* is not already an array (or does not expose the array interface), then a new array will be created (and filled from *op* using the sequence protocol). The new array will have `NPY_ARRAY_DEFAULT` as its flags member. The *context* argument is unused.

NPY_ARRAY_C_CONTIGUOUS
Make sure the returned array is C-style contiguous

NPY_ARRAY_F_CONTIGUOUS
Make sure the returned array is Fortran-style contiguous.

NPY_ARRAY_ALIGNED
Make sure the returned array is aligned on proper boundaries for its data type. An aligned array has the data pointer and every strides factor as a multiple of the alignment factor for the data-type- descriptor.

NPY_ARRAY_WRITEABLE
Make sure the returned array can be written to.

NPY_ARRAY_ENSURECOPY
Make sure a copy is made of *op*. If this flag is not present, data is not copied if it can be avoided.

NPY_ARRAY_ENSUREARRAY
Make sure the result is a base-class ndarray. By default, if *op* is an instance of a subclass of ndarray, an instance of that same subclass is returned. If this flag is set, an ndarray object will be returned instead.

NPY_ARRAY_FORCECAST
Force a cast to the output type even if it cannot be done safely. Without this flag, a data cast will occur only if it can be done safely, otherwise an error is raised.

NPY_ARRAY_WRITEBACKIFCOPY
If *op* is already an array, but does not satisfy the requirements, then a copy is made (which will satisfy the requirements). If this flag is present and a copy (of an object that is already an array) must be made, then the corresponding `NPY_ARRAY_WRITEBACKIFCOPY` flag is set in the returned copy and *op* is made to be read-only. You must be sure to call `PyArray_ResolveWritebackIfCopy` to copy the contents back into *op* and the *op* array will be made writeable again. If *op* is not writeable to begin with, or if it is not already an array, then an error is raised.

Combinations of array flags can also be added.

PyObject ***PyArray_CheckFromAny**(PyObject *op, *PyArray_Descr* *dtype, int min_depth, int max_depth, int requirements, PyObject *context)

Nearly identical to `PyArray_FromAny` (…) except *requirements* can contain `NPY_ARRAY_NOTSWAPPED` (over-riding the specification in *dtype*) and `NPY_ARRAY_ELEMENTSTRIDES` which indicates that the array should be aligned in the sense that the strides are multiples of the element size.

PyObject ***PyArray_FromArray**(*PyArrayObject* *op, *PyArray_Descr* *newtype, int requirements)

Special case of *PyArray_FromAny* for when *op* is already an array but it needs to be of a specific *newtype* (including byte-order) or has certain *requirements*.

PyObject ***PyArray_FromStructInterface**(PyObject *op)

Returns an ndarray object from a Python object that exposes the *__array_struct__* attribute and follows the array interface protocol. If the object does not contain this attribute then a borrowed reference to `Py_NotImplemented` is returned.

PyObject ***PyArray_FromInterface**(PyObject *op)

Returns an ndarray object from a Python object that exposes the *__array_interface__* attribute following the array interface protocol. If the object does not contain this attribute then a borrowed reference to `Py_NotImplemented` is returned.

PyObject ***PyArray_FromArrayAttr**(PyObject *op, *PyArray_Descr* *dtype, PyObject *context)

Return an ndarray object from a Python object that exposes the *__array__* method. The third-party implementations of *__array__* must take `dtype` and `copy` keyword arguments. `context` is unused.

PyObject ***PyArray_ContiguousFromAny**(PyObject *op, int typenum, int min_depth, int max_depth)

This function returns a (C-style) contiguous and behaved function array from any nested sequence or array interface exporting object, *op*, of (non-flexible) type given by the enumerated *typenum*, of minimum depth *min_depth*, and of maximum depth *max_depth*. Equivalent to a call to *PyArray_FromAny* with requirements set to *NPY_ARRAY_DEFAULT* and the type_num member of the type argument set to *typenum*.

PyObject ***PyArray_ContiguousFromObject**(PyObject *op, int typenum, int min_depth, int max_depth)

This function returns a well-behaved C-style contiguous array from any nested sequence or array-interface exporting object. The minimum number of dimensions the array can have is given by *min_depth* while the maximum is *max_depth*. This is equivalent to call *PyArray_FromAny* with requirements *NPY_ARRAY_DEFAULT* and *NPY_ARRAY_ENSUREARRAY*.

PyObject ***PyArray_FromObject**(PyObject *op, int typenum, int min_depth, int max_depth)

Return an aligned and in native-byteorder array from any nested sequence or array-interface exporting object, op, of a type given by the enumerated typenum. The minimum number of dimensions the array can have is given by min_depth while the maximum is max_depth. This is equivalent to a call to *PyArray_FromAny* with requirements set to BEHAVED.

PyObject ***PyArray_EnsureArray**(PyObject *op)

This function **steals a reference** to `op` and makes sure that `op` is a base-class ndarray. It special cases array scalars, but otherwise calls *PyArray_FromAny* (`op`, NULL, 0, 0, *NPY_ARRAY_ENSUREARRAY*, NULL).

PyObject ***PyArray_FromString**(char *string, *npy_intp* slen, *PyArray_Descr* *dtype, *npy_intp* num, char *sep)

Construct a one-dimensional ndarray of a single type from a binary or (ASCII) text `string` of length `slen`. The data-type of the array to-be-created is given by `dtype`. If num is -1, then **copy** the entire string and return an appropriately sized array, otherwise, `num` is the number of items to **copy** from the string. If `sep` is NULL (or “”), then interpret the string as bytes of binary data, otherwise convert the sub-strings separated by `sep` to items of data-type `dtype`. Some data-types may not be readable in text mode and an error will be raised if that occurs. All errors return NULL.

PyObject ***PyArray_FromFile**(FILE *fp, *PyArray_Descr* *dtype, *npy_intp* num, char *sep)

Construct a one-dimensional ndarray of a single type from a binary or text file. The open file pointer is `fp`, the data-type of the array to be created is given by `dtype`. This must match the data in the file. If `num` is -1, then read until the end of the file and return an appropriately sized array, otherwise, `num` is the number of items to read. If `sep` is NULL (or “”), then read from the file in binary mode, otherwise read from the file in text mode with `sep` providing the item separator. Some array types cannot be read in text mode in which case an error is raised.

PyObject ***PyArray_FromBuffer**(PyObject *buf, *PyArray_Descr* *dtype, *npy_intp* count, *npy_intp* offset)

Construct a one-dimensional ndarray of a single type from an object, `buf`, that exports the (single-segment) buffer protocol (or has an attribute __buffer__ that returns an object that exports the buffer protocol). A writeable buffer will be tried first followed by a read- only buffer. The *NPY_ARRAY_WRITEABLE* flag of the returned array will reflect which one was successful. The data is assumed to start at `offset` bytes from the start of the memory location for the object. The type of the data in the buffer will be interpreted depending on the data- type descriptor, `dtype`. If `count` is negative then it will be determined from the size of the buffer and the requested itemsize, otherwise, `count` represents how many elements should be converted from the buffer.

int **PyArray_CopyInto**(*PyArrayObject* *dest, *PyArrayObject* *src)

Copy from the source array, `src`, into the destination array, `dest`, performing a data-type conversion if necessary. If an error occurs return -1 (otherwise 0). The shape of `src` must be broadcastable to the shape of `dest`. NumPy checks for overlapping memory when copying two arrays.

int **PyArray_CopyObject**(*PyArrayObject* *dest, PyObject *src)

Assign an object `src` to a NumPy array `dest` according to array-coercion rules. This is basically identical to *PyArray_FromAny*, but assigns directly to the output array. Returns 0 on success and -1 on failures.

PyArrayObject ***PyArray_GETCONTIGUOUS**(PyObject *op)

If `op` is already (C-style) contiguous and well-behaved then just return a reference, otherwise return a (contiguous and well-behaved) copy of the array. The parameter op must be a (sub-class of an) ndarray and no checking for that is done.

PyObject ***PyArray_FROM_O**(PyObject *obj)

Convert `obj` to an ndarray. The argument can be any nested sequence or object that exports the array interface. This is a macro form of *PyArray_FromAny* using `NULL`, 0, 0, 0 for the other arguments. Your code must be able to handle any data-type descriptor and any combination of data-flags to use this macro.

PyObject ***PyArray_FROM_OF**(PyObject *obj, int requirements)

Similar to *PyArray_FROM_O* except it can take an argument of *requirements* indicating properties the resulting array must have. Available requirements that can be enforced are *NPY_ARRAY_C_CONTIGUOUS*, *NPY_ARRAY_F_CONTIGUOUS*, *NPY_ARRAY_ALIGNED*, *NPY_ARRAY_WRITEABLE*, *NPY_ARRAY_NOTSWAPPED*, *NPY_ARRAY_ENSURECOPY*, *NPY_ARRAY_WRITEBACKIFCOPY*, *NPY_ARRAY_FORCECAST*, and *NPY_ARRAY_ENSUREARRAY*. Standard combinations of flags can also be used:

PyObject ***PyArray_FROM_OT**(PyObject *obj, int typenum)

Similar to *PyArray_FROM_O* except it can take an argument of *typenum* specifying the type-number the returned array.

PyObject ***PyArray_FROM_OTF**(PyObject *obj, int typenum, int requirements)

Combination of *PyArray_FROM_OF* and *PyArray_FROM_OT* allowing both a *typenum* and a *flags* argument to be provided.

PyObject ***PyArray_FROMANY**(PyObject *obj, int typenum, int min, int max, int requirements)

Similar to *PyArray_FromAny* except the data-type is specified using a typenumber. *PyArray_DescrFromType* (*typenum*) is passed directly to *PyArray_FromAny*. This macro also adds *NPY_ARRAY_DEFAULT* to requirements if *NPY_ARRAY_ENSURECOPY* is passed in as requirements.

PyObject ***PyArray_CheckAxis**(PyObject *obj, int *axis, int requirements)

Encapsulate the functionality of functions and methods that take the axis= keyword and work properly with None as the axis argument. The input array is `obj`, while `*axis` is a converted integer (so that `*axis == NPY_RAVEL_AXIS` is the None value), and `requirements` gives the needed properties of `obj`. The output is a converted version of the input so that requirements are met and if needed a flattening has occurred. On output negative values of `*axis` are converted and the new value is checked to ensure consistency with the shape of `obj`.

Dealing with types

General check of Python Type

int **PyArray_Check**(PyObject *op)

Evaluates true if *op* is a Python object whose type is a sub-type of *PyArray_Type*.

int **PyArray_CheckExact**(PyObject *op)

Evaluates true if *op* is a Python object with type *PyArray_Type*.

int **PyArray_HasArrayInterface**(PyObject *op, PyObject *out)

If `op` implements any part of the array interface, then `out` will contain a new reference to the newly created ndarray using the interface or `out` will contain `NULL` if an error during conversion occurs. Otherwise, out will contain a borrowed reference to `Py_NotImplemented` and no error condition is set.

int **PyArray_HasArrayInterfaceType**(PyObject *op, *PyArray_Descr* *dtype, PyObject *context, PyObject *out)

If `op` implements any part of the array interface, then `out` will contain a new reference to the newly created ndarray using the interface or `out` will contain `NULL` if an error during conversion occurs. Otherwise, out will contain a borrowed reference to Py_NotImplemented and no error condition is set. This version allows setting of the dtype in the part of the array interface that looks for the *__array__* attribute. *context* is unused.

int **PyArray_IsZeroDim**(PyObject *op)

Evaluates true if *op* is an instance of (a subclass of) *PyArray_Type* and has 0 dimensions.

PyArray_IsScalar(op, cls)

Evaluates true if *op* is an instance of `Py{cls}ArrType_Type`.

int **PyArray_CheckScalar**(PyObject *op)

Evaluates true if *op* is either an array scalar (an instance of a sub-type of *PyGenericArrType_Type*), or an instance of (a sub-class of) *PyArray_Type* whose dimensionality is 0.

int **PyArray_IsPythonNumber**(PyObject *op)

Evaluates true if *op* is an instance of a builtin numeric type (int, float, complex, long, bool)

int **PyArray_IsPythonScalar**(PyObject *op)

Evaluates true if *op* is a builtin Python scalar object (int, float, complex, bytes, str, long, bool).

int **PyArray_IsAnyScalar**(PyObject *op)

Evaluates true if *op* is either a Python scalar object (see *PyArray_IsPythonScalar*) or an array scalar (an instance of a sub- type of *PyGenericArrType_Type*).

int **PyArray_CheckAnyScalar**(PyObject *op)

Evaluates true if *op* is a Python scalar object (see *PyArray_IsPythonScalar*), an array scalar (an instance of a sub-type of *PyGenericArrType_Type*) or an instance of a sub-type of *PyArray_Type* whose dimensionality is 0.

Data-type accessors

Some of the descriptor attributes may not always be defined and should or cannot not be accessed directly.

Changed in version 2.0: Prior to NumPy 2.0 the ABI was different but unnecessary large for user DTypes. These accessors were all added in 2.0 and can be backported (see migration_c_descr).

npy_intp **PyDataType_ELSIZE**(*PyArray_Descr* *descr)

The element size of the datatype (`itemsize` in Python).

Note: If the `descr` is attached to an array `PyArray_ITEMSIZE(arr)` can be used and is available on all NumPy versions.

void **PyDataType_SET_ELSIZE**(*PyArray_Descr* *descr, *npy_intp* size)

Allows setting of the itemsize, this is *only* relevant for string/bytes datatypes as it is the current pattern to define one with a new size.

npy_intp **PyDataType_ALIGNENT**(*PyArray_Descr* *descr)

The alignment of the datatype.

PyObject ***PyDataType_METADATA**(*PyArray_Descr* *descr)

The Metadata attached to a dtype, either `NULL` or a dictionary.

PyObject ***PyDataType_NAMES**(*PyArray_Descr* *descr)

`NULL` or a tuple of structured field names attached to a dtype.

PyObject ***PyDataType_FIELDS**(*PyArray_Descr* *descr)

`NULL`, `None`, or a dict of structured dtype fields, this dict must not be mutated, NumPy may change the way fields are stored in the future.

This is the same dict as returned by *np.dtype.fields*.

NpyAuxData ***PyDataType_C_METADATA**(*PyArray_Descr* *descr)

C-metadata object attached to a descriptor. This accessor should not be needed usually. The C-Metadata field does provide access to the datetime/timedelta time unit information.

PyArray_ArrayDescr ***PyDataType_SUBARRAY**(*PyArray_Descr* *descr)

Information about a subarray dtype equivalent to the Python *np.dtype.base* and *np.dtype.shape*.

If this is non- `NULL`, then this data-type descriptor is a C-style contiguous array of another data-type descriptor. In other-words, each element that this descriptor describes is actually an array of some other base descriptor. This is most useful as the data-type descriptor for a field in another data-type descriptor. The fields member should be `NULL` if this is non- `NULL` (the fields member of the base descriptor can be non- `NULL` however).

type **PyArray_ArrayDescr**

```
typedef struct {
    PyArray_Descr *base;
    PyObject *shape;
} PyArray_ArrayDescr;
```

PyArray_Descr ***base**

The data-type-descriptor object of the base-type.

PyObject ***shape**

The shape (always C-style contiguous) of the sub-array as a Python tuple.

Data-type checking

For the typenum macros, the argument is an integer representing an enumerated array data type. For the array type checking macros the argument must be a `PyObject*` that can be directly interpreted as a *PyArrayObject**.

int **PyTypeNum_ISUNSIGNED**(int num)

int **PyDataType_ISUNSIGNED**(*PyArray_Descr* *descr)

int **PyArray_ISUNSIGNED**(*PyArrayObject* *obj)

Type represents an unsigned integer.

int **PyTypeNum_ISSIGNED**(int num)

int **PyDataType_ISSIGNED**(*PyArray_Descr* *descr)

int **PyArray_ISSIGNED**(*PyArrayObject* *obj)

Type represents a signed integer.

int **PyTypeNum_ISINTEGER**(int num)

int **PyDataType_ISINTEGER**(*PyArray_Descr* *descr)

int **PyArray_ISINTEGER**(*PyArrayObject* *obj)

Type represents any integer.

int **PyTypeNum_ISFLOAT**(int num)

int **PyDataType_ISFLOAT**(*PyArray_Descr* *descr)

int **PyArray_ISFLOAT**(*PyArrayObject* *obj)

Type represents any floating point number.

int **PyTypeNum_ISCOMPLEX**(int num)

int **PyDataType_ISCOMPLEX**(*PyArray_Descr* *descr)

int **PyArray_ISCOMPLEX**(*PyArrayObject* *obj)

Type represents any complex floating point number.

int **PyTypeNum_ISNUMBER**(int num)

int **PyDataType_ISNUMBER**(*PyArray_Descr* *descr)

int **PyArray_ISNUMBER**(*PyArrayObject* *obj)

Type represents any integer, floating point, or complex floating point number.

int **PyTypeNum_ISSTRING**(int num)

int **PyDataType_ISSTRING**(*PyArray_Descr* *descr)

int **PyArray_ISSTRING**(*PyArrayObject* *obj)

Type represents a string data type.

int **PyTypeNum_ISFLEXIBLE**(int num)

int **PyDataType_ISFLEXIBLE**(*PyArray_Descr* *descr)

int **PyArray_ISFLEXIBLE**(*PyArrayObject* *obj)

Type represents one of the flexible array types (*NPY_STRING*, *NPY_UNICODE*, or *NPY_VOID*).

int **PyDataType_ISUNSIZED**(*PyArray_Descr* *descr)

Type has no size information attached, and can be resized. Should only be called on flexible dtypes. Types that are attached to an array will always be sized, hence the array form of this macro not existing.

For structured datatypes with no fields this function now returns False.

int **PyTypeNum_ISUSERDEF**(int num)

int **PyDataType_ISUSERDEF**(*PyArray_Descr* *descr)

int **PyArray_ISUSERDEF**(*PyArrayObject* *obj)

Type represents a user-defined type.

int **PyTypeNum_ISEXTENDED**(int num)

int **PyDataType_ISEXTENDED**(*PyArray_Descr* *descr)

int **PyArray_ISEXTENDED**(*PyArrayObject* *obj)

Type is either flexible or user-defined.

int **PyTypeNum_ISOBJECT**(int num)

int **PyDataType_ISOBJECT**(*PyArray_Descr* *descr)

int **PyArray_ISOBJECT**(*PyArrayObject* *obj)

Type represents object data type.

int **PyTypeNum_ISBOOL**(int num)

int **PyDataType_ISBOOL**(*PyArray_Descr* *descr)

int **PyArray_ISBOOL**(*PyArrayObject* *obj)

Type represents Boolean data type.

int **PyDataType_HASFIELDS**(*PyArray_Descr* *descr)

int **PyArray_HASFIELDS**(*PyArrayObject* *obj)

Type has fields associated with it.

int **PyArray_ISNOTSWAPPED**(*PyArrayObject* *m)

Evaluates true if the data area of the ndarray *m* is in machine byte-order according to the array's data-type descriptor.

int **PyArray_ISBYTESWAPPED**(*PyArrayObject* *m)

Evaluates true if the data area of the ndarray *m* is **not** in machine byte-order according to the array's data-type descriptor.

npy_bool **PyArray_EquivTypes**(*PyArray_Descr* *type1, *PyArray_Descr* *type2)

Return *NPY_TRUE* if *type1* and *type2* actually represent equivalent types for this platform (the fortran member of each type is ignored). For example, on 32-bit platforms, *NPY_LONG* and *NPY_INT* are equivalent. Otherwise return *NPY_FALSE*.

npy_bool **PyArray_EquivArrTypes**(*PyArrayObject* *a1, *PyArrayObject* *a2)

Return *NPY_TRUE* if *a1* and *a2* are arrays with equivalent types for this platform.

npy_bool **PyArray_EquivTypenums**(int typenum1, int typenum2)

Special case of *PyArray_EquivTypes*(...) that does not accept flexible data types but may be easier to call.

int **PyArray_EquivByteorders**(int b1, int b2)

True if byteorder characters *b1* and *b2* (*NPY_LITTLE*, *NPY_BIG*, *NPY_NATIVE*, *NPY_IGNORE*) are either equal or equivalent as to their specification of a native byte order. Thus, on a little-endian machine *NPY_LITTLE* and *NPY_NATIVE* are equivalent where they are not equivalent on a big-endian machine.

Converting data types

PyObject ***PyArray_Cast**(*PyArrayObject* *arr, int typenum)

Mainly for backwards compatibility to the Numeric C-API and for simple casts to non-flexible types. Return a new array object with the elements of *arr* cast to the data-type *typenum* which must be one of the enumerated types and not a flexible type.

PyObject ***PyArray_CastToType**(*PyArrayObject* *arr, *PyArray_Descr* *type, int fortran)

Return a new array of the *type* specified, casting the elements of *arr* as appropriate. The fortran argument specifies the ordering of the output array.

int **PyArray_CastTo**(*PyArrayObject* *out, *PyArrayObject* *in)

As of 1.6, this function simply calls *PyArray_CopyInto*, which handles the casting.

Cast the elements of the array *in* into the array *out*. The output array should be writeable, have an integer-multiple of the number of elements in the input array (more than one copy can be placed in out), and have a data type that is one of the builtin types. Returns 0 on success and -1 if an error occurs.

int **PyArray_CanCastSafely**(int fromtype, int totype)

Returns non-zero if an array of data type *fromtype* can be cast to an array of data type *totype* without losing information. An exception is that 64-bit integers are allowed to be cast to 64-bit floating point values even though this can lose precision on large integers so as not to proliferate the use of long doubles without explicit requests. Flexible array types are not checked according to their lengths with this function.

int **PyArray_CanCastTo**(*PyArray_Descr* *fromtype, *PyArray_Descr* *totype)

PyArray_CanCastTypeTo supersedes this function in NumPy 1.6 and later.

Equivalent to PyArray_CanCastTypeTo(fromtype, totype, NPY_SAFE_CASTING).

int **PyArray_CanCastTypeTo**(*PyArray_Descr* *fromtype, *PyArray_Descr* *totype, *NPY_CASTING* casting)

Returns non-zero if an array of data type *fromtype* (which can include flexible types) can be cast safely to an array of data type *totype* (which can include flexible types) according to the casting rule *casting*. For simple types with *NPY_SAFE_CASTING*, this is basically a wrapper around *PyArray_CanCastSafely*, but for flexible types such as strings or unicode, it produces results taking into account their sizes. Integer and float types can only be cast to a string or unicode type using *NPY_SAFE_CASTING* if the string or unicode type is big enough to hold the max value of the integer/float type being cast from.

int **PyArray_CanCastArrayTo**(*PyArrayObject* *arr, *PyArray_Descr* *totype, *NPY_CASTING* casting)

Returns non-zero if *arr* can be cast to *totype* according to the casting rule given in *casting*. If *arr* is an array scalar, its value is taken into account, and non-zero is also returned when the value will not overflow or be truncated to an integer when converting to a smaller type.

PyArray_Descr ***PyArray_MinScalarType**(*PyArrayObject* *arr)

Note: With the adoption of NEP 50 in NumPy 2, this function is not used internally. It is currently provided for backwards compatibility, but expected to be eventually deprecated.

If *arr* is an array, returns its data type descriptor, but if *arr* is an array scalar (has 0 dimensions), it finds the data type of smallest size to which the value may be converted without overflow or truncation to an integer.

This function will not demote complex to float or anything to boolean, but will demote a signed integer to an unsigned integer when the scalar value is positive.

PyArray_Descr ***PyArray_PromoteTypes**(*PyArray_Descr* *type1, *PyArray_Descr* *type2)

Finds the data type of smallest size and kind to which *type1* and *type2* may be safely converted. This function is symmetric and associative. A string or unicode result will be the proper size for storing the max value of the input types converted to a string or unicode.

PyArray_Descr ***PyArray_ResultType**(*npy_intp* narrs, *PyArrayObject* **arrs, *npy_intp* ndtypes, *PyArray_Descr* **dtypes)

This applies type promotion to all the input arrays and dtype objects, using the NumPy rules for combining scalars and arrays, to determine the output type for an operation with the given set of operands. This is the same result type that ufuncs produce.

See the documentation of *numpy.result_type* for more detail about the type promotion algorithm.

int **PyArray_ObjectType**(PyObject *op, int mintype)

This function is superseded by *PyArray_ResultType*.

This function is useful for determining a common type that two or more arrays can be converted to. It only works for non-flexible array types as no itemsize information is passed. The *mintype* argument represents the minimum type acceptable, and *op* represents the object that will be converted to an array. The return value is the enumerated typenumber that represents the data-type that *op* should have.

PyArrayObject ***PyArray_ConvertToCommonType**(PyObject *op, int *n)

The functionality this provides is largely superseded by iterator *NpyIter* introduced in 1.6, with flag *NPY_ITER_COMMON_DTYPE* or with the same dtype parameter for all operands.

Convert a sequence of Python objects contained in *op* to an array of ndarrays each having the same data type. The type is selected in the same way as *PyArray_ResultType*. The length of the sequence is returned in *n*, and an *n* -length array of *PyArrayObject* pointers is the return value (or NULL if an error occurs). The returned array must be freed by the caller of this routine (using *PyDataMem_FREE*) and all the array objects in it DECREF 'd or a memory-leak will occur. The example template-code below shows a typical usage:

```
mps = PyArray_ConvertToCommonType(obj, &n);
if (mps==NULL) return NULL;
{code}
<before return>
for (i=0; i<n; i++) Py_DECREF(mps[i]);
PyDataMem_FREE(mps);
{return}
```

char ***PyArray_Zero**(*PyArrayObject* *arr)

A pointer to newly created memory of size *arr* ->itemsize that holds the representation of 0 for that type. The returned pointer, *ret*, **must be freed** using *PyDataMem_FREE* (ret) when it is not needed anymore.

char ***PyArray_One**(*PyArrayObject* *arr)

A pointer to newly created memory of size *arr* ->itemsize that holds the representation of 1 for that type. The returned pointer, *ret*, **must be freed** using *PyDataMem_FREE* (ret) when it is not needed anymore.

int **PyArray_ValidType**(int typenum)

Returns *NPY_TRUE* if *typenum* represents a valid type-number (builtin or user-defined or character code). Otherwise, this function returns *NPY_FALSE*.

User-defined data types

void **PyArray_InitArrFuncs**(*PyArray_ArrFuncs* *f)

Initialize all function pointers and members to NULL.

int **PyArray_RegisterDataType**(*PyArray_DescrProto* *dtype)

Note: As of NumPy 2.0 this API is considered legacy, the new DType API is more powerful and provides additional flexibility. The API may eventually be deprecated but support is continued for the time being.

Compiling for NumPy 1.x and 2.x

NumPy 2.x requires passing in a `PyArray_DescrProto` typed struct rather than a `PyArray_Descr`. This is necessary to allow changes. To allow code to run and compile on both 1.x and 2.x you need to change the type of your struct to `PyArray_DescrProto` and add:

```
/* Allow compiling on NumPy 1.x */
#if NPY_ABI_VERSION < 0x02000000
#define PyArray_DescrProto PyArray_Descr
#endif
```

for 1.x compatibility. Further, the struct will *not* be the actual descriptor anymore, only it's type number will be updated. After successful registration, you must thus fetch the actual dtype with:

```
int type_num = PyArray_RegisterDataType(&my_descr_proto);
if (type_num < 0) {
    /* error */
}
PyArray_Descr *my_descr = PyArray_DescrFromType(type_num);
```

With these two changes, the code should compile and work on both 1.x and 2.x or later.

In the unlikely case that you are heap allocating the dtype struct you should free it again on NumPy 2, since a copy is made. The struct is not a valid Python object, so do not use `Py_DECREF` on it.

Register a data-type as a new user-defined data type for arrays. The type must have most of its entries filled in. This is not always checked and errors can produce segfaults. In particular, the typeobj member of the `dtype` structure must be filled with a Python type that has a fixed-size element-size that corresponds to the elsize member of *dtype*. Also the `f` member must have the required functions: nonzero, copyswap, copyswapn, getitem, setitem, and cast (some of the cast functions may be `NULL` if no support is desired). To avoid confusion, you should choose a unique character typecode but this is not enforced and not relied on internally.

A user-defined type number is returned that uniquely identifies the type. A pointer to the new structure can then be obtained from *PyArray_DescrFromType* using the returned type number. A -1 is returned if an error occurs. If this *dtype* has already been registered (checked only by the address of the pointer), then return the previously-assigned type-number.

The number of user DTypes known to numpy is stored in `NPY_NUMUSERTYPES`, a static global variable that is public in the C API. Accessing this symbol is inherently *not* thread-safe. If for some reason you need to use this API in a multithreaded context, you will need to add your own locking, NumPy does not ensure new data types can be added in a thread-safe manner.

int **PyArray_RegisterCastFunc**(*PyArray_Descr* *descr, int totype, *PyArray_VectorUnaryFunc* *castfunc)

Register a low-level casting function, *castfunc*, to convert from the data-type, *descr*, to the given data-type number, *totype*. Any old casting function is over-written. A `0` is returned on success or a `-1` on failure.

type **PyArray_VectorUnaryFunc**

The function pointer type for low-level casting functions.

int **PyArray_RegisterCanCast**(*PyArray_Descr* *descr, int totype, *NPY_SCALARKIND* scalar)

Register the data-type number, *totype*, as castable from data-type object, *descr*, of the given *scalar* kind. Use *scalar* = *NPY_NOSCALAR* to register that an array of data-type *descr* can be cast safely to a data-type whose type_number is *totype*. The return value is 0 on success or -1 on failure.

Special functions for NPY_OBJECT

Warning: When working with arrays or buffers filled with objects NumPy tries to ensure such buffers are filled with `None` before any data may be read. However, code paths may existed where an array is only initialized to `NULL`. NumPy itself accepts `NULL` as an alias for `None`, but may `assert` non-`NULL` when compiled in debug mode.

Because NumPy is not yet consistent about initialization with None, users **must** expect a value of `NULL` when working with buffers created by NumPy. Users **should** also ensure to pass fully initialized buffers to NumPy, since NumPy may make this a strong requirement in the future.

There is currently an intention to ensure that NumPy always initializes object arrays before they may be read. Any failure to do so will be regarded as a bug. In the future, users may be able to rely on non-NULL values when reading from any array, although exceptions for writing to freshly created arrays may remain (e.g. for output arrays in ufunc code). As of NumPy 1.23 known code paths exists where proper filling is not done.

int **PyArray_INCREF**(*PyArrayObject* *op)

Used for an array, *op*, that contains any Python objects. It increments the reference count of every object in the array according to the data-type of *op*. A -1 is returned if an error occurs, otherwise 0 is returned.

void **PyArray_Item_INCREF**(char *ptr, *PyArray_Descr* *dtype)

A function to INCREF all the objects at the location *ptr* according to the data-type *dtype*. If *ptr* is the start of a structured type with an object at any offset, then this will (recursively) increment the reference count of all object-like items in the structured type.

int **PyArray_XDECREF**(*PyArrayObject* *op)

Used for an array, *op*, that contains any Python objects. It decrements the reference count of every object in the array according to the data-type of *op*. Normal return value is 0. A -1 is returned if an error occurs.

void **PyArray_Item_XDECREF**(char *ptr, *PyArray_Descr* *dtype)

A function to XDECREF all the object-like items at the location *ptr* as recorded in the data-type, *dtype*. This works recursively so that if `dtype` itself has fields with data-types that contain object-like items, all the object-like fields will be XDECREF `'d`.

int **PyArray_SetWritebackIfCopyBase**(*PyArrayObject* *arr, *PyArrayObject* *base)

Precondition: `arr` is a copy of `base` (though possibly with different strides, ordering, etc.) Sets the *NPY_ARRAY_WRITEBACKIFCOPY* flag and `arr->base`, and set `base` to READONLY. Call *PyArray_ResolveWritebackIfCopy* before calling `Py_DECREF` in order to copy any changes back to `base` and reset the READONLY flag.

Returns 0 for success, -1 for failure.

Array flags

The `flags` attribute of the `PyArrayObject` structure contains important information about the memory used by the array (pointed to by the data member) This flag information must be kept accurate or strange results and even segfaults may result.

There are 6 (binary) flags that describe the memory area used by the data buffer. These constants are defined in `arrayobject.h` and determine the bit-position of the flag. Python exposes a nice attribute- based interface as well as a dictionary-like interface for getting (and, if appropriate, setting) these flags.

Memory areas of all kinds can be pointed to by an ndarray, necessitating these flags. If you get an arbitrary `PyArray_Object` in C-code, you need to be aware of the flags that are set. If you need to guarantee a certain kind of array (like *NPY_ARRAY_C_CONTIGUOUS* and *NPY_ARRAY_BEHAVED*), then pass these requirements into the PyArray_FromAny function.

In versions 1.6 and earlier of NumPy, the following flags did not have the _ARRAY_ macro namespace in them. That form of the constant names is deprecated in 1.7.

Basic Array Flags

An ndarray can have a data segment that is not a simple contiguous chunk of well-behaved memory you can manipulate. It may not be aligned with word boundaries (very important on some platforms). It might have its data in a different byte-order than the machine recognizes. It might not be writeable. It might be in Fortran-contiguous order. The array flags are used to indicate what can be said about data associated with an array.

NPY_ARRAY_C_CONTIGUOUS

The data area is in C-style contiguous order (last index varies the fastest).

NPY_ARRAY_F_CONTIGUOUS

The data area is in Fortran-style contiguous order (first index varies the fastest).

Note: Arrays can be both C-style and Fortran-style contiguous simultaneously. This is clear for 1-dimensional arrays, but can also be true for higher dimensional arrays.

Even for contiguous arrays a stride for a given dimension `arr.strides[dim]` may be *arbitrary* if `arr.shape[dim] == 1` or the array has no elements. It does *not* generally hold that `self.strides[-1] == self.itemsize` for C-style contiguous arrays or `self.strides[0] == self.itemsize` for Fortran-style contiguous arrays is true. The correct way to access the `itemsize` of an array from the C API is `PyArray_ITEMSIZE(arr)`.

See also:

Internal memory layout of an ndarray

NPY_ARRAY_OWNDATA

The data area is owned by this array. Should never be set manually, instead create a `PyObject` wrapping the data and set the array's base to that object. For an example, see the test in `test_mem_policy`.

NPY_ARRAY_ALIGNED

The data area and all array elements are aligned appropriately.

NPY_ARRAY_WRITEABLE

The data area can be written to.

Notice that the above 3 flags are defined so that a new, well- behaved array has these flags defined as true.

NPY_ARRAY_WRITEBACKIFCOPY

The data area represents a (well-behaved) copy whose information should be transferred back to the original when *PyArray_ResolveWritebackIfCopy* is called.

This is a special flag that is set if this array represents a copy made because a user required certain flags in *PyArray_FromAny* and a copy had to be made of some other array (and the user asked for this flag to be set in such a situation). The base attribute then points to the "misbehaved" array (which is set read_only). *PyArray_ResolveWritebackIfCopy* will copy its contents back to the "misbehaved" array (casting if necessary) and will reset the "misbehaved" array to *NPY_ARRAY_WRITEABLE*. If the "misbehaved" array was not *NPY_ARRAY_WRITEABLE* to begin with then *PyArray_FromAny* would have returned an error because *NPY_ARRAY_WRITEBACKIFCOPY* would not have been possible.

PyArray_UpdateFlags (obj, flags) will update the `obj->flags` for `flags` which can be any of *NPY_ARRAY_C_CONTIGUOUS*, *NPY_ARRAY_F_CONTIGUOUS*, *NPY_ARRAY_ALIGNED*, or *NPY_ARRAY_WRITEABLE*.

Combinations of array flags

NPY_ARRAY_BEHAVED

NPY_ARRAY_ALIGNED | *NPY_ARRAY_WRITEABLE*

NPY_ARRAY_CARRAY

NPY_ARRAY_C_CONTIGUOUS | *NPY_ARRAY_BEHAVED*

NPY_ARRAY_CARRAY_RO

NPY_ARRAY_C_CONTIGUOUS | *NPY_ARRAY_ALIGNED*

NPY_ARRAY_FARRAY

NPY_ARRAY_F_CONTIGUOUS | *NPY_ARRAY_BEHAVED*

NPY_ARRAY_FARRAY_RO

NPY_ARRAY_F_CONTIGUOUS | *NPY_ARRAY_ALIGNED*

NPY_ARRAY_DEFAULT

NPY_ARRAY_CARRAY

NPY_ARRAY_IN_ARRAY

NPY_ARRAY_C_CONTIGUOUS | *NPY_ARRAY_ALIGNED*

NPY_ARRAY_IN_FARRAY

NPY_ARRAY_F_CONTIGUOUS | *NPY_ARRAY_ALIGNED*

NPY_ARRAY_OUT_ARRAY

NPY_ARRAY_C_CONTIGUOUS | *NPY_ARRAY_WRITEABLE* | *NPY_ARRAY_ALIGNED*

NPY_ARRAY_OUT_FARRAY

NPY_ARRAY_F_CONTIGUOUS | *NPY_ARRAY_WRITEABLE* | *NPY_ARRAY_ALIGNED*

NPY_ARRAY_INOUT_ARRAY

NPY_ARRAY_C_CONTIGUOUS | *NPY_ARRAY_WRITEABLE* | *NPY_ARRAY_ALIGNED* | *NPY_ARRAY_WRITEBACKIFCOPY*

NPY_ARRAY_INOUT_FARRAY

NPY_ARRAY_F_CONTIGUOUS | *NPY_ARRAY_WRITEABLE* | *NPY_ARRAY_ALIGNED* | *NPY_ARRAY_WRITEBACKIFCOPY*

NPY_ARRAY_UPDATE_ALL

NPY_ARRAY_C_CONTIGUOUS | *NPY_ARRAY_F_CONTIGUOUS* | *NPY_ARRAY_ALIGNED*

Flag-like constants

These constants are used in *PyArray_FromAny* (and its macro forms) to specify desired properties of the new array.

NPY_ARRAY_FORCECAST

Cast to the desired type, even if it can't be done without losing information.

NPY_ARRAY_ENSURECOPY

Make sure the resulting array is a copy of the original.

NPY_ARRAY_ENSUREARRAY

Make sure the resulting object is an actual ndarray, and not a sub-class.

These constants are used in *PyArray_CheckFromAny* (and its macro forms) to specify desired properties of the new array.

NPY_ARRAY_NOTSWAPPED

Make sure the returned array has a data-type descriptor that is in machine byte-order, over-riding any specification in the *dtype* argument. Normally, the byte-order requirement is determined by the *dtype* argument. If this flag is set and the dtype argument does not indicate a machine byte-order descriptor (or is NULL and the object is already an array with a data-type descriptor that is not in machine byte- order), then a new data-type descriptor is created and used with its byte-order field set to native.

NPY_ARRAY_BEHAVED_NS

NPY_ARRAY_ALIGNED | *NPY_ARRAY_WRITEABLE* | *NPY_ARRAY_NOTSWAPPED*

NPY_ARRAY_ELEMENTSTRIDES

Make sure the returned array has strides that are multiples of the element size.

Flag checking

For all of these macros *arr* must be an instance of a (subclass of) *PyArray_Type*.

int **PyArray_CHKFLAGS**(PyObject *arr, int flags)

The first parameter, arr, must be an ndarray or subclass. The parameter, *flags*, should be an integer consisting of bitwise combinations of the possible flags an array can have: *NPY_ARRAY_C_CONTIGUOUS*, *NPY_ARRAY_F_CONTIGUOUS*, *NPY_ARRAY_OWNDATA*, *NPY_ARRAY_ALIGNED*, *NPY_ARRAY_WRITEABLE*, *NPY_ARRAY_WRITEBACKIFCOPY*.

int **PyArray_IS_C_CONTIGUOUS**(PyObject *arr)

Evaluates true if *arr* is C-style contiguous.

int **PyArray_IS_F_CONTIGUOUS**(PyObject *arr)

Evaluates true if *arr* is Fortran-style contiguous.

int **PyArray_ISFORTRAN**(PyObject *arr)

Evaluates true if *arr* is Fortran-style contiguous and *not* C-style contiguous. *PyArray_IS_F_CONTIGUOUS* is the correct way to test for Fortran-style contiguity.

int **PyArray_ISWRITEABLE**(PyObject *arr)

Evaluates true if the data area of *arr* can be written to

int **PyArray_ISALIGNED**(PyObject *arr)

Evaluates true if the data area of *arr* is properly aligned on the machine.

int **PyArray_ISBEHAVED**(PyObject *arr)

Evaluates true if the data area of *arr* is aligned and writeable and in machine byte-order according to its descriptor.

int **PyArray_ISBEHAVED_RO**(PyObject *arr)

Evaluates true if the data area of *arr* is aligned and in machine byte-order.

int **PyArray_ISCARRAY**(PyObject *arr)

Evaluates true if the data area of *arr* is C-style contiguous, and *PyArray_ISBEHAVED* (*arr*) is true.

int **PyArray_ISFARRAY**(PyObject *arr)

Evaluates true if the data area of *arr* is Fortran-style contiguous and *PyArray_ISBEHAVED* (*arr*) is true.

int **PyArray_ISCARRAY_RO**(PyObject *arr)

Evaluates true if the data area of *arr* is C-style contiguous, aligned, and in machine byte-order.

int **PyArray_ISFARRAY_RO**(PyObject *arr)

Evaluates true if the data area of *arr* is Fortran-style contiguous, aligned, and in machine byte-order **.**

int **PyArray_ISONESEGMENT**(PyObject *arr)

Evaluates true if the data area of *arr* consists of a single (C-style or Fortran-style) contiguous segment.

void **PyArray_UpdateFlags**(*PyArrayObject* *arr, int flagmask)

The `NPY_ARRAY_C_CONTIGUOUS`, `NPY_ARRAY_ALIGNED`, and `NPY_ARRAY_F_CONTIGUOUS` array flags can be "calculated" from the array object itself. This routine updates one or more of these flags of *arr* as specified in *flagmask* by performing the required calculation.

Warning: It is important to keep the flags updated (using `PyArray_UpdateFlags` can help) whenever a manipulation with an array is performed that might cause them to change. Later calculations in NumPy that rely on the state of these flags do not repeat the calculation to update them.

int **PyArray_FailUnlessWriteable**(*PyArrayObject* *obj, const char *name)

This function does nothing and returns 0 if *obj* is writeable. It raises an exception and returns -1 if *obj* is not writeable. It may also do other house-keeping, such as issuing warnings on arrays which are transitioning to become views. Always call this function at some point before writing to an array.

name is a name for the array, used to give better error messages. It can be something like "assignment destination", "output array", or even just "array".

ArrayMethod API

ArrayMethod loops are intended as a generic mechanism for writing loops over arrays, including ufunc loops and casts. The public API is defined in the `numpy/dtype_api.h` header. See *PyArrayMethod_Context and PyArrayMethod_Spec* for documentation on the C structs exposed in the ArrayMethod API.

Slots and Typedefs

These are used to identify which kind of function an ArrayMethod slot implements. See *Slots and Typedefs* below for documentation on the functions that must be implemented for each slot.

NPY_METH_resolve_descriptors

typedef *NPY_CASTING* (**PyArrayMethod_ResolveDescriptors**)(struct *PyArrayMethodObject_tag* *method, *PyArray_DTypeMeta* *const *dtypes, *PyArray_Descr* *const *given_descrs, *PyArray_Descr* **loop_descrs, *npy_intp* *view_offset)

The function used to set the descriptors for an operation based on the descriptors of the operands. For example, a ufunc operation with two input operands and one output operand that is called without `out` being set in the python API, `resolve_descriptors` will be passed the descriptors for the two operands and determine the correct descriptor to use for the output based on the output DType set for the ArrayMethod. If `out` is set, then the output descriptor would be passed in as well and should not be overridden.

The *method* is a pointer to the underlying cast or ufunc loop. In the future we may expose this struct publicly but for now this is an opaque pointer and the method cannot be inspected. The *dtypes* is an `nargs` length array of `PyArray_DTypeMeta` pointers, *given_descrs* is an `nargs` length array of input descriptor instances (output descriptors may be NULL if no output was provided by the user), and *loop_descrs* is an `nargs` length array of descriptors that must be filled in by the resolve descriptors implementation. *view_offset* is currently only interesting for casts and can normally be ignored. When a cast does not require any operation, this can be signalled by setting `view_offset` to 0. On error, you must return `(NPY_CASTING)-1` with an error set.

NPY_METH_strided_loop

NPY_METH_contiguous_loop

NPY_METH_unaligned_strided_loop

NPY_METH_unaligned_contiguous_loop

One dimensional strided loops implementing the behavior (either a ufunc or cast). In most cases, `NPY_METH_strided_loop` is the generic and only version that needs to be implemented. `NPY_METH_contiguous_loop` can be implemented additionally as a more light-weight/faster version and it is used when all inputs and outputs are contiguous.

To deal with possibly unaligned data, NumPy needs to be able to copy unaligned to aligned data. When implementing a new DType, the "cast" or copy for it needs to implement `NPY_METH_unaligned_strided_loop`. Unlike the normal versions, this loop must not assume that the data can be accessed in an aligned fashion. These loops must copy each value before accessing or storing:

```
type_in in_value;
type_out out_value
memcpy(&value, in_data, sizeof(type_in));
out_value = in_value;
memcpy(out_data, &out_value, sizeof(type_out)
```

while a normal loop can just use:

```
*(type_out *)out_data = *(type_in)in_data;
```

The unaligned loops are currently only used in casts and will never be picked in ufuncs (ufuncs create a temporary copy to ensure aligned inputs). These slot IDs are ignored when `NPY_METH_get_loop` is defined, where instead whichever loop returned by the `get_loop` function is used.

NPY_METH_contiguous_indexed_loop

A specialized inner-loop option to speed up common `ufunc.at` computations.

typedef int (**PyArrayMethod_StridedLoop**)(*PyArrayMethod_Context* *context, char *const *data, const *npy_intp* *dimensions, const *npy_intp* *strides, *NpyAuxData* *auxdata)

An implementation of an ArrayMethod loop. All of the loop slot IDs listed above must provide a `PyArrayMethod_StridedLoop` implementation. The *context* is a struct containing context for the loop operation - in particular the input descriptors. The *data* are an array of pointers to the beginning of the input and output array buffers. The *dimensions* are the loop dimensions for the operation. The *strides* are an `nargs` length array of strides for each input. The *auxdata* is an optional set of auxiliary data that can be passed in to the loop - helpful to turn on and off optional behavior or reduce boilerplate by allowing similar ufuncs to share loop implementations or to allocate space that is persistent over multiple strided loop calls.

NPY_METH_get_loop

Allows more fine-grained control over loop selection. Accepts an implementation of PyArrayMethod_GetLoop, which in turn returns a strided loop implementation. If `NPY_METH_get_loop` is defined, the other loop slot IDs are ignored, if specified.

typedef int (**PyArrayMethod_GetLoop**)(*PyArrayMethod_Context* *context, int aligned, int move_references, const *npy_intp* *strides, *PyArrayMethod_StridedLoop* **out_loop, *NpyAuxData* **out_transferdata, *NPY_ARRAYMETHOD_FLAGS* *flags);

Sets the loop to use for an operation at runtime. The *context* is the runtime context for the operation. *aligned* indicates whether the data access for the loop is aligned (1) or unaligned (0). *move_references* indicates whether embedded references in the data should be copied. *strides* are the strides for the input array, *out_loop* is a pointer that must be filled in with a pointer to the loop implementation. *out_transferdata* can be optionally filled in to allow passing in extra user-defined context to an operation. *flags* must be filled in with ArrayMethod flags relevant for the operation. This is for example necessary to indicate if the inner loop requires the Python GIL to be held.

NPY_METH_get_reduction_initial

typedef int (**PyArrayMethod_GetReductionInitial**)(*PyArrayMethod_Context* *context, *npy_bool* reduction_is_empty, char *initial)

Query an ArrayMethod for the initial value for use in reduction. The *context* is the ArrayMethod context, mainly to access the input descriptors. *reduction_is_empty* indicates whether the reduction is empty. When it is, the value returned may differ. In this case it is a "default" value that may differ from the "identity" value normally used. For example:

- `0.0` is the default for `sum([])`. But `-0.0` is the correct identity otherwise as it preserves the sign for `sum([-0.0])`.
- We use no identity for object, but return the default of `0` and `1` for the empty `sum([], dtype=object)` and `prod([], dtype=object)`. This allows `np.sum(np.array(["a", "b"], dtype=object))` to work.
- `-inf` or `INT_MIN` for `max` is an identity, but at least `INT_MIN` not a good *default* when there are no items.

initial is a pointer to the data for the initial value, which should be filled in. Returns -1, 0, or 1 indicating error, no initial value, and the initial value being successfully filled. Errors must not be given when no initial value is correct, since NumPy may call this even when it is not strictly necessary to do so.

Flags

enum **NPY_ARRAYMETHOD_FLAGS**

These flags allow switching on and off custom runtime behavior for ArrayMethod loops. For example, if a ufunc cannot possibly trigger floating point errors, then the `NPY_METH_NO_FLOATINGPOINT_ERRORS` flag should be set on the ufunc when it is registered.

enumerator **NPY_METH_REQUIRES_PYAPI**

Indicates the method must hold the GIL. If this flag is not set, the GIL is released before the loop is called.

enumerator **NPY_METH_NO_FLOATINGPOINT_ERRORS**

Indicates the method cannot generate floating errors, so checking for floating errors after the loop completes can be skipped.

enumerator **NPY_METH_SUPPORTS_UNALIGNED**

Indicates the method supports unaligned access.

enumerator **NPY_METH_IS_REORDERABLE**

Indicates that the result of applying the loop repeatedly (for example, in a reduction operation) does not depend on the order of application.

enumerator **NPY_METH_RUNTIME_FLAGS**

The flags that can be changed at runtime.

Typedefs

Typedefs for functions that users of the ArrayMethod API can implement are described below.

typedef int (**PyArrayMethod_TraverseLoop**)(void *traverse_context, const *PyArray_Descr* *descr, char *data, *npy_intp* size, *npy_intp* stride, *NpyAuxData* *auxdata)

A traverse loop working on a single array. This is similar to the general strided-loop function. This is designed for loops that need to visit every element of a single array.

Currently this is used for array clearing, via the `NPY_DT_get_clear_loop` DType API hook, and zero-filling, via the `NPY_DT_get_fill_zero_loop` DType API hook. These are most useful for handling arrays storing embedded references to python objects or heap-allocated data.

The *descr* is the descriptor for the array, *data* is a pointer to the array buffer, *size* is the 1D size of the array buffer, *stride* is the stride, and *auxdata* is optional extra data for the loop.

The *traverse_context* is passed in because we may need to pass in Interpreter state or similar in the future, but we don't want to pass in a full context (with pointers to dtypes, method, caller which all make no sense for a traverse function). We assume for now that this context can be just passed through in the future (for structured dtypes).

typedef int (**PyArrayMethod_GetTraverseLoop**)(void *traverse_context, const *PyArray_Descr* *descr, int aligned, *npy_intp* fixed_stride, *PyArrayMethod_TraverseLoop* **out_loop, *NpyAuxData* **out_auxdata, *NPY_ARRAYMETHOD_FLAGS* *flags)

Simplified get_loop function specific to dtype traversal

It should set the flags needed for the traversal loop and set *out_loop* to the loop function, which must be a valid `PyArrayMethod_TraverseLoop` pointer. Currently this is used for zero-filling and clearing arrays storing embedded references.

API Functions and Typedefs

These functions are part of the main numpy array API and were added along with the rest of the ArrayMethod API.

int **PyUFunc_AddLoopFromSpec**(PyObject *ufunc, *PyArrayMethod_Spec* *spec)

Add loop directly to a ufunc from a given ArrayMethod spec. the main ufunc registration function. This adds a new implementation/loop to a ufunc. It replaces *PyUFunc_RegisterLoopForType*.

int **PyUFunc_AddPromoter**(PyObject *ufunc, PyObject *DType_tuple, PyObject *promoter)

Note that currently the output dtypes are always `NULL` unless they are also part of the signature. This is an implementation detail and could change in the future. However, in general promoters should not have a need for output dtypes. Register a new promoter for a ufunc. The first argument is the ufunc to register the promoter with. The second argument is a Python tuple containing DTypes or None matching the number of inputs and outputs for the ufuncs. The last argument is a promoter is a function stored in a PyCapsule. It is passed the operation and requested DType signatures and can mutate it to attempt a new search for a matching loop/promoter.

typedef int (**PyArrayMethod_PromoterFunction**)(PyObject *ufunc, *PyArray_DTypeMeta* *const op_dtypes[], *PyArray_DTypeMeta* *const signature[], *PyArray_DTypeMeta* *new_op_dtypes[])

Type of the promoter function, which must be wrapped into a `PyCapsule` with name `"numpy._ufunc_promoter"`. It is passed the operation and requested DType signatures and can mutate the signatures to attempt a search for a new loop or promoter that can accomplish the operation by casting the inputs to the "promoted" DTypes.

int **PyUFunc_GiveFloatingpointErrors**(const char *name, int fpe_errors)

Checks for a floating point error after performing a floating point operation in a manner that takes into account the error signaling configured via *numpy.errstate*. Takes the name of the operation to use in the error message and an integer flag that is one of `NPY_FPE_DIVIDEBYZERO`, `NPY_FPE_OVERFLOW`, `NPY_FPE_UNDERFLOW`, `NPY_FPE_INVALID` to indicate which error to check for.

Returns -1 on failure (an error was raised) and 0 on success.

int **PyUFunc_AddWrappingLoop**(PyObject *ufunc_obj, *PyArray_DTypeMeta* *new_dtypes[], *PyArray_DTypeMeta* *wrapped_dtypes[], *PyArrayMethod_TranslateGivenDescriptors* *translate_given_descrs, *PyArrayMethod_TranslateLoopDescriptors* *translate_loop_descrs)

Allows creating of a fairly lightweight wrapper around an existing ufunc loop. The idea is mainly for units, as this is currently slightly limited in that it enforces that you cannot use a loop from another ufunc.

typedef int (**PyArrayMethod_TranslateGivenDescriptors**)(int nin, int nout, *PyArray_DTypeMeta* *wrapped_dtypes[], *PyArray_Descr* *given_descrs[], *PyArray_Descr* *new_descrs[]);

The function to convert the given descriptors (passed in to `resolve_descriptors`) and translates them for the wrapped loop. The new descriptors MUST be viewable with the old ones, *NULL* must be supported (for output arguments) and should normally be forwarded.

The output of of this function will be used to construct views of the arguments as if they were the translated dtypes and does not use a cast. This means this mechanism is mostly useful for DTypes that "wrap" another DType implementation. For example, a unit DType could use this to wrap an existing floating point DType without needing to re-implement low-level ufunc logic. In the unit example, `resolve_descriptors` would handle computing the output unit from the input unit.

typedef int (**PyArrayMethod_TranslateLoopDescriptors**)(int nin, int nout, *PyArray_DTypeMeta* *new_dtypes[], *PyArray_Descr* *given_descrs[], *PyArray_Descr* *original_descrs[], *PyArray_Descr* *loop_descrs[]);

The function to convert the actual loop descriptors (as returned by the original *resolve_descriptors* function) to the ones the output array should use. This function must return "viewable" types, it must not mutate them in any form that would break the inner-loop logic. Does not need to support NULL.

Wrapping Loop Example

Suppose you want to wrap the `float64` multiply implementation for a `WrappedDoubleDType`. You would add a wrapping loop like so:

```
PyArray_DTypeMeta *orig_dtypes[3] = {
    &WrappedDoubleDType, &WrappedDoubleDType, &WrappedDoubleDType};
PyArray_DTypeMeta *wrapped_dtypes[3] = {
     &PyArray_Float64DType, &PyArray_Float64DType, &PyArray_Float64DType}

PyObject *mod = PyImport_ImportModule("numpy");
if (mod == NULL) {
    return -1;
}
PyObject *multiply = PyObject_GetAttrString(mod, "multiply");
Py_DECREF(mod);

if (multiply == NULL) {
    return -1;
}

int res = PyUFunc_AddWrappingLoop(
    multiply, orig_dtypes, wrapped_dtypes, &translate_given_descrs
    &translate_loop_descrs);

Py_DECREF(multiply);
```

Note that this also requires two functions to be defined above this code:

```
static int
translate_given_descrs(int nin, int nout,
                       PyArray_DTypeMeta *NPY_UNUSED(wrapped_dtypes[]),
                       PyArray_Descr *given_descrs[],
                       PyArray_Descr *new_descrs[])
{
    for (int i = 0; i < nin + nout; i++) {
        if (given_descrs[i] == NULL) {
            new_descrs[i] = NULL;
        }
        else {
            new_descrs[i] = PyArray_DescrFromType(NPY_DOUBLE);
        }
    }
    return 0;
```

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```
}

static int
translate_loop_descrs(int nin, int NPY_UNUSED(nout),
                      PyArray_DTypeMeta *NPY_UNUSED(new_dtypes[]),
                      PyArray_Descr *given_descrs[],
                      PyArray_Descr *original_descrs[],
                      PyArray_Descr *loop_descrs[])
{
    // more complicated parametric DTypes may need to
    // to do additional checking, but we know the wrapped
    // DTypes *have* to be float64 for this example.
    loop_descrs[0] = PyArray_DescrFromType(NPY_FLOAT64);
    Py_INCREF(loop_descrs[0]);
    loop_descrs[1] = PyArray_DescrFromType(NPY_FLOAT64);
    Py_INCREF(loop_descrs[1]);
    loop_descrs[2] = PyArray_DescrFromType(NPY_FLOAT64);
    Py_INCREF(loop_descrs[2]);
}
```

API for calling array methods

Conversion

PyObject ***PyArray_GetField**(*PyArrayObject* *self, *PyArray_Descr* *dtype, int offset)

Equivalent to `ndarray.getfield` (*self*, *dtype*, *offset*). This function steals a reference to `PyArray_Descr` and returns a new array of the given *dtype* using the data in the current array at a specified *offset* in bytes. The *offset* plus the itemsize of the new array type must be less than `self->descr->elsize` or an error is raised. The same shape and strides as the original array are used. Therefore, this function has the effect of returning a field from a structured array. But, it can also be used to select specific bytes or groups of bytes from any array type.

int **PyArray_SetField**(*PyArrayObject* *self, *PyArray_Descr* *dtype, int offset, PyObject *val)

Equivalent to `ndarray.setfield` (*self*, *val*, *dtype*, *offset*). Set the field starting at *offset* in bytes and of the given *dtype* to *val*. The *offset* plus *dtype* ->elsize must be less than *self* ->descr->elsize or an error is raised. Otherwise, the *val* argument is converted to an array and copied into the field pointed to. If necessary, the elements of *val* are repeated to fill the destination array, But, the number of elements in the destination must be an integer multiple of the number of elements in *val*.

PyObject ***PyArray_Byteswap**(*PyArrayObject* *self, *npy_bool* inplace)

Equivalent to `ndarray.byteswap` (*self*, *inplace*). Return an array whose data area is byteswapped. If *inplace* is non-zero, then do the byteswap inplace and return a reference to self. Otherwise, create a byteswapped copy and leave self unchanged.

PyObject ***PyArray_NewCopy**(*PyArrayObject* *old, *NPY_ORDER* order)

Equivalent to `ndarray.copy` (*self*, *fortran*). Make a copy of the *old* array. The returned array is always aligned and writeable with data interpreted the same as the old array. If *order* is `NPY_CORDER`, then a C-style contiguous array is returned. If *order* is `NPY_FORTRANORDER`, then a Fortran-style contiguous array is returned. If *order is* `NPY_ANYORDER`, then the array returned is Fortran-style contiguous only if the old one is; otherwise, it is C-style contiguous.

PyObject ***PyArray_ToList**(*PyArrayObject* *self)

Equivalent to `ndarray.tolist` (*self*). Return a nested Python list from *self*.

PyObject ***PyArray_ToString**(*PyArrayObject* *self, *NPY_ORDER* order)

Equivalent to `ndarray.tobytes` (*self*, *order*). Return the bytes of this array in a Python string.

PyObject ***PyArray_ToFile**(*PyArrayObject* *self, FILE *fp, char *sep, char *format)

Write the contents of *self* to the file pointer *fp* in C-style contiguous fashion. Write the data as binary bytes if *sep* is the string “”or `NULL`. Otherwise, write the contents of *self* as text using the *sep* string as the item separator. Each item will be printed to the file. If the *format* string is not `NULL` or “”, then it is a Python print statement format string showing how the items are to be written.

int **PyArray_Dump**(PyObject *self, PyObject *file, int protocol)

Pickle the object in *self* to the given *file* (either a string or a Python file object). If *file* is a Python string it is considered to be the name of a file which is then opened in binary mode. The given *protocol* is used (if *protocol* is negative, or the highest available is used). This is a simple wrapper around cPickle.dump(*self*, *file*, *protocol*).

PyObject ***PyArray_Dumps**(PyObject *self, int protocol)

Pickle the object in *self* to a Python string and return it. Use the Pickle *protocol* provided (or the highest available if *protocol* is negative).

int **PyArray_FillWithScalar**(*PyArrayObject* *arr, PyObject *obj)

Fill the array, *arr*, with the given scalar object, *obj*. The object is first converted to the data type of *arr*, and then copied into every location. A -1 is returned if an error occurs, otherwise 0 is returned.

PyObject ***PyArray_View**(*PyArrayObject* *self, *PyArray_Descr* *dtype, PyTypeObject *ptype)

Equivalent to `ndarray.view` (*self*, *dtype*). Return a new view of the array *self* as possibly a different data-type, *dtype*, and different array subclass *ptype*.

If *dtype* is `NULL`, then the returned array will have the same data type as *self*. The new data-type must be consistent with the size of *self*. Either the itemsizes must be identical, or *self* must be single-segment and the total number of bytes must be the same. In the latter case the dimensions of the returned array will be altered in the last (or first for Fortran-style contiguous arrays) dimension. The data area of the returned array and self is exactly the same.

Shape Manipulation

PyObject ***PyArray_Newshape**(*PyArrayObject* *self, *PyArray_Dims* *newshape, *NPY_ORDER* order)

Result will be a new array (pointing to the same memory location as *self* if possible), but having a shape given by *newshape*. If the new shape is not compatible with the strides of *self*, then a copy of the array with the new specified shape will be returned.

PyObject ***PyArray_Reshape**(*PyArrayObject* *self, PyObject *shape)

Equivalent to `ndarray.reshape` (*self*, *shape*) where *shape* is a sequence. Converts *shape* to a `PyArray_Dims` structure and calls `PyArray_Newshape` internally. For back-ward compatibility – Not recommended

PyObject ***PyArray_Squeeze**(*PyArrayObject* *self)

Equivalent to `ndarray.squeeze` (*self*). Return a new view of *self* with all of the dimensions of length 1 removed from the shape.

Warning: matrix objects are always 2-dimensional. Therefore, `PyArray_Squeeze` has no effect on arrays of matrix sub-class.

PyObject ***PyArray_SwapAxes**(*PyArrayObject* *self, int a1, int a2)

Equivalent to `ndarray.swapaxes` (*self*, *a1*, *a2*). The returned array is a new view of the data in *self* with the given axes, *a1* and *a2*, swapped.

PyObject ***PyArray_Resize**(*PyArrayObject* *self, *PyArray_Dims* *newshape, int refcheck, *NPY_ORDER* fortran)

Equivalent to `ndarray.resize` (*self*, *newshape*, refcheck = *refcheck*, order= fortran). This function only works on single-segment arrays. It changes the shape of *self* inplace and will reallocate the memory for *self* if *newshape* has a different total number of elements then the old shape. If reallocation is necessary, then *self* must own its

data, have *self* - >base==NULL, have *self* - >weakrefs==NULL, and (unless refcheck is 0) not be referenced by any other array. The fortran argument can be *NPY_ANYORDER*, *NPY_CORDER*, or *NPY_FORTRANORDER*. It currently has no effect. Eventually it could be used to determine how the resize operation should view the data when constructing a differently-dimensioned array. Returns None on success and NULL on error.

PyObject ***PyArray_Transpose**(*PyArrayObject* *self, *PyArray_Dims* *permute)

Equivalent to *ndarray.transpose* (*self*, *permute*). Permute the axes of the ndarray object *self* according to the data structure *permute* and return the result. If *permute* is NULL, then the resulting array has its axes reversed. For example if *self* has shape $10 \times 20 \times 30$, and *permute* .ptr is (0,2,1) the shape of the result is $10 \times 30 \times 20$. If *permute* is NULL, the shape of the result is $30 \times 20 \times 10$.

PyObject ***PyArray_Flatten**(*PyArrayObject* *self, *NPY_ORDER* order)

Equivalent to *ndarray.flatten* (*self*, *order*). Return a 1-d copy of the array. If *order* is *NPY_FORTRANORDER* the elements are scanned out in Fortran order (first-dimension varies the fastest). If *order* is *NPY_CORDER*, the elements of self are scanned in C-order (last dimension varies the fastest). If *order* *NPY_ANYORDER*, then the result of *PyArray_ISFORTRAN* (*self*) is used to determine which order to flatten.

PyObject ***PyArray_Ravel**(*PyArrayObject* *self, *NPY_ORDER* order)

Equivalent to *self*.ravel(*order*). Same basic functionality as *PyArray_Flatten* (*self*, *order*) except if *order* is 0 and *self* is C-style contiguous, the shape is altered but no copy is performed.

Item selection and manipulation

PyObject ***PyArray_TakeFrom**(*PyArrayObject* *self, PyObject *indices, int axis, *PyArrayObject* *ret, *NPY_CLIPMODE* clipmode)

Equivalent to *ndarray.take* (*self*, *indices*, *axis*, *ret*, *clipmode*) except *axis* =None in Python is obtained by setting *axis* = *NPY_MAXDIMS* in C. Extract the items from self indicated by the integer-valued *indices* along the given *axis.* The clipmode argument can be *NPY_RAISE*, *NPY_WRAP*, or *NPY_CLIP* to indicate what to do with out-of-bound indices. The *ret* argument can specify an output array rather than having one created internally.

PyObject ***PyArray_PutTo**(*PyArrayObject* *self, PyObject *values, PyObject *indices, *NPY_CLIPMODE* clipmode)

Equivalent to *self*.put(*values*, *indices*, *clipmode*). Put *values* into *self* at the corresponding (flattened) *indices*. If *values* is too small it will be repeated as necessary.

PyObject ***PyArray_PutMask**(*PyArrayObject* *self, PyObject *values, PyObject *mask)

Place the *values* in *self* wherever corresponding positions (using a flattened context) in *mask* are true. The *mask* and *self* arrays must have the same total number of elements. If *values* is too small, it will be repeated as necessary.

PyObject ***PyArray_Repeat**(*PyArrayObject* *self, PyObject *op, int axis)

Equivalent to *ndarray.repeat* (*self*, *op*, *axis*). Copy the elements of *self*, *op* times along the given *axis*. Either *op* is a scalar integer or a sequence of length *self* ->dimensions[*axis*] indicating how many times to repeat each item along the axis.

PyObject ***PyArray_Choose**(*PyArrayObject* *self, PyObject *op, *PyArrayObject* *ret, *NPY_CLIPMODE* clipmode)

Equivalent to *ndarray.choose* (*self*, *op*, *ret*, *clipmode*). Create a new array by selecting elements from the sequence of arrays in *op* based on the integer values in *self*. The arrays must all be broadcastable to the same shape and the entries in *self* should be between 0 and len(*op*). The output is placed in *ret* unless it is NULL in which case a new output is created. The *clipmode* argument determines behavior for when entries in *self* are not between 0 and len(*op*).

NPY_RAISE

raise a ValueError;

NPY_WRAP

wrap values < 0 by adding len(*op*) and values >=len(*op*) by subtracting len(*op*) until they are in range;

NPY_CLIP

all values are clipped to the region [0, len(*op*)).

PyObject ***PyArray_Sort**(*PyArrayObject* *self, int axis, *NPY_SORTKIND* kind)

Equivalent to `ndarray.sort` (*self*, *axis*, *kind*). Return an array with the items of *self* sorted along *axis*. The array is sorted using the algorithm denoted by *kind*, which is an integer/enum pointing to the type of sorting algorithms used.

PyObject ***PyArray_ArgSort**(*PyArrayObject* *self, int axis)

Equivalent to `ndarray.argsort` (*self*, *axis*). Return an array of indices such that selection of these indices along the given `axis` would return a sorted version of *self*. If *self* ->descr is a data-type with fields defined, then self->descr->names is used to determine the sort order. A comparison where the first field is equal will use the second field and so on. To alter the sort order of a structured array, create a new data-type with a different order of names and construct a view of the array with that new data-type.

PyObject ***PyArray_LexSort**(PyObject *sort_keys, int axis)

Given a sequence of arrays (*sort_keys*) of the same shape, return an array of indices (similar to `PyArray_ArgSort` (...)) that would sort the arrays lexicographically. A lexicographic sort specifies that when two keys are found to be equal, the order is based on comparison of subsequent keys. A merge sort (which leaves equal entries unmoved) is required to be defined for the types. The sort is accomplished by sorting the indices first using the first *sort_key* and then using the second *sort_key* and so forth. This is equivalent to the lexsort(*sort_keys*, *axis*) Python command. Because of the way the merge-sort works, be sure to understand the order the *sort_keys* must be in (reversed from the order you would use when comparing two elements).

If these arrays are all collected in a structured array, then `PyArray_Sort` (...) can also be used to sort the array directly.

PyObject ***PyArray_SearchSorted**(*PyArrayObject* *self, PyObject *values, *NPY_SEARCHSIDE* side, PyObject *perm)

Equivalent to `ndarray.searchsorted` (*self*, *values*, *side*, *perm*). Assuming *self* is a 1-d array in ascending order, then the output is an array of indices the same shape as *values* such that, if the elements in *values* were inserted before the indices, the order of *self* would be preserved. No checking is done on whether or not self is in ascending order.

The *side* argument indicates whether the index returned should be that of the first suitable location (if `NPY_SEARCHLEFT`) or of the last (if `NPY_SEARCHRIGHT`).

The *sorter* argument, if not `NULL`, must be a 1D array of integer indices the same length as *self*, that sorts it into ascending order. This is typically the result of a call to `PyArray_ArgSort` (...) Binary search is used to find the required insertion points.

int **PyArray_Partition**(*PyArrayObject* *self, *PyArrayObject* *ktharray, int axis, *NPY_SELECTKIND* which)

Equivalent to `ndarray.partition` (*self*, *ktharray*, *axis*, *kind*). Partitions the array so that the values of the element indexed by *ktharray* are in the positions they would be if the array is fully sorted and places all elements smaller than the kth before and all elements equal or greater after the kth element. The ordering of all elements within the partitions is undefined. If *self* ->descr is a data-type with fields defined, then self->descr->names is used to determine the sort order. A comparison where the first field is equal will use the second field and so on. To alter the sort order of a structured array, create a new data-type with a different order of names and construct a view of the array with that new data-type. Returns zero on success and -1 on failure.

PyObject ***PyArray_ArgPartition**(*PyArrayObject* *op, *PyArrayObject* *ktharray, int axis, *NPY_SELECTKIND* which)

Equivalent to `ndarray.argpartition` (*self*, *ktharray*, *axis*, *kind*). Return an array of indices such that selection of these indices along the given `axis` would return a partitioned version of *self*.

PyObject ***PyArray_Diagonal**(*PyArrayObject* *self, int offset, int axis1, int axis2)

Equivalent to `ndarray.diagonal` (*self*, *offset*, *axis1*, *axis2*). Return the *offset* diagonals of the 2-d arrays defined by *axis1* and *axis2*.

npy_intp **PyArray_CountNonzero**(*PyArrayObject* *self)

Counts the number of non-zero elements in the array object *self*.

PyObject ***PyArray_Nonzero**(*PyArrayObject* *self)

Equivalent to `ndarray.nonzero` (*self*). Returns a tuple of index arrays that select elements of *self* that are nonzero. If (nd= `PyArray_NDIM` (`self`))==1, then a single index array is returned. The index arrays have data type `NPY_INTP`. If a tuple is returned (nd $\neq$ 1), then its length is nd.

PyObject ***PyArray_Compress**(*PyArrayObject* *self, PyObject *condition, int axis, *PyArrayObject* *out)

Equivalent to `ndarray.compress` (*self*, *condition*, *axis*). Return the elements along *axis* corresponding to elements of *condition* that are true.

Calculation

Tip: Pass in `NPY_RAVEL_AXIS` for axis in order to achieve the same effect that is obtained by passing in `axis=None` in Python (treating the array as a 1-d array).

Note: The out argument specifies where to place the result. If out is NULL, then the output array is created, otherwise the output is placed in out which must be the correct size and type. A new reference to the output array is always returned even when out is not NULL. The caller of the routine has the responsibility to `Py_DECREF` out if not NULL or a memory-leak will occur.

PyObject ***PyArray_ArgMax**(*PyArrayObject* *self, int axis, *PyArrayObject* *out)

Equivalent to `ndarray.argmax` (*self*, *axis*). Return the index of the largest element of *self* along *axis*.

PyObject ***PyArray_ArgMin**(*PyArrayObject* *self, int axis, *PyArrayObject* *out)

Equivalent to `ndarray.argmin` (*self*, *axis*). Return the index of the smallest element of *self* along *axis*.

PyObject ***PyArray_Max**(*PyArrayObject* *self, int axis, *PyArrayObject* *out)

Equivalent to `ndarray.max` (*self*, *axis*). Returns the largest element of *self* along the given *axis*. When the result is a single element, returns a numpy scalar instead of an ndarray.

PyObject ***PyArray_Min**(*PyArrayObject* *self, int axis, *PyArrayObject* *out)

Equivalent to `ndarray.min` (*self*, *axis*). Return the smallest element of *self* along the given *axis*. When the result is a single element, returns a numpy scalar instead of an ndarray.

PyObject ***PyArray_Ptp**(*PyArrayObject* *self, int axis, *PyArrayObject* *out)

Return the difference between the largest element of *self* along *axis* and the smallest element of *self* along *axis*. When the result is a single element, returns a numpy scalar instead of an ndarray.

Note: The rtype argument specifies the data-type the reduction should take place over. This is important if the data-type of the array is not "large" enough to handle the output. By default, all integer data-types are made at least as large as `NPY_LONG` for the "add" and "multiply" ufuncs (which form the basis for mean, sum, cumsum, prod, and cumprod functions).

PyObject ***PyArray_Mean**(*PyArrayObject* *self, int axis, int rtype, *PyArrayObject* *out)

Equivalent to `ndarray.mean` (*self*, *axis*, *rtype*). Returns the mean of the elements along the given *axis*, using

the enumerated type *rtype* as the data type to sum in. Default sum behavior is obtained using `NPY_NOTYPE` for *rtype*.

PyObject ***PyArray_Trace**(*PyArrayObject* *self, int offset, int axis1, int axis2, int rtype, *PyArrayObject* *out)

Equivalent to `ndarray.trace` (*self*, *offset*, *axis1*, *axis2*, *rtype*). Return the sum (using *rtype* as the data type of summation) over the *offset* diagonal elements of the 2-d arrays defined by *axis1* and *axis2* variables. A positive offset chooses diagonals above the main diagonal. A negative offset selects diagonals below the main diagonal.

PyObject ***PyArray_Clip**(*PyArrayObject* *self, PyObject *min, PyObject *max)

Equivalent to `ndarray.clip` (*self*, *min*, *max*). Clip an array, *self*, so that values larger than *max* are fixed to *max* and values less than *min* are fixed to *min*.

PyObject ***PyArray_Conjugate**(*PyArrayObject* *self, *PyArrayObject* *out)

Equivalent to `ndarray.conjugate` (*self*). Return the complex conjugate of *self*. If *self* is not of complex data type, then return *self* with a reference.

Parameters

- **self** – Input array.
- **out** – Output array. If provided, the result is placed into this array.

Returns

The complex conjugate of *self*.

PyObject ***PyArray_Round**(*PyArrayObject* *self, int decimals, *PyArrayObject* *out)

Equivalent to `ndarray.round` (*self*, *decimals*, *out*). Returns the array with elements rounded to the nearest decimal place. The decimal place is defined as the $10^{-\text{decimals}}$ digit so that negative *decimals* cause rounding to the nearest 10's, 100's, etc. If out is `NULL`, then the output array is created, otherwise the output is placed in *out* which must be the correct size and type.

PyObject ***PyArray_Std**(*PyArrayObject* *self, int axis, int rtype, *PyArrayObject* *out)

Equivalent to `ndarray.std` (*self*, *axis*, *rtype*). Return the standard deviation using data along *axis* converted to data type *rtype*.

PyObject ***PyArray_Sum**(*PyArrayObject* *self, int axis, int rtype, *PyArrayObject* *out)

Equivalent to `ndarray.sum` (*self*, *axis*, *rtype*). Return 1-d vector sums of elements in *self* along *axis*. Perform the sum after converting data to data type *rtype*.

PyObject ***PyArray_CumSum**(*PyArrayObject* *self, int axis, int rtype, *PyArrayObject* *out)

Equivalent to `ndarray.cumsum` (*self*, *axis*, *rtype*). Return cumulative 1-d sums of elements in *self* along *axis*. Perform the sum after converting data to data type *rtype*.

PyObject ***PyArray_Prod**(*PyArrayObject* *self, int axis, int rtype, *PyArrayObject* *out)

Equivalent to `ndarray.prod` (*self*, *axis*, *rtype*). Return 1-d products of elements in *self* along *axis*. Perform the product after converting data to data type *rtype*.

PyObject ***PyArray_CumProd**(*PyArrayObject* *self, int axis, int rtype, *PyArrayObject* *out)

Equivalent to `ndarray.cumprod` (*self*, *axis*, *rtype*). Return 1-d cumulative products of elements in `self` along `axis`. Perform the product after converting data to data type `rtype`.

PyObject ***PyArray_All**(*PyArrayObject* *self, int axis, *PyArrayObject* *out)

Equivalent to `ndarray.all` (*self*, *axis*). Return an array with True elements for every 1-d sub-array of `self` defined by `axis` in which all the elements are True.

PyObject ***PyArray_Any**(*PyArrayObject* *self, int axis, *PyArrayObject* *out)

Equivalent to `ndarray.any` (*self*, *axis*). Return an array with True elements for every 1-d sub-array of *self* defined by *axis* in which any of the elements are True.

Functions

Array Functions

int **PyArray_AsCArray**(PyObject **op, void *ptr, *npy_intp* *dims, int nd, *PyArray_Descr* *typedescr)

Sometimes it is useful to access a multidimensional array as a C-style multi-dimensional array so that algorithms can be implemented using C's a[i][j][k] syntax. This routine returns a pointer, *ptr*, that simulates this kind of C-style array, for 1-, 2-, and 3-d ndarrays.

Parameters

- **op** – The address to any Python object. This Python object will be replaced with an equivalent well-behaved, C-style contiguous, ndarray of the given data type specified by the last two arguments. Be sure that stealing a reference in this way to the input object is justified.
- **ptr** – The address to a (ctype* for 1-d, ctype** for 2-d or ctype*** for 3-d) variable where ctype is the equivalent C-type for the data type. On return, *ptr* will be addressable as a 1-d, 2-d, or 3-d array.
- **dims** – An output array that contains the shape of the array object. This array gives boundaries on any looping that will take place.
- **nd** – The dimensionality of the array (1, 2, or 3).
- **typedescr** – A *PyArray_Descr* structure indicating the desired data-type (including required byteorder). The call will steal a reference to the parameter.

Note: The simulation of a C-style array is not complete for 2-d and 3-d arrays. For example, the simulated arrays of pointers cannot be passed to subroutines expecting specific, statically-defined 2-d and 3-d arrays. To pass to functions requiring those kind of inputs, you must statically define the required array and copy data.

---

int **PyArray_Free**(PyObject *op, void *ptr)

Must be called with the same objects and memory locations returned from *PyArray_AsCArray* (…). This function cleans up memory that otherwise would get leaked.

PyObject ***PyArray_Concatenate**(PyObject *obj, int axis)

Join the sequence of objects in *obj* together along *axis* into a single array. If the dimensions or types are not compatible an error is raised.

PyObject ***PyArray_InnerProduct**(PyObject *obj1, PyObject *obj2)

Compute a product-sum over the last dimensions of *obj1* and *obj2*. Neither array is conjugated.

PyObject ***PyArray_MatrixProduct**(PyObject *obj1, PyObject *obj)

Compute a product-sum over the last dimension of *obj1* and the second-to-last dimension of *obj2*. For 2-d arrays this is a matrix-product. Neither array is conjugated.

PyObject ***PyArray_MatrixProduct2**(PyObject *obj1, PyObject *obj, *PyArrayObject* *out)

Same as PyArray_MatrixProduct, but store the result in *out*. The output array must have the correct shape, type, and be C-contiguous, or an exception is raised.

PyArrayObject ***PyArray_EinsteinSum**(char *subscripts, *npy_intp* nop, *PyArrayObject* **op_in, *PyArray_Descr* *dtype, *NPY_ORDER* order, *NPY_CASTING* casting, *PyArrayObject* *out)

Applies the Einstein summation convention to the array operands provided, returning a new array or placing the result in *out*. The string in *subscripts* is a comma separated list of index letters. The number of operands is in *nop*, and *op_in* is an array containing those operands. The data type of the output can be forced with *dtype*, the

output order can be forced with *order* (*NPY_KEEPORDER* is recommended), and when *dtype* is specified, *casting* indicates how permissive the data conversion should be.

See the *einsum* function for more details.

PyObject ***PyArray_Correlate***(PyObject *op1, PyObject *op2, int mode)

Compute the 1-d correlation of the 1-d arrays *op1* and *op2* . The correlation is computed at each output point by multiplying *op1* by a shifted version of *op2* and summing the result. As a result of the shift, needed values outside of the defined range of *op1* and *op2* are interpreted as zero. The mode determines how many shifts to return: 0 - return only shifts that did not need to assume zero- values; 1 - return an object that is the same size as *op1*, 2 - return all possible shifts (any overlap at all is accepted).

Notes

This does not compute the usual correlation: if op2 is larger than op1, the arguments are swapped, and the conjugate is never taken for complex arrays. See PyArray_Correlate2 for the usual signal processing correlation.

PyObject ***PyArray_Correlate2***(PyObject *op1, PyObject *op2, int mode)

Updated version of PyArray_Correlate, which uses the usual definition of correlation for 1d arrays. The correlation is computed at each output point by multiplying *op1* by a shifted version of *op2* and summing the result. As a result of the shift, needed values outside of the defined range of *op1* and *op2* are interpreted as zero. The mode determines how many shifts to return: 0 - return only shifts that did not need to assume zero- values; 1 - return an object that is the same size as *op1*, 2 - return all possible shifts (any overlap at all is accepted).

Notes

Compute z as follows:

```
z[k] = sum_n op1[n] * conj(op2[n+k])
```

PyObject ***PyArray_Where***(PyObject *condition, PyObject *x, PyObject *y)

If both `x` and `y` are `NULL`, then return *PyArray_Nonzero* (*condition*). Otherwise, both *x* and *y* must be given and the object returned is shaped like *condition* and has elements of *x* and *y* where *condition* is respectively True or False.

Other functions

npy_bool ***PyArray_CheckStrides***(int elsize, int nd, *npy_intp* numbytes, *npy_intp* const *dims, *npy_intp* const *newstrides)

Determine if *newstrides* is a strides array consistent with the memory of an *nd* -dimensional array with shape `dims` and element-size, *elsize*. The *newstrides* array is checked to see if jumping by the provided number of bytes in each direction will ever mean jumping more than *numbytes* which is the assumed size of the available memory segment. If *numbytes* is 0, then an equivalent *numbytes* is computed assuming *nd*, *dims*, and *elsize* refer to a single-segment array. Return *NPY_TRUE* if *newstrides* is acceptable, otherwise return *NPY_FALSE*.

npy_intp ***PyArray_MultiplyList***(*npy_intp* const *seq, int n)

int ***PyArray_MultiplyIntList***(int const *seq, int n)

Both of these routines multiply an *n* -length array, *seq*, of integers and return the result. No overflow checking is performed.

int ***PyArray_CompareLists***(*npy_intp* const *l1, *npy_intp* const *l2, int n)

Given two *n* -length arrays of integers, *l1*, and *l2*, return 1 if the lists are identical; otherwise, return 0.

Auxiliary data with object semantics

type **NpyAuxData**

When working with more complex dtypes which are composed of other dtypes, such as the struct dtype, creating inner loops that manipulate the dtypes requires carrying along additional data. NumPy supports this idea through a struct *NpyAuxData*, mandating a few conventions so that it is possible to do this.

Defining an *NpyAuxData* is similar to defining a class in C++, but the object semantics have to be tracked manually since the API is in C. Here's an example for a function which doubles up an element using an element copier function as a primitive.

```
typedef struct {
    NpyAuxData base;
    ElementCopier_Func *func;
    NpyAuxData *funcdata;
} eldoubler_aux_data;

void free_element_doubler_aux_data(NpyAuxData *data)
{
    eldoubler_aux_data *d = (eldoubler_aux_data *)data;
    /* Free the memory owned by this auxdata */
    NPY_AUXDATA_FREE(d->funcdata);
    PyArray_free(d);
}

NpyAuxData *clone_element_doubler_aux_data(NpyAuxData *data)
{
    eldoubler_aux_data *ret = PyArray_malloc(sizeof(eldoubler_aux_data));
    if (ret == NULL) {
        return NULL;
    }

    /* Raw copy of all data */
    memcpy(ret, data, sizeof(eldoubler_aux_data));

    /* Fix up the owned auxdata so we have our own copy */
    ret->funcdata = NPY_AUXDATA_CLONE(ret->funcdata);
    if (ret->funcdata == NULL) {
        PyArray_free(ret);
        return NULL;
    }

    return (NpyAuxData *)ret;
}

NpyAuxData *create_element_doubler_aux_data(
                            ElementCopier_Func *func,
                            NpyAuxData *funcdata)
{
    eldoubler_aux_data *ret = PyArray_malloc(sizeof(eldoubler_aux_data));
    if (ret == NULL) {
        PyErr_NoMemory();
        return NULL;
    }
    memset(&ret, 0, sizeof(eldoubler_aux_data));
    ret->base->free = &free_element_doubler_aux_data;
    ret->base->clone = &clone_element_doubler_aux_data;
```

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```
    ret->func = func;
    ret->funcdata = funcdata;

    return (NpyAuxData *)ret;
}
```

type **NpyAuxData_FreeFunc**

The function pointer type for NpyAuxData free functions.

type **NpyAuxData_CloneFunc**

The function pointer type for NpyAuxData clone functions. These functions should never set the Python exception on error, because they may be called from a multi-threaded context.

void **NPY_AUXDATA_FREE**(*NpyAuxData* *auxdata)

A macro which calls the auxdata's free function appropriately, does nothing if auxdata is NULL.

NpyAuxData ***NPY_AUXDATA_CLONE**(*NpyAuxData* *auxdata)

A macro which calls the auxdata's clone function appropriately, returning a deep copy of the auxiliary data.

Array iterators

As of NumPy 1.6.0, these array iterators are superseded by the new array iterator, *NpyIter*.

An array iterator is a simple way to access the elements of an N-dimensional array quickly and efficiently, as seen in *the example* which provides more description of this useful approach to looping over an array from C.

PyObject ***PyArray_IterNew**(PyObject *arr)

Return an array iterator object from the array, *arr*. This is equivalent to *arr*. **flat**. The array iterator object makes it easy to loop over an N-dimensional non-contiguous array in C-style contiguous fashion.

PyObject ***PyArray_IterAllButAxis**(PyObject *arr, int *axis)

Return an array iterator that will iterate over all axes but the one provided in **axis*. The returned iterator cannot be used with *PyArray_ITER_GOTO1D*. This iterator could be used to write something similar to what ufuncs do wherein the loop over the largest axis is done by a separate sub-routine. If **axis* is negative then **axis* will be set to the axis having the smallest stride and that axis will be used.

PyObject ***PyArray_BroadcastToShape**(PyObject *arr, *npy_intp* const *dimensions, int nd)

Return an array iterator that is broadcast to iterate as an array of the shape provided by *dimensions* and *nd*.

int **PyArrayIter_Check**(PyObject *op)

Evaluates true if *op* is an array iterator (or instance of a subclass of the array iterator type).

void **PyArray_ITER_RESET**(PyObject *iterator)

Reset an *iterator* to the beginning of the array.

void **PyArray_ITER_NEXT**(PyObject *iterator)

Increment the index and the dataptr members of the *iterator* to point to the next element of the array. If the array is not (C-style) contiguous, also increment the N-dimensional coordinates array.

void ***PyArray_ITER_DATA**(PyObject *iterator)

A pointer to the current element of the array.

void **PyArray_ITER_GOTO**(PyObject *iterator, *npy_intp* *destination)

Set the *iterator* index, dataptr, and coordinates members to the location in the array indicated by the N-dimensional c-array, *destination*, which must have size at least *iterator* ->nd_m1+1.

void **PyArray_ITER_GOTO1D**(PyObject *iterator, *npy_intp* index)

Set the *iterator* index and dataptr to the location in the array indicated by the integer *index* which points to an element in the C-styled flattened array.

int **PyArray_ITER_NOTDONE**(PyObject *iterator)

Evaluates TRUE as long as the iterator has not looped through all of the elements, otherwise it evaluates FALSE.

Broadcasting (multi-iterators)

PyObject ***PyArray_MultiIterNew**(int num, ...)

A simplified interface to broadcasting. This function takes the number of arrays to broadcast and then *num* extra (`PyObject *`) arguments. These arguments are converted to arrays and iterators are created. *PyArray_Broadcast* is then called on the resulting multi-iterator object. The resulting, broadcasted mult-iterator object is then returned. A broadcasted operation can then be performed using a single loop and using *PyArray_MultiIter_NEXT*(..)

void **PyArray_MultiIter_RESET**(PyObject *multi)

Reset all the iterators to the beginning in a multi-iterator object, *multi*.

void **PyArray_MultiIter_NEXT**(PyObject *multi)

Advance each iterator in a multi-iterator object, *multi*, to its next (broadcasted) element.

void ***PyArray_MultiIter_DATA**(PyObject *multi, int i)

Return the data-pointer of the i^{th} iterator in a multi-iterator object.

void **PyArray_MultiIter_NEXTi**(PyObject *multi, int i)

Advance the pointer of only the i^{th} iterator.

void **PyArray_MultiIter_GOTO**(PyObject *multi, *npy_intp* *destination)

Advance each iterator in a multi-iterator object, *multi*, to the given N -dimensional *destination* where N is the number of dimensions in the broadcasted array.

void **PyArray_MultiIter_GOTO1D**(PyObject *multi, *npy_intp* index)

Advance each iterator in a multi-iterator object, *multi*, to the corresponding location of the *index* into the flattened broadcasted array.

int **PyArray_MultiIter_NOTDONE**(PyObject *multi)

Evaluates TRUE as long as the multi-iterator has not looped through all of the elements (of the broadcasted result), otherwise it evaluates FALSE.

npy_intp **PyArray_MultiIter_SIZE**(*PyArrayMultiIterObject* *multi)

New in version 1.26.0.

Returns the total broadcasted size of a multi-iterator object.

int **PyArray_MultiIter_NDIM**(*PyArrayMultiIterObject* *multi)

New in version 1.26.0.

Returns the number of dimensions in the broadcasted result of a multi-iterator object.

npy_intp **PyArray_MultiIter_INDEX**(*PyArrayMultiIterObject* *multi)

New in version 1.26.0.

Returns the current (1-d) index into the broadcasted result of a multi-iterator object.

int **PyArray_MultiIter_NUMITER**(*PyArrayMultiIterObject* *multi)

New in version 1.26.0.

Returns the number of iterators that are represented by a multi-iterator object.

void ***PyArray_MultiIter_ITERS**(*PyArrayMultiIterObject* *multi)

New in version 1.26.0.

Returns an array of iterator objects that holds the iterators for the arrays to be broadcast together. On return, the iterators are adjusted for broadcasting.

npy_intp ***PyArray_MultiIter_DIMS**(*PyArrayMultiIterObject* *multi)

New in version 1.26.0.

Returns a pointer to the dimensions/shape of the broadcasted result of a multi-iterator object.

int **PyArray_Broadcast**(*PyArrayMultiIterObject* *mit)

This function encapsulates the broadcasting rules. The *mit* container should already contain iterators for all the arrays that need to be broadcast. On return, these iterators will be adjusted so that iteration over each simultaneously will accomplish the broadcasting. A negative number is returned if an error occurs.

int **PyArray_RemoveSmallest**(*PyArrayMultiIterObject* *mit)

This function takes a multi-iterator object that has been previously "broadcasted," finds the dimension with the smallest "sum of strides" in the broadcasted result and adapts all the iterators so as not to iterate over that dimension (by effectively making them of length-1 in that dimension). The corresponding dimension is returned unless *mit* ->nd is 0, then -1 is returned. This function is useful for constructing ufunc-like routines that broadcast their inputs correctly and then call a strided 1-d version of the routine as the inner-loop. This 1-d version is usually optimized for speed and for this reason the loop should be performed over the axis that won't require large stride jumps.

Neighborhood iterator

Neighborhood iterators are subclasses of the iterator object, and can be used to iter over a neighborhood of a point. For example, you may want to iterate over every voxel of a 3d image, and for every such voxel, iterate over an hypercube. Neighborhood iterator automatically handle boundaries, thus making this kind of code much easier to write than manual boundaries handling, at the cost of a slight overhead.

PyObject ***PyArray_NeighborhoodIterNew**(*PyArrayIterObject* *iter, *npy_intp* bounds, int mode, *PyArrayObject* *fill_value)

This function creates a new neighborhood iterator from an existing iterator. The neighborhood will be computed relatively to the position currently pointed by *iter*, the bounds define the shape of the neighborhood iterator, and the mode argument the boundaries handling mode.

The *bounds* argument is expected to be a (2 * iter->ao->nd) arrays, such as the range bound[2*i]->bounds[2*i+1] defines the range where to walk for dimension i (both bounds are included in the walked coordinates). The bounds should be ordered for each dimension (bounds[2*i] <= bounds[2*i+1]).

The mode should be one of:

NPY_NEIGHBORHOOD_ITER_ZERO_PADDING

Zero padding. Outside bounds values will be 0.

NPY_NEIGHBORHOOD_ITER_ONE_PADDING

One padding, Outside bounds values will be 1.

NPY_NEIGHBORHOOD_ITER_CONSTANT_PADDING

Constant padding. Outside bounds values will be the same as the first item in fill_value.

NPY_NEIGHBORHOOD_ITER_MIRROR_PADDING

Mirror padding. Outside bounds values will be as if the array items were mirrored. For example, for the array [1, 2, 3, 4], x[-2] will be 2, x[-2] will be 1, x[4] will be 4, x[5] will be 1, etc…

NPY_NEIGHBORHOOD_ITER_CIRCULAR_PADDING

Circular padding. Outside bounds values will be as if the array was repeated. For example, for the array [1, 2, 3, 4], x[-2] will be 3, x[-2] will be 4, x[4] will be 1, x[5] will be 2, etc…

If the mode is constant filling (*NPY_NEIGHBORHOOD_ITER_CONSTANT_PADDING*), fill_value should point to an array object which holds the filling value (the first item will be the filling value if the array contains more than one item). For other cases, fill_value may be NULL.

- The iterator holds a reference to iter
- Return NULL on failure (in which case the reference count of iter is not changed)
- iter itself can be a Neighborhood iterator: this can be useful for .e.g automatic boundaries handling
- the object returned by this function should be safe to use as a normal iterator
- If the position of iter is changed, any subsequent call to PyArrayNeighborhoodIter_Next is undefined behavior, and PyArrayNeighborhoodIter_Reset must be called.
- If the position of iter is not the beginning of the data and the underlying data for iter is contiguous, the iterator will point to the start of the data instead of position pointed by iter. To avoid this situation, iter should be moved to the required position only after the creation of iterator, and PyArrayNeighborhoodIter_Reset must be called.

```
PyArrayIterObject *iter;
PyArrayNeighborhoodIterObject *neigh_iter;
iter = PyArray_IterNew(x);

/*For a 3x3 kernel */
bounds = {-1, 1, -1, 1};
neigh_iter = (PyArrayNeighborhoodIterObject*)PyArray_NeighborhoodIterNew(
     iter, bounds, NPY_NEIGHBORHOOD_ITER_ZERO_PADDING, NULL);

for(i = 0; i < iter->size; ++i) {
     for (j = 0; j < neigh_iter->size; ++j) {
             /* Walk around the item currently pointed by iter->dataptr */
             PyArrayNeighborhoodIter_Next(neigh_iter);
     }

     /* Move to the next point of iter */
     PyArrayIter_Next(iter);
     PyArrayNeighborhoodIter_Reset(neigh_iter);
}
```

int **PyArrayNeighborhoodIter_Reset**(*PyArrayNeighborhoodIterObject* *iter)

Reset the iterator position to the first point of the neighborhood. This should be called whenever the iter argument given at PyArray_NeighborhoodIterObject is changed (see example)

int **PyArrayNeighborhoodIter_Next**(*PyArrayNeighborhoodIterObject* *iter)

After this call, iter->dataptr points to the next point of the neighborhood. Calling this function after every point of the neighborhood has been visited is undefined.

Array scalars

PyObject ***PyArray_Return**(*PyArrayObject* *arr)

This function steals a reference to *arr*.

This function checks to see if *arr* is a 0-dimensional array and, if so, returns the appropriate array scalar. It should be used whenever 0-dimensional arrays could be returned to Python.

PyObject ***PyArray_Scalar**(void *data, *PyArray_Descr* *dtype, PyObject *base)

Return an array scalar object of the given *dtype* by **copying** from memory pointed to by *data*. *base* is expected to be the array object that is the owner of the data. *base* is required if *dtype* is a `void` scalar, or if the `NPY_USE_GETITEM` flag is set and it is known that the `getitem` method uses the `arr` argument without checking if it is `NULL`. Otherwise *base* may be `NULL`.

If the data is not in native byte order (as indicated by `dtype->byteorder`) then this function will byteswap the data, because array scalars are always in correct machine-byte order.

PyObject ***PyArray_ToScalar**(void *data, *PyArrayObject* *arr)

Return an array scalar object of the type and itemsize indicated by the array object *arr* copied from the memory pointed to by *data* and swapping if the data in *arr* is not in machine byte-order.

PyObject ***PyArray_FromScalar**(PyObject *scalar, *PyArray_Descr* *outcode)

Return a 0-dimensional array of type determined by *outcode* from *scalar* which should be an array-scalar object. If *outcode* is NULL, then the type is determined from *scalar*.

void **PyArray_ScalarAsCtype**(PyObject *scalar, void *ctypeptr)

Return in *ctypeptr* a pointer to the actual value in an array scalar. There is no error checking so *scalar* must be an array-scalar object, and ctypeptr must have enough space to hold the correct type. For flexible-sized types, a pointer to the data is copied into the memory of *ctypeptr*, for all other types, the actual data is copied into the address pointed to by *ctypeptr*.

int **PyArray_CastScalarToCtype**(PyObject *scalar, void *ctypeptr, *PyArray_Descr* *outcode)

Return the data (cast to the data type indicated by *outcode*) from the array-scalar, *scalar*, into the memory pointed to by *ctypeptr* (which must be large enough to handle the incoming memory).

Returns -1 on failure, and 0 on success.

PyObject ***PyArray_TypeObjectFromType**(int type)

Returns a scalar type-object from a type-number, *type* . Equivalent to *PyArray_DescrFromType*(*type*)->typeobj except for reference counting and error-checking. Returns a new reference to the typeobject on success or `NULL` on failure.

NPY_SCALARKIND **PyArray_ScalarKind**(int typenum, *PyArrayObject* **arr)

Legacy way to query special promotion for scalar values. This is not used in NumPy itself anymore and is expected to be deprecated eventually.

New DTypes can define promotion rules specific to Python scalars.

int **PyArray_CanCoerceScalar**(char thistype, char neededtype, *NPY_SCALARKIND* scalar)

Legacy way to query special promotion for scalar values. This is not used in NumPy itself anymore and is expected to be deprecated eventually.

Use `PyArray_ResultType` for similar purposes.

Data-type descriptors

Warning: Data-type objects must be reference counted so be aware of the action on the data-type reference of different C-API calls. The standard rule is that when a data-type object is returned it is a new reference. Functions that take *PyArray_Descr** objects and return arrays steal references to the data-type their inputs unless otherwise noted. Therefore, you must own a reference to any data-type object used as input to such a function.

int **PyArray_DescrCheck**(PyObject *obj)

Evaluates as true if *obj* is a data-type object (*PyArray_Descr**).

PyArray_Descr ***PyArray_DescrNew**(*PyArray_Descr* *obj)

Return a new data-type object copied from *obj* (the fields reference is just updated so that the new object points to the same fields dictionary if any).

PyArray_Descr ***PyArray_DescrNewFromType**(int typenum)

Create a new data-type object from the built-in (or user-registered) data-type indicated by *typenum*. All builtin types should not have any of their fields changed. This creates a new copy of the *PyArray_Descr* structure so that you can fill it in as appropriate. This function is especially needed for flexible data-types which need to have a new elsize member in order to be meaningful in array construction.

PyArray_Descr ***PyArray_DescrNewByteorder**(*PyArray_Descr* *obj, char newendian)

Create a new data-type object with the byteorder set according to *newendian*. All referenced data-type objects (in subdescr and fields members of the data-type object) are also changed (recursively).

The value of *newendian* is one of these macros:

NPY_IGNORE

NPY_SWAP

NPY_NATIVE

NPY_LITTLE

NPY_BIG

If a byteorder of *NPY_IGNORE* is encountered it is left alone. If newendian is *NPY_SWAP*, then all byte-orders are swapped. Other valid newendian values are *NPY_NATIVE*, *NPY_LITTLE*, and *NPY_BIG* which all cause the returned data-typed descriptor (and all it's referenced data-type descriptors) to have the corresponding byte-order.

PyArray_Descr ***PyArray_DescrFromObject**(PyObject *op, *PyArray_Descr* *mintype)

Determine an appropriate data-type object from the object *op* (which should be a "nested" sequence object) and the minimum data-type descriptor mintype (which can be `NULL`). Similar in behavior to array(*op*).dtype. Don't confuse this function with *PyArray_DescrConverter*. This function essentially looks at all the objects in the (nested) sequence and determines the data-type from the elements it finds.

PyArray_Descr ***PyArray_DescrFromScalar**(PyObject *scalar)

Return a data-type object from an array-scalar object. No checking is done to be sure that *scalar* is an array scalar. If no suitable data-type can be determined, then a data-type of *NPY_OBJECT* is returned by default.

PyArray_Descr ***PyArray_DescrFromType**(int typenum)

Returns a data-type object corresponding to *typenum*. The *typenum* can be one of the enumerated types, a character code for one of the enumerated types, or a user-defined type. If you want to use a flexible size array, then you need to `flexible typenum` and set the results `elsize` parameter to the desired size. The typenum is one of the *NPY_TYPES*.

int **PyArray_DescrConverter**(PyObject *obj, *PyArray_Descr* **dtype)

Convert any compatible Python object, *obj*, to a data-type object in *dtype*. A large number of Python objects can be converted to data-type objects. See *Data type objects (dtype)* for a complete description. This version of the converter converts None objects to a *NPY_DEFAULT_TYPE* data-type object. This function can be used with the "O&" character code in `PyArg_ParseTuple` processing.

int **PyArray_DescrConverter2**(PyObject *obj, *PyArray_Descr* **dtype)

Convert any compatible Python object, *obj*, to a data-type object in *dtype*. This version of the converter converts None objects so that the returned data-type is `NULL`. This function can also be used with the "O&" character in PyArg_ParseTuple processing.

int **PyArray_DescrAlignConverter**(PyObject *obj, *PyArray_Descr* **dtype)

Like *PyArray_DescrConverter* except it aligns C-struct-like objects on word-boundaries as the compiler would.

int **PyArray_DescrAlignConverter2**(PyObject *obj, *PyArray_Descr* **dtype)

Like *PyArray_DescrConverter2* except it aligns C-struct-like objects on word-boundaries as the compiler would.

Data Type Promotion and Inspection

PyArray_DTypeMeta ***PyArray_CommonDType**(const *PyArray_DTypeMeta* *dtype1, const *PyArray_DTypeMeta* *dtype2)

This function defines the common DType operator. Note that the common DType will not be `object` (unless one of the DTypes is `object`). Similar to *numpy.result_type*, but works on the classes and not instances.

PyArray_DTypeMeta ***PyArray_PromoteDTypeSequence**(*npy_intp* length, *PyArray_DTypeMeta* **dtypes_in)

Promotes a list of DTypes with each other in a way that should guarantee stable results even when changing the order. This function is smarter and can often return successful and unambiguous results when `common_dtype(common_dtype(dt1, dt2), dt3)` would depend on the operation order or fail. Nevertheless, DTypes should aim to ensure that their common-dtype implementation is associative and commutative! (Mainly, unsigned and signed integers are not.)

For guaranteed consistent results DTypes must implement common-Dtype "transitively". If A promotes B and B promotes C, than A must generally also promote C; where "promotes" means implements the promotion. (There are some exceptions for abstract DTypes)

In general this approach always works as long as the most generic dtype is either strictly larger, or compatible with all other dtypes. For example promoting `float16` with any other float, integer, or unsigned integer again gives a floating point number.

PyArray_Descr ***PyArray_GetDefaultDescr**(const *PyArray_DTypeMeta* *DType)

Given a DType class, returns the default instance (descriptor). This checks for a `singleton` first and only calls the `default_descr` function if necessary.

Custom Data Types

New in version 2.0.

These functions allow defining custom flexible data types outside of NumPy. See NEP 42 for more details about the rationale and design of the new DType system. See the numpy-user-dtypes repository for a number of example DTypes. Also see *PyArray_DTypeMeta and PyArrayDTypeMeta_Spec* for documentation on `PyArray_DTypeMeta` and `PyArrayDTypeMeta_Spec`.

int **PyArrayInitDTypeMeta_FromSpec**(*PyArray_DTypeMeta* *Dtype, *PyArrayDTypeMeta_Spec* *spec)

Initialize a new DType. It must currently be a static Python C type that is declared as *`PyArray_DTypeMeta`* and not `PyTypeObject`. Further, it must subclass *np.dtype* and set its type to *`PyArrayDTypeMeta_Type`* (before calling `PyType_Ready`), which has additional fields compared to a normal `PyTypeObject`. See the examples in the `numpy-user-dtypes` repository for usage with both parametric and non-parametric data types.

Flags

Flags that can be set on the `PyArrayDTypeMeta_Spec` to initialize the DType.

NPY_DT_ABSTRACT

Indicates the DType is an abstract "base" DType in a DType hierarchy and should not be directly instantiated.

NPY_DT_PARAMETRIC

Indicates the DType is parametric and does not have a unique singleton instance.

NPY_DT_NUMERIC

Indicates the DType represents a numerical value.

Slot IDs and API Function Typedefs

These IDs correspond to slots in the DType API and are used to identify implementations of each slot from the items of the `slots` array member of `PyArrayDTypeMeta_Spec` struct.

NPY_DT_discover_descr_from_pyobject

typedef *PyArray_Descr* *(**PyArrayDTypeMeta_DiscoverDescrFromPyobject**)(*PyArray_DTypeMeta* *cls, PyObject *obj)

Used during DType inference to find the correct DType for a given PyObject. Must return a descriptor instance appropriate to store the data in the python object that is passed in. *obj* is the python object to inspect and *cls* is the DType class to create a descriptor for.

NPY_DT_default_descr

typedef *PyArray_Descr* *(**PyArrayDTypeMeta_DefaultDescriptor**)(*PyArray_DTypeMeta* *cls)

Returns the default descriptor instance for the DType. Must be defined for parametric data types. Non-parametric data types return the singleton by default.

NPY_DT_common_dtype

typedef *PyArray_DTypeMeta* *(**PyArrayDTypeMeta_CommonDType**)(*PyArray_DTypeMeta* *dtype1, *PyArray_DTypeMeta* *dtype2)

Given two input DTypes, determines the appropriate "common" DType that can store values for both types. Returns `Py_NotImplemented` if no such type exists.

NPY_DT_common_instance

typedef *PyArray_Descr* *(**PyArrayDTypeMeta_CommonInstance**)(*PyArray_Descr* *dtype1, *PyArray_Descr* *dtype2)

Given two input descriptors, determines the appropriate "common" descriptor that can store values for both instances. Returns `NULL` on error.

NPY_DT_ensure_canonical

typedef *PyArray_Descr* *(**PyArrayDTypeMeta_EnsureCanonical**)(*PyArray_Descr* *dtype)

Returns the "canonical" representation for a descriptor instance. The notion of a canonical descriptor generalizes the concept of byte order, in that a canonical descriptor always has native byte order. If the descriptor is already canonical, this function returns a new reference to the input descriptor.

NPY_DT_setitem

typedef int (**PyArrayDTypeMeta_SetItem**)(*PyArray_Descr**, PyObject*, char*)

Implements scalar setitem for an array element given a PyObject.

NPY_DT_getitem

typedef PyObject *(**PyArrayDTypeMeta_GetItem**)(*PyArray_Descr**, char*)

Implements scalar getitem for an array element. Must return a python scalar.

NPY_DT_get_clear_loop

If defined, sets a traversal loop that clears data in the array. This is most useful for arrays of references that must clean up array entries before the array is garbage collected. Implements `PyArrayMethod_GetTraverseLoop`.

NPY_DT_get_fill_zero_loop

If defined, sets a traversal loop that fills an array with "zero" values, which may have a DType-specific meaning. This is called inside *numpy.zeros* for arrays that need to write a custom sentinel value that represents zero if for some reason a zero-filled array is not sufficient. Implements `PyArrayMethod_GetTraverseLoop`.

NPY_DT_finalize_descr

typedef *PyArray_Descr* *(**PyArrayDTypeMeta_FinalizeDescriptor**)(*PyArray_Descr* *dtype)

If defined, a function that is called to "finalize" a descriptor instance after an array is created. One use of this function is to force newly created arrays to have a newly created descriptor instance, no matter what input descriptor is provided by a user.

PyArray_ArrFuncs slots

In addition the above slots, the following slots are exposed to allow filling the *PyArray_ArrFuncs* struct attached to descriptor instances. Note that in the future these will be replaced by proper DType API slots but for now we have exposed the legacy `PyArray_ArrFuncs` slots.

NPY_DT_PyArray_ArrFuncs_getitem

Allows setting a per-dtype getitem. Note that this is not necessary to define unless the default version calling the function defined with the `NPY_DT_getitem` ID is unsuitable. This version will be slightly faster than using `NPY_DT_getitem` at the cost of sometimes needing to deal with a NULL input array.

NPY_DT_PyArray_ArrFuncs_setitem

Allows setting a per-dtype setitem. Note that this is not necessary to define unless the default version calling the function defined with the `NPY_DT_setitem` ID is unsuitable for some reason.

NPY_DT_PyArray_ArrFuncs_compare

Computes a comparison for *numpy.sort*, implements `PyArray_CompareFunc`.

NPY_DT_PyArray_ArrFuncs_argmax
: Computes the argmax for *numpy.argmax*, implements PyArray_ArgFunc.

NPY_DT_PyArray_ArrFuncs_argmin
: Computes the argmin for *numpy.argmin*, implements PyArray_ArgFunc.

NPY_DT_PyArray_ArrFuncs_dotfunc
: Computes the dot product for *numpy.dot*, implements PyArray_DotFunc.

NPY_DT_PyArray_ArrFuncs_scanfunc
: A formatted input function for *numpy.fromfile*, implements PyArray_ScanFunc.

NPY_DT_PyArray_ArrFuncs_fromstr
: A string parsing function for *numpy.fromstring*, implements PyArray_FromStrFunc.

NPY_DT_PyArray_ArrFuncs_nonzero
: Computes the nonzero function for *numpy.nonzero*, implements PyArray_NonzeroFunc.

NPY_DT_PyArray_ArrFuncs_fill
: An array filling function for *numpy.ndarray.fill*, implements PyArray_FillFunc.

NPY_DT_PyArray_ArrFuncs_fillwithscalar
: A function to fill an array with a scalar value for *numpy.ndarray.fill*, implements PyArray_FillWithScalarFunc.

NPY_DT_PyArray_ArrFuncs_sort
: An array of PyArray_SortFunc of length NPY_NSORTS. If set, allows defining custom sorting implementations for each of the sorting algorithms numpy implements.

NPY_DT_PyArray_ArrFuncs_argsort
: An array of PyArray_ArgSortFunc of length NPY_NSORTS. If set, allows defining custom argsorting implementations for each of the sorting algorithms numpy implements.

Macros and Static Inline Functions

These macros and static inline functions are provided to allow more understandable and idiomatic code when working with PyArray_DTypeMeta instances.

NPY_DTYPE(descr)
: Returns a PyArray_DTypeMeta * pointer to the DType of a given descriptor instance.

static inline *PyArray_DTypeMeta* ***NPY_DT_NewRef**(*PyArray_DTypeMeta* *o)
: Returns a PyArray_DTypeMeta * pointer to a new reference to a DType.

Conversion utilities

For use with PyArg_ParseTuple

All of these functions can be used in PyArg_ParseTuple(...) with the "O&" format specifier to automatically convert any Python object to the required C-object. All of these functions return *NPY_SUCCEED* if successful and *NPY_FAIL* if not. The first argument to all of these function is a Python object. The second argument is the **address** of the C-type to convert the Python object to.

Warning: Be sure to understand what steps you should take to manage the memory when using these conversion functions. These functions can require freeing memory, and/or altering the reference counts of specific objects based on your use.

int **PyArray_Converter**(PyObject *obj, PyObject **address)

Convert any Python object to a *PyArrayObject*. If *PyArray_Check* (*obj*) is TRUE then its reference count is incremented and a reference placed in *address*. If *obj* is not an array, then convert it to an array using *PyArray_FromAny* . No matter what is returned, you must DECREF the object returned by this routine in *address* when you are done with it.

int **PyArray_OutputConverter**(PyObject *obj, *PyArrayObject* **address)

This is a default converter for output arrays given to functions. If *obj* is Py_None or NULL, then **address* will be NULL but the call will succeed. If *PyArray_Check* (*obj*) is TRUE then it is returned in **address* without incrementing its reference count.

int **PyArray_IntpConverter**(PyObject *obj, *PyArray_Dims* *seq)

Convert any Python sequence, *obj*, smaller than *NPY_MAXDIMS* to a C-array of *npy_intp*. The Python object could also be a single number. The *seq* variable is a pointer to a structure with members ptr and len. On successful return, *seq* ->ptr contains a pointer to memory that must be freed, by calling *PyDimMem_FREE*, to avoid a memory leak. The restriction on memory size allows this converter to be conveniently used for sequences intended to be interpreted as array shapes.

int **PyArray_BufferConverter**(PyObject *obj, *PyArray_Chunk* *buf)

Convert any Python object, *obj*, with a (single-segment) buffer interface to a variable with members that detail the object's use of its chunk of memory. The *buf* variable is a pointer to a structure with base, ptr, len, and flags members. The *PyArray_Chunk* structure is binary compatible with the Python's buffer object (through its len member on 32-bit platforms and its ptr member on 64-bit platforms). On return, the base member is set to *obj* (or its base if *obj* is already a buffer object pointing to another object). If you need to hold on to the memory be sure to INCREF the base member. The chunk of memory is pointed to by *buf* ->ptr member and has length *buf* ->len. The flags member of *buf* is *NPY_ARRAY_ALIGNED* with the *NPY_ARRAY_WRITEABLE* flag set if *obj* has a writeable buffer interface.

int **PyArray_AxisConverter**(PyObject *obj, int *axis)

Convert a Python object, *obj*, representing an axis argument to the proper value for passing to the functions that take an integer axis. Specifically, if *obj* is None, *axis* is set to *NPY_RAVEL_AXIS* which is interpreted correctly by the C-API functions that take axis arguments.

int **PyArray_BoolConverter**(PyObject *obj, *npy_bool* *value)

Convert any Python object, *obj*, to *NPY_TRUE* or *NPY_FALSE*, and place the result in *value*.

int **PyArray_ByteorderConverter**(PyObject *obj, char *endian)

Convert Python strings into the corresponding byte-order character: '>', '<', 's', '=', or 'l'.

int **PyArray_SortkindConverter**(PyObject *obj, *NPY_SORTKIND* *sort)

Convert Python strings into one of *NPY_QUICKSORT* (starts with 'q' or 'Q'), *NPY_HEAPSORT* (starts with 'h' or 'H'), *NPY_MERGESORT* (starts with 'm' or 'M') or *NPY_STABLESORT* (starts with 't' or 'T'). *NPY_MERGESORT* and *NPY_STABLESORT* are aliased to each other for backwards compatibility and may refer to one of several stable sorting algorithms depending on the data type.

int **PyArray_SearchsideConverter**(PyObject *obj, *NPY_SEARCHSIDE* *side)

Convert Python strings into one of *NPY_SEARCHLEFT* (starts with 'l' or 'L'), or *NPY_SEARCHRIGHT* (starts with 'r' or 'R').

int **PyArray_OrderConverter**(PyObject *obj, *NPY_ORDER* *order)

Convert the Python strings 'C', 'F', 'A', and 'K' into the *NPY_ORDER* enumeration *NPY_CORDER*, *NPY_FORTRANORDER*, *NPY_ANYORDER*, and *NPY_KEEPORDER*.

int **PyArray_CastingConverter**(PyObject *obj, *NPY_CASTING* *casting)

Convert the Python strings 'no', 'equiv', 'safe', 'same_kind', and 'unsafe' into the *NPY_CASTING* enumeration *NPY_NO_CASTING*, *NPY_EQUIV_CASTING*, *NPY_SAFE_CASTING*, *NPY_SAME_KIND_CASTING*, and *NPY_UNSAFE_CASTING*.

int **PyArray_ClipmodeConverter**(PyObject *object, *NPY_CLIPMODE* *val)

Convert the Python strings 'clip', 'wrap', and 'raise' into the *NPY_CLIPMODE* enumeration *NPY_CLIP*, *NPY_WRAP*, and *NPY_RAISE*.

int **PyArray_ConvertClipmodeSequence**(PyObject *object, *NPY_CLIPMODE* *modes, int n)

Converts either a sequence of clipmodes or a single clipmode into a C array of *NPY_CLIPMODE* values. The number of clipmodes *n* must be known before calling this function. This function is provided to help functions allow a different clipmode for each dimension.

Other conversions

int **PyArray_PyIntAsInt**(PyObject *op)

Convert all kinds of Python objects (including arrays and array scalars) to a standard integer. On error, -1 is returned and an exception set. You may find useful the macro:

```
#define error_converting(x)  (((x) == -1) && PyErr_Occurred())
```

npy_intp **PyArray_PyIntAsIntp**(PyObject *op)

Convert all kinds of Python objects (including arrays and array scalars) to a (platform-pointer-sized) integer. On error, -1 is returned and an exception set.

int **PyArray_IntpFromSequence**(PyObject *seq, *npy_intp* *vals, int maxvals)

Convert any Python sequence (or single Python number) passed in as *seq* to (up to) *maxvals* pointer-sized integers and place them in the *vals* array. The sequence can be smaller then *maxvals* as the number of converted objects is returned.

Including and importing the C API

To use the NumPy C-API you typically need to include the `numpy/ndarrayobject.h` header and `numpy/ufuncobject.h` for some ufunc related functionality (`arrayobject.h` is an alias for `ndarrayobject.h`).

These two headers export most relevant functionality. In general any project which uses the NumPy API must import NumPy using one of the functions `PyArray_ImportNumPyAPI()` or `import_array()`. In some places, functionality which requires `import_array()` is not needed, because you only need type definitions. In this case, it is sufficient to include `numpy/ndarratypes.h`.

For the typical Python project, multiple C or C++ files will be compiled into a single shared object (the Python C-module) and `PyArray_ImportNumPyAPI()` should be called inside it's module initialization.

When you have a single C-file, this will consist of:

```
#include "numpy/ndarrayobject.h"

PyMODINIT_FUNC PyInit_my_module(void)
{
    if (PyArray_ImportNumPyAPI() < 0) {
        return NULL;
    }
    /* Other initialization code. */
}
```

However, most projects will have additional C files which are all linked together into a single Python module. In this case, the helper C files typically do not have a canonical place where `PyArray_ImportNumPyAPI` should be called (although it is OK and fast to call it often).

To solve this, NumPy provides the following pattern that the the main file is modified to define `PY_ARRAY_UNIQUE_SYMBOL` before the include:

```
/* Main module file */
#define PY_ARRAY_UNIQUE_SYMBOL MyModule
#include "numpy/ndarrayobject.h"

PyMODINIT_FUNC PyInit_my_module(void)
{
    if (PyArray_ImportNumPyAPI() < 0) {
        return NULL;
    }
    /* Other initialization code. */
}
```

while the other files use:

```
/* Second file without any import */
#define NO_IMPORT_ARRAY
#define PY_ARRAY_UNIQUE_SYMBOL MyModule
#include "numpy/ndarrayobject.h"
```

You can of course add the defines to a local header used throughout. You just have to make sure that the main file does _not_ define `NO_IMPORT_ARRAY`.

For `numpy/ufuncobject.h` the same logic applies, but the unique symbol mechanism is `#define PY_UFUNC_UNIQUE_SYMBOL` (both can match).

Additionally, you will probably wish to add a `#define NPY_NO_DEPRECATED_API NPY_1_7_API_VERSION` to avoid warnings about possible use of old API.

Note: If you are experiencing access violations make sure that the NumPy API was properly imported and the symbol `PyArray_API` is not `NULL`. When in a debugger, this symbols actual name will be `PY_ARRAY_UNIQUE_SYMBOL``+``PyArray_API`, so for example `MyModulePyArray_API` in the above. (E.g. even a `printf("%p\n", PyArray_API);` just before the crash.)

Mechanism details and dynamic linking

The main part of the mechanism is that without NumPy needs to define a `void **PyArray_API` table for you to look up all functions. Depending on your macro setup, this takes different routes depending on whether *NO_IMPORT_ARRAY* and *PY_ARRAY_UNIQUE_SYMBOL* are defined:

- If neither is defined, the C-API is declared to `static void **PyArray_API`, so it is only visible within the compilation unit/file using `#include <numpy/arrayobject.h>`.
- If only `PY_ARRAY_UNIQUE_SYMBOL` is defined (it could be empty) then the it is declared to a non-static `void **` allowing it to be used by other files which are linked.
- If `NO_IMPORT_ARRAY` is defined, the table is declared as `extern void **`, meaning that it must be linked to a file which does not use `NO_IMPORT_ARRAY`.

The `PY_ARRAY_UNIQUE_SYMBOL` mechanism additionally mangles the names to avoid conflicts.

Changed in version NumPy: 2.1 changed the headers to avoid sharing the table outside of a single shared object/dll (this was always the case on Windows). Please see *NPY_API_SYMBOL_ATTRIBUTE* for details.

In order to make use of the C-API from another extension module, the *import_array* function must be called. If the extension module is self-contained in a single .c file, then that is all that needs to be done. If, however, the extension module involves multiple files where the C-API is needed then some additional steps must be taken.

int **PyArray_ImportNumPyAPI**(void)

Ensures that the NumPy C-API is imported and usable. It returns `0` on success and `-1` with an error set if NumPy couldn't be imported. While preferable to call it once at module initialization, this function is very light-weight if called multiple times.

New in version 2.0: This function is backported in the `npy_2_compat.h` header.

import_array(void)

This function must be called in the initialization section of a module that will make use of the C-API. It imports the module where the function-pointer table is stored and points the correct variable to it. This macro includes a `return NULL;` on error, so that `PyArray_ImportNumPyAPI()` is preferable for custom error checking. You may also see use of `_import_array()` (a function, not a macro, but you may want to raise a better error if it fails) and the variations `import_array1(ret)` which customizes the return value.

PY_ARRAY_UNIQUE_SYMBOL

NPY_API_SYMBOL_ATTRIBUTE

New in version 2.1.

An additional symbol which can be used to share e.g. visibility beyond shared object boundaries. By default, NumPy adds the C visibility hidden attribute (if available): `void __attribute__((visibility("hidden"))) **PyArray_API;`. You can change this by defining `NPY_API_SYMBOL_ATTRIBUTE`, which will make this: `void NPY_API_SYMBOL_ATTRIBUTE **PyArray_API;` (with additional name mangling via the unique symbol).

Adding an empty `#define NPY_API_SYMBOL_ATTRIBUTE` will have the same behavior as NumPy 1.x.

Note: Windows never had shared visibility although you can use this macro to achieve it. We generally discourage sharing beyond shared boundary lines since importing the array API includes NumPy version checks.

NO_IMPORT_ARRAY

Defining `NO_IMPORT_ARRAY` before the `ndarrayobject.h` include indicates that the NumPy C API import is handled in a different file and the include mechanism will not be added here. You must have one file without `NO_IMPORT_ARRAY` defined.

```
#define PY_ARRAY_UNIQUE_SYMBOL cool_ARRAY_API
#include <numpy/arrayobject.h>
```

On the other hand, coolhelper.c would contain at the top:

```
#define NO_IMPORT_ARRAY
#define PY_ARRAY_UNIQUE_SYMBOL cool_ARRAY_API
#include <numpy/arrayobject.h>
```

You can also put the common two last lines into an extension-local header file as long as you make sure that NO_IMPORT_ARRAY is #defined before #including that file.

Internally, these #defines work as follows:

- If neither is defined, the C-API is declared to be `static void**`, so it is only visible within the compilation unit that #includes numpy/arrayobject.h.
- If *`PY_ARRAY_UNIQUE_SYMBOL`* is #defined, but *`NO_IMPORT_ARRAY`* is not, the C-API is declared to be `void**`, so that it will also be visible to other compilation units.
- If *`NO_IMPORT_ARRAY`* is #defined, regardless of whether *`PY_ARRAY_UNIQUE_SYMBOL`* is, the C-API is declared to be `extern void**`, so it is expected to be defined in another compilation unit.

- Whenever *PY_ARRAY_UNIQUE_SYMBOL* is #defined, it also changes the name of the variable holding the C-API, which defaults to `PyArray_API`, to whatever the macro is #defined to.

Checking the API Version

Because python extensions are not used in the same way as usual libraries on most platforms, some errors cannot be automatically detected at build time or even runtime. For example, if you build an extension using a function available only for numpy >= 1.3.0, and you import the extension later with numpy 1.2, you will not get an import error (but almost certainly a segmentation fault when calling the function). That's why several functions are provided to check for numpy versions. The macros *NPY_VERSION* and *NPY_FEATURE_VERSION* corresponds to the numpy version used to build the extension, whereas the versions returned by the functions *PyArray_GetNDArrayCVersion* and *PyArray_GetNDArrayCFeatureVersion* corresponds to the runtime numpy's version.

The rules for ABI and API compatibilities can be summarized as follows:

- Whenever *NPY_VERSION* != `PyArray_GetNDArrayCVersion()`, the extension has to be recompiled (ABI incompatibility).
- *NPY_VERSION* == `PyArray_GetNDArrayCVersion()` and *NPY_FEATURE_VERSION* <= `PyArray_GetNDArrayCFeatureVersion()` means backward compatible changes.

ABI incompatibility is automatically detected in every numpy's version. API incompatibility detection was added in numpy 1.4.0. If you want to supported many different numpy versions with one extension binary, you have to build your extension with the lowest *NPY_FEATURE_VERSION* as possible.

NPY_VERSION

The current version of the ndarray object (check to see if this variable is defined to guarantee the `numpy/arrayobject.h` header is being used).

NPY_FEATURE_VERSION

The current version of the C-API.

unsigned int **PyArray_GetNDArrayCVersion** (void)

This just returns the value *NPY_VERSION*. *NPY_VERSION* changes whenever a backward incompatible change at the ABI level. Because it is in the C-API, however, comparing the output of this function from the value defined in the current header gives a way to test if the C-API has changed thus requiring a re-compilation of extension modules that use the C-API. This is automatically checked in the function *import_array*.

unsigned int **PyArray_GetNDArrayCFeatureVersion** (void)

This just returns the value *NPY_FEATURE_VERSION*. *NPY_FEATURE_VERSION* changes whenever the API changes (e.g. a function is added). A changed value does not always require a recompile.

Memory management

char ***PyDataMem_NEW** (size_t nbytes)

void **PyDataMem_FREE** (char *ptr)

char ***PyDataMem_RENEW** (void *ptr, size_t newbytes)

Functions to allocate, free, and reallocate memory. These are used internally to manage array data memory unless overridden.

npy_intp ***PyDimMem_NEW** (int nd)

void **PyDimMem_FREE** (char *ptr)

npy_intp ***PyDimMem_RENEW** (void *ptr, size_t newnd)

Macros to allocate, free, and reallocate dimension and strides memory.

void ***PyArray_malloc**(size_t nbytes)

void **PyArray_free**(void *ptr)

void ***PyArray_realloc**(*npy_intp* *ptr, size_t nbytes)

These macros use different memory allocators, depending on the constant *NPY_USE_PYMEM*. The system malloc is used when *NPY_USE_PYMEM* is 0, if *NPY_USE_PYMEM* is 1, then the Python memory allocator is used.

NPY_USE_PYMEM

int **PyArray_ResolveWritebackIfCopy**(*PyArrayObject* *obj)

If `obj->flags` has *NPY_ARRAY_WRITEBACKIFCOPY*, this function clears the flags, *DECREF* s *obj->base* and makes it writeable, and sets `obj->base` to NULL. It then copies `obj->data` to *obj->base->data*, and returns the error state of the copy operation. This is the opposite of *PyArray_SetWritebackIfCopyBase*. Usually this is called once you are finished with `obj`, just before `Py_DECREF(obj)`. It may be called multiple times, or with `NULL` input. See also *PyArray_DiscardWritebackIfCopy*.

Returns 0 if nothing was done, -1 on error, and 1 if action was taken.

Threading support

These macros are only meaningful if *NPY_ALLOW_THREADS* evaluates True during compilation of the extension module. Otherwise, these macros are equivalent to whitespace. Python uses a single Global Interpreter Lock (GIL) for each Python process so that only a single thread may execute at a time (even on multi-cpu machines). When calling out to a compiled function that may take time to compute (and does not have side-effects for other threads like updated global variables), the GIL should be released so that other Python threads can run while the time-consuming calculations are performed. This can be accomplished using two groups of macros. Typically, if one macro in a group is used in a code block, all of them must be used in the same code block. *NPY_ALLOW_THREADS* is true (defined as `1`) unless the build option `-Ddisable-threading` is set to `true` - in which case *NPY_ALLOW_THREADS* is false (`0`).

NPY_ALLOW_THREADS

Group 1

This group is used to call code that may take some time but does not use any Python C-API calls. Thus, the GIL should be released during its calculation.

NPY_BEGIN_ALLOW_THREADS

Equivalent to `Py_BEGIN_ALLOW_THREADS` except it uses *NPY_ALLOW_THREADS* to determine if the macro if replaced with white-space or not.

NPY_END_ALLOW_THREADS

Equivalent to `Py_END_ALLOW_THREADS` except it uses *NPY_ALLOW_THREADS* to determine if the macro if replaced with white-space or not.

NPY_BEGIN_THREADS_DEF

Place in the variable declaration area. This macro sets up the variable needed for storing the Python state.

NPY_BEGIN_THREADS

Place right before code that does not need the Python interpreter (no Python C-API calls). This macro saves the Python state and releases the GIL.

NPY_END_THREADS

Place right after code that does not need the Python interpreter. This macro acquires the GIL and restores the Python state from the saved variable.

void **NPY_BEGIN_THREADS_DESCR**(*PyArray_Descr* *dtype)

Useful to release the GIL only if *dtype* does not contain arbitrary Python objects which may need the Python interpreter during execution of the loop.

void **NPY_END_THREADS_DESCR**(*PyArray_Descr* *dtype)

Useful to regain the GIL in situations where it was released using the BEGIN form of this macro.

void **NPY_BEGIN_THREADS_THRESHOLDED**(int loop_size)

Useful to release the GIL only if *loop_size* exceeds a minimum threshold, currently set to 500. Should be matched with a *NPY_END_THREADS* to regain the GIL.

Group 2

This group is used to re-acquire the Python GIL after it has been released. For example, suppose the GIL has been released (using the previous calls), and then some path in the code (perhaps in a different subroutine) requires use of the Python C-API, then these macros are useful to acquire the GIL. These macros accomplish essentially a reverse of the previous three (acquire the LOCK saving what state it had) and then re-release it with the saved state.

NPY_ALLOW_C_API_DEF

Place in the variable declaration area to set up the necessary variable.

NPY_ALLOW_C_API

Place before code that needs to call the Python C-API (when it is known that the GIL has already been released).

NPY_DISABLE_C_API

Place after code that needs to call the Python C-API (to re-release the GIL).

Tip: Never use semicolons after the threading support macros.

Priority

NPY_PRIORITY

Default priority for arrays.

NPY_SUBTYPE_PRIORITY

Default subtype priority.

NPY_SCALAR_PRIORITY

Default scalar priority (very small)

double **PyArray_GetPriority**(PyObject *obj, double def)

Return the *__array_priority__* attribute (converted to a double) of *obj* or *def* if no attribute of that name exists. Fast returns that avoid the attribute lookup are provided for objects of type *PyArray_Type*.

Default buffers

NPY_BUFSIZE

Default size of the user-settable internal buffers.

NPY_MIN_BUFSIZE

Smallest size of user-settable internal buffers.

NPY_MAX_BUFSIZE

Largest size allowed for the user-settable buffers.

Other constants

NPY_NUM_FLOATTYPE

The number of floating-point types

NPY_MAXDIMS

The maximum number of dimensions that may be used by NumPy. This is set to 64 and was 32 before NumPy 2.

Note: We encourage you to avoid `NPY_MAXDIMS`. A future version of NumPy may wish to remove any dimension limitation (and thus the constant). The limitation was created so that NumPy can use stack allocations internally for scratch space.

If your algorithm has a reasonable maximum number of dimension you could check and use that locally.

NPY_MAXARGS

The maximum number of array arguments that can be used in some functions. This used to be 32 before NumPy 2 and is now 64. To continue to allow using it as a check whether a number of arguments is compatible ufuncs, this macro is now runtime dependent.

Note: We discourage any use of `NPY_MAXARGS` that isn't explicitly tied to checking for known NumPy limitations.

NPY_FALSE

Defined as 0 for use with Bool.

NPY_TRUE

Defined as 1 for use with Bool.

NPY_FAIL

The return value of failed converter functions which are called using the "O&" syntax in `PyArg_ParseTuple`-like functions.

NPY_SUCCEED

The return value of successful converter functions which are called using the "O&" syntax in `PyArg_ParseTuple`-like functions.

NPY_RAVEL_AXIS

Some NumPy functions (mainly the C-entrypoints for Python functions) have an `axis` argument. This macro may be passed for `axis=None`.

Note: This macro is NumPy version dependent at runtime. The value is now the minimum integer. However, on NumPy 1.x `NPY_MAXDIMS` was used (at the time set to 32).

Miscellaneous Macros

int **PyArray_SAMESHAPE**(*PyArrayObject* *a1, *PyArrayObject* *a2)

Evaluates as True if arrays *a1* and *a2* have the same shape.

PyArray_MAX(a, b)

Returns the maximum of *a* and *b*. If (*a*) or (*b*) are expressions they are evaluated twice.

PyArray_MIN(a, b)

Returns the minimum of *a* and *b*. If (*a*) or (*b*) are expressions they are evaluated twice.

void **PyArray_DiscardWritebackIfCopy**(*PyArrayObject* *obj)

If `obj->flags` has *NPY_ARRAY_WRITEBACKIFCOPY*, this function clears the flags, *DECREF* s *obj->base* and makes it writeable, and sets `obj->base` to NULL. In contrast to *PyArray_ResolveWritebackIfCopy* it makes no attempt to copy the data from *obj->base*. This undoes *PyArray_SetWritebackIfCopyBase*. Usually this is called after an error when you are finished with `obj`, just before `Py_DECREF(obj)`. It may be called multiple times, or with `NULL` input.

Enumerated Types

enum **NPY_SORTKIND**

A special variable-type which can take on different values to indicate the sorting algorithm being used.

enumerator **NPY_QUICKSORT**

enumerator **NPY_HEAPSORT**

enumerator **NPY_MERGESORT**

enumerator **NPY_STABLESORT**

Used as an alias of *NPY_MERGESORT* and vice versa.

enumerator **NPY_NSORTS**

Defined to be the number of sorts. It is fixed at three by the need for backwards compatibility, and consequently *NPY_MERGESORT* and *NPY_STABLESORT* are aliased to each other and may refer to one of several stable sorting algorithms depending on the data type.

enum **NPY_SCALARKIND**

A special variable type indicating the number of "kinds" of scalars distinguished in determining scalar-coercion rules. This variable can take on the values:

enumerator **NPY_NOSCALAR**

enumerator **NPY_BOOL_SCALAR**

enumerator **NPY_INTPOS_SCALAR**

enumerator **NPY_INTNEG_SCALAR**

enumerator **NPY_FLOAT_SCALAR**

enumerator **NPY_COMPLEX_SCALAR**

enumerator **NPY_OBJECT_SCALAR**

enumerator **NPY_NSCALARKINDS**

Defined to be the number of scalar kinds (not including *NPY_NOSCALAR*).

enum **NPY_ORDER**

An enumeration type indicating the element order that an array should be interpreted in. When a brand new array is created, generally only **NPY_CORDER** and **NPY_FORTRANORDER** are used, whereas when one or more inputs are provided, the order can be based on them.

enumerator **NPY_ANYORDER**

Fortran order if all the inputs are Fortran, C otherwise.

enumerator **NPY_CORDER**

C order.

enumerator **NPY_FORTRANORDER**

Fortran order.

enumerator **NPY_KEEPORDER**

An order as close to the order of the inputs as possible, even if the input is in neither C nor Fortran order.

enum **NPY_CLIPMODE**

A variable type indicating the kind of clipping that should be applied in certain functions.

enumerator **NPY_RAISE**

The default for most operations, raises an exception if an index is out of bounds.

enumerator **NPY_CLIP**

Clips an index to the valid range if it is out of bounds.

enumerator **NPY_WRAP**

Wraps an index to the valid range if it is out of bounds.

enum **NPY_SEARCHSIDE**

A variable type indicating whether the index returned should be that of the first suitable location (if *NPY_SEARCHLEFT*) or of the last (if *NPY_SEARCHRIGHT*).

enumerator **NPY_SEARCHLEFT**

enumerator **NPY_SEARCHRIGHT**

enum **NPY_SELECTKIND**

A variable type indicating the selection algorithm being used.

enumerator **NPY_INTROSELECT**

enum **NPY_CASTING**

An enumeration type indicating how permissive data conversions should be. This is used by the iterator added in NumPy 1.6, and is intended to be used more broadly in a future version.

enumerator **NPY_NO_CASTING**

Only allow identical types.

enumerator **NPY_EQUIV_CASTING**

Allow identical and casts involving byte swapping.

enumerator **NPY_SAFE_CASTING**

Only allow casts which will not cause values to be rounded, truncated, or otherwise changed.

enumerator **NPY_SAME_KIND_CASTING**

Allow any safe casts, and casts between types of the same kind. For example, float64 -> float32 is permitted with this rule.

enumerator **NPY_UNSAFE_CASTING**

Allow any cast, no matter what kind of data loss may occur.

2.1.5 Array iterator API

Array iterator

The array iterator encapsulates many of the key features in ufuncs, allowing user code to support features like output parameters, preservation of memory layouts, and buffering of data with the wrong alignment or type, without requiring difficult coding.

This page documents the API for the iterator. The iterator is named `NpyIter` and functions are named `NpyIter_*`.

There is an *introductory guide to array iteration* which may be of interest for those using this C API. In many instances, testing out ideas by creating the iterator in Python is a good idea before writing the C iteration code.

Iteration example

The best way to become familiar with the iterator is to look at its usage within the NumPy codebase itself. For example, here is a slightly tweaked version of the code for *PyArray_CountNonzero*, which counts the number of non-zero elements in an array.

```
npy_intp PyArray_CountNonzero(PyArrayObject* self)
{
    /* Nonzero boolean function */
    PyArray_NonzeroFunc* nonzero = PyArray_DESCR(self)->f->nonzero;

    NpyIter* iter;
    NpyIter_IterNextFunc *iternext;
    char** dataptr;
    npy_intp nonzero_count;
    npy_intp* strideptr,* innersizeptr;

    /* Handle zero-sized arrays specially */
    if (PyArray_SIZE(self) == 0) {
        return 0;
    }

    /*
     * Create and use an iterator to count the nonzeros.
     *   flag NPY_ITER_READONLY
     *     - The array is never written to.
     *   flag NPY_ITER_EXTERNAL_LOOP
     *     - Inner loop is done outside the iterator for efficiency.
     *   flag NPY_ITER_NPY_ITER_REFS_OK
     *     - Reference types are acceptable.
     *   order NPY_KEEPORDER
     *     - Visit elements in memory order, regardless of strides.
     *       This is good for performance when the specific order
     *       elements are visited is unimportant.
     *   casting NPY_NO_CASTING
     *     - No casting is required for this operation.
     */
    iter = NpyIter_New(self, NPY_ITER_READONLY|
                             NPY_ITER_EXTERNAL_LOOP|
```

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```
                            NPY_ITER_REFS_OK,
                        NPY_KEEPORDER, NPY_NO_CASTING,
                        NULL);
    if (iter == NULL) {
        return -1;
    }

    /*
     * The iternext function gets stored in a local variable
     * so it can be called repeatedly in an efficient manner.
     */
    iternext = NpyIter_GetIterNext(iter, NULL);
    if (iternext == NULL) {
        NpyIter_Deallocate(iter);
        return -1;
    }
    /* The location of the data pointer which the iterator may update */
    dataptr = NpyIter_GetDataPtrArray(iter);
    /* The location of the stride which the iterator may update */
    strideptr = NpyIter_GetInnerStrideArray(iter);
    /* The location of the inner loop size which the iterator may update */
    innersizeptr = NpyIter_GetInnerLoopSizePtr(iter);

    nonzero_count = 0;
    do {
        /* Get the inner loop data/stride/count values */
        char* data = *dataptr;
        npy_intp stride = *strideptr;
        npy_intp count = *innersizeptr;

        /* This is a typical inner loop for NPY_ITER_EXTERNAL_LOOP */
        while (count--) {
            if (nonzero(data, self)) {
                ++nonzero_count;
            }
            data += stride;
        }

        /* Increment the iterator to the next inner loop */
    } while(iternext(iter));

    NpyIter_Deallocate(iter);

    return nonzero_count;
}
```

Multi-iteration example

Here is a copy function using the iterator. The `order` parameter is used to control the memory layout of the allocated result, typically *NPY_KEEPORDER* is desired.

```
PyObject *CopyArray(PyObject *arr, NPY_ORDER order)
{
    NpyIter *iter;
    NpyIter_IterNextFunc *iternext;
    PyObject *op[2], *ret;
    npy_uint32 flags;
    npy_uint32 op_flags[2];
    npy_intp itemsize, *innersizeptr, innerstride;
    char **dataptrarray;

    /*
     * No inner iteration - inner loop is handled by CopyArray code
     */
    flags = NPY_ITER_EXTERNAL_LOOP;
    /*
     * Tell the constructor to automatically allocate the output.
     * The data type of the output will match that of the input.
     */
    op[0] = arr;
    op[1] = NULL;
    op_flags[0] = NPY_ITER_READONLY;
    op_flags[1] = NPY_ITER_WRITEONLY | NPY_ITER_ALLOCATE;

    /* Construct the iterator */
    iter = NpyIter_MultiNew(2, op, flags, order, NPY_NO_CASTING,
                            op_flags, NULL);
    if (iter == NULL) {
        return NULL;
    }

    /*
     * Make a copy of the iternext function pointer and
     * a few other variables the inner loop needs.
     */
    iternext = NpyIter_GetIterNext(iter, NULL);
    innerstride = NpyIter_GetInnerStrideArray(iter)[0];
    itemsize = NpyIter_GetDescrArray(iter)[0]->elsize;
    /*
     * The inner loop size and data pointers may change during the
     * loop, so just cache the addresses.
     */
    innersizeptr = NpyIter_GetInnerLoopSizePtr(iter);
    dataptrarray = NpyIter_GetDataPtrArray(iter);

    /*
     * Note that because the iterator allocated the output,
     * it matches the iteration order and is packed tightly,
     * so we don't need to check it like the input.
     */
    if (innerstride == itemsize) {
        do {
            memcpy(dataptrarray[1], dataptrarray[0],
                                    itemsize * (*innersizeptr));
```

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```
        } while (iternext(iter));
    } else {
        /* For efficiency, should specialize this based on item size... */
        npy_intp i;
        do {
            npy_intp size = *innersizeptr;
            char *src = dataptrarray[0], *dst = dataptrarray[1];
            for(i = 0; i < size; i++, src += innerstride, dst += itemsize) {
                memcpy(dst, src, itemsize);
            }
        } while (iternext(iter));
    }

    /* Get the result from the iterator object array */
    ret = NpyIter_GetOperandArray(iter)[1];
    Py_INCREF(ret);

    if (NpyIter_Deallocate(iter) != NPY_SUCCEED) {
        Py_DECREF(ret);
        return NULL;
    }

    return ret;
}
```

Multi index tracking example

This example shows you how to work with the *NPY_ITER_MULTI_INDEX* flag. For simplicity, we assume the argument is a two-dimensional array.

```
int PrintMultiIndex(PyArrayObject *arr) {
    NpyIter *iter;
    NpyIter_IterNextFunc *iternext;
    npy_intp multi_index[2];

    iter = NpyIter_New(
        arr, NPY_ITER_READONLY | NPY_ITER_MULTI_INDEX | NPY_ITER_REFS_OK,
        NPY_KEEPORDER, NPY_NO_CASTING, NULL);
    if (iter == NULL) {
        return -1;
    }
    if (NpyIter_GetNDim(iter) != 2) {
        NpyIter_Deallocate(iter);
        PyErr_SetString(PyExc_ValueError, "Array must be 2-D");
        return -1;
    }
    if (NpyIter_GetIterSize(iter) != 0) {
        iternext = NpyIter_GetIterNext(iter, NULL);
        if (iternext == NULL) {
            NpyIter_Deallocate(iter);
            return -1;
        }
        NpyIter_GetMultiIndexFunc *get_multi_index =
            NpyIter_GetGetMultiIndex(iter, NULL);
        if (get_multi_index == NULL) {
```

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```
            NpyIter_Deallocate(iter);
            return -1;
        }

        do {
            get_multi_index(iter, multi_index);
            printf("multi_index is [%" NPY_INTP_FMT ", %" NPY_INTP_FMT "]\n",
                   multi_index[0], multi_index[1]);
        } while (iternext(iter));
    }
    if (!NpyIter_Deallocate(iter)) {
        return -1;
    }
    return 0;
}
```

When called with a 2x3 array, the above example prints:

```
multi_index is [0, 0]
multi_index is [0, 1]
multi_index is [0, 2]
multi_index is [1, 0]
multi_index is [1, 1]
multi_index is [1, 2]
```

Iterator data types

The iterator layout is an internal detail, and user code only sees an incomplete struct.

type **NpyIter**

This is an opaque pointer type for the iterator. Access to its contents can only be done through the iterator API.

type **NpyIter_Type**

This is the type which exposes the iterator to Python. Currently, no API is exposed which provides access to the values of a Python-created iterator. If an iterator is created in Python, it must be used in Python and vice versa. Such an API will likely be created in a future version.

type **NpyIter_IterNextFunc**

This is a function pointer for the iteration loop, returned by *NpyIter_GetIterNext*.

type **NpyIter_GetMultiIndexFunc**

This is a function pointer for getting the current iterator multi-index, returned by *NpyIter_GetGetMultiIndex*.

Construction and destruction

NpyIter ***NpyIter_New**(*PyArrayObject* *op, *npy_uint32* flags, *NPY_ORDER* order, *NPY_CASTING* casting, *PyArray_Descr* *dtype)

Creates an iterator for the given numpy array object `op`.

Flags that may be passed in `flags` are any combination of the global and per-operand flags documented in *NpyIter_MultiNew*, except for *NPY_ITER_ALLOCATE*.

Any of the *NPY_ORDER* enum values may be passed to `order`. For efficient iteration, *NPY_KEEPORDER* is the best option, and the other orders enforce the particular iteration pattern.

Any of the *NPY_CASTING* enum values may be passed to `casting`. The values include *NPY_NO_CASTING*, *NPY_EQUIV_CASTING*, *NPY_SAFE_CASTING*, *NPY_SAME_KIND_CASTING*, and *NPY_UNSAFE_CASTING*. To allow the casts to occur, copying or buffering must also be enabled.

If `dtype` isn't `NULL`, then it requires that data type. If copying is allowed, it will make a temporary copy if the data is castable. If *NPY_ITER_UPDATEIFCOPY* is enabled, it will also copy the data back with another cast upon iterator destruction.

Returns NULL if there is an error, otherwise returns the allocated iterator.

To make an iterator similar to the old iterator, this should work.

```
iter = NpyIter_New(op, NPY_ITER_READWRITE,
                   NPY_CORDER, NPY_NO_CASTING, NULL);
```

If you want to edit an array with aligned `double` code, but the order doesn't matter, you would use this.

```
dtype = PyArray_DescrFromType(NPY_DOUBLE);
iter = NpyIter_New(op, NPY_ITER_READWRITE|
                   NPY_ITER_BUFFERED|
                   NPY_ITER_NBO|
                   NPY_ITER_ALIGNED,
                   NPY_KEEPORDER,
                   NPY_SAME_KIND_CASTING,
                   dtype);
Py_DECREF(dtype);
```

NpyIter ***NpyIter_MultiNew**(*npy_intp* nop, *PyArrayObject* **op, *npy_uint32* flags, *NPY_ORDER* order, *NPY_CASTING* casting, *npy_uint32* *op_flags, *PyArray_Descr* **op_dtypes)

Creates an iterator for broadcasting the `nop` array objects provided in `op`, using regular NumPy broadcasting rules.

Any of the *NPY_ORDER* enum values may be passed to `order`. For efficient iteration, *NPY_KEEPORDER* is the best option, and the other orders enforce the particular iteration pattern. When using *NPY_KEEPORDER*, if you also want to ensure that the iteration is not reversed along an axis, you should pass the flag *NPY_ITER_DONT_NEGATE_STRIDES*.

Any of the *NPY_CASTING* enum values may be passed to `casting`. The values include *NPY_NO_CASTING*, *NPY_EQUIV_CASTING*, *NPY_SAFE_CASTING*, *NPY_SAME_KIND_CASTING*, and *NPY_UNSAFE_CASTING*. To allow the casts to occur, copying or buffering must also be enabled.

If `op_dtypes` isn't `NULL`, it specifies a data type or `NULL` for each `op[i]`.

Returns NULL if there is an error, otherwise returns the allocated iterator.

Flags that may be passed in `flags`, applying to the whole iterator, are:

NPY_ITER_C_INDEX

Causes the iterator to track a raveled flat index matching C order. This option cannot be used with *NPY_ITER_F_INDEX*.

NPY_ITER_F_INDEX

Causes the iterator to track a raveled flat index matching Fortran order. This option cannot be used with *NPY_ITER_C_INDEX*.

NPY_ITER_MULTI_INDEX

Causes the iterator to track a multi-index. This prevents the iterator from coalescing axes to produce bigger inner loops. If the loop is also not buffered and no index is being tracked (*NpyIter_RemoveAxis* can be called), then the iterator size can be `-1` to indicate that the iterator is too large. This can happen due to complex broadcasting and will result in errors being created when the setting the iterator range, removing the multi index, or getting the

next function. However, it is possible to remove axes again and use the iterator normally if the size is small enough after removal.

NPY_ITER_EXTERNAL_LOOP

Causes the iterator to skip iteration of the innermost loop, requiring the user of the iterator to handle it.

This flag is incompatible with *NPY_ITER_C_INDEX*, *NPY_ITER_F_INDEX*, and *NPY_ITER_MULTI_INDEX*.

NPY_ITER_DONT_NEGATE_STRIDES

This only affects the iterator when *NPY_KEEPORDER* is specified for the order parameter. By default with *NPY_KEEPORDER*, the iterator reverses axes which have negative strides, so that memory is traversed in a forward direction. This disables this step. Use this flag if you want to use the underlying memory-ordering of the axes, but don't want an axis reversed. This is the behavior of `numpy.ravel(a, order='K')`, for instance.

NPY_ITER_COMMON_DTYPE

Causes the iterator to convert all the operands to a common data type, calculated based on the ufunc type promotion rules. Copying or buffering must be enabled.

If the common data type is known ahead of time, don't use this flag. Instead, set the requested dtype for all the operands.

NPY_ITER_REFS_OK

Indicates that arrays with reference types (object arrays or structured arrays containing an object type) may be accepted and used in the iterator. If this flag is enabled, the caller must be sure to check whether `NpyIter_IterationNeedsAPI(iter)` is true, in which case it may not release the GIL during iteration.

NPY_ITER_ZEROSIZE_OK

Indicates that arrays with a size of zero should be permitted. Since the typical iteration loop does not naturally work with zero-sized arrays, you must check that the IterSize is larger than zero before entering the iteration loop. Currently only the operands are checked, not a forced shape.

NPY_ITER_REDUCE_OK

Permits writeable operands with a dimension with zero stride and size greater than one. Note that such operands must be read/write.

When buffering is enabled, this also switches to a special buffering mode which reduces the loop length as necessary to not trample on values being reduced.

Note that if you want to do a reduction on an automatically allocated output, you must use *NpyIter_GetOperandArray* to get its reference, then set every value to the reduction unit before doing the iteration loop. In the case of a buffered reduction, this means you must also specify the flag *NPY_ITER_DELAY_BUFALLOC*, then reset the iterator after initializing the allocated operand to prepare the buffers.

NPY_ITER_RANGED

Enables support for iteration of sub-ranges of the full `iterindex` range `[0, NpyIter_IterSize(iter))`. Use the function *NpyIter_ResetToIterIndexRange* to specify a range for iteration.

This flag can only be used with *NPY_ITER_EXTERNAL_LOOP* when *NPY_ITER_BUFFERED* is enabled. This is because without buffering, the inner loop is always the size of the innermost iteration dimension, and allowing it to get cut up would require special handling, effectively making it more like the buffered version.

NPY_ITER_BUFFERED

Causes the iterator to store buffering data, and use buffering to satisfy data type, alignment, and byte-order requirements. To buffer an operand, do not specify the *NPY_ITER_COPY* or *NPY_ITER_UPDATEIFCOPY* flags, because they will override buffering. Buffering is especially useful for Python code using the iterator, allowing for larger chunks of data at once to amortize the Python interpreter overhead.

If used with *NPY_ITER_EXTERNAL_LOOP*, the inner loop for the caller may get larger chunks than would be possible without buffering, because of how the strides are laid out.

Note that if an operand is given the flag *NPY_ITER_COPY* or *NPY_ITER_UPDATEIFCOPY*, a copy will be made in preference to buffering. Buffering will still occur when the array was broadcast so elements need to be duplicated to get a constant stride.

In normal buffering, the size of each inner loop is equal to the buffer size, or possibly larger if *NPY_ITER_GROWINNER* is specified. If *NPY_ITER_REDUCE_OK* is enabled and a reduction occurs, the inner loops may become smaller depending on the structure of the reduction.

NPY_ITER_GROWINNER

When buffering is enabled, this allows the size of the inner loop to grow when buffering isn't necessary. This option is best used if you're doing a straight pass through all the data, rather than anything with small cache-friendly arrays of temporary values for each inner loop.

NPY_ITER_DELAY_BUFALLOC

When buffering is enabled, this delays allocation of the buffers until *NpyIter_Reset* or another reset function is called. This flag exists to avoid wasteful copying of buffer data when making multiple copies of a buffered iterator for multi-threaded iteration.

Another use of this flag is for setting up reduction operations. After the iterator is created, and a reduction output is allocated automatically by the iterator (be sure to use READWRITE access), its value may be initialized to the reduction unit. Use *NpyIter_GetOperandArray* to get the object. Then, call *NpyIter_Reset* to allocate and fill the buffers with their initial values.

NPY_ITER_COPY_IF_OVERLAP

If any write operand has overlap with any read operand, eliminate all overlap by making temporary copies (enabling UPDATEIFCOPY for write operands, if necessary). A pair of operands has overlap if there is a memory address that contains data common to both arrays.

Because exact overlap detection has exponential runtime in the number of dimensions, the decision is made based on heuristics, which has false positives (needless copies in unusual cases) but has no false negatives.

If any read/write overlap exists, this flag ensures the result of the operation is the same as if all operands were copied. In cases where copies would need to be made, **the result of the computation may be undefined without this flag!**

Flags that may be passed in `op_flags[i]`, where `0 <= i < nop`:

NPY_ITER_READWRITE

NPY_ITER_READONLY

NPY_ITER_WRITEONLY

Indicate how the user of the iterator will read or write to `op[i]`. Exactly one of these flags must be specified per operand. Using `NPY_ITER_READWRITE` or `NPY_ITER_WRITEONLY` for a user-provided operand may trigger `WRITEBACKIFCOPY` semantics. The data will be written back to the original array when `NpyIter_Deallocate` is called.

NPY_ITER_COPY

Allow a copy of `op[i]` to be made if it does not meet the data type or alignment requirements as specified by the constructor flags and parameters.

NPY_ITER_UPDATEIFCOPY

Triggers *NPY_ITER_COPY*, and when an array operand is flagged for writing and is copied, causes the data in a copy to be copied back to `op[i]` when `NpyIter_Deallocate` is called.

If the operand is flagged as write-only and a copy is needed, an uninitialized temporary array will be created and then copied to back to `op[i]` on calling `NpyIter_Deallocate`, instead of doing the unnecessary copy operation.

NPY_ITER_NBO

NPY_ITER_ALIGNED

NPY_ITER_CONTIG

Causes the iterator to provide data for `op[i]` that is in native byte order, aligned according to the dtype requirements, contiguous, or any combination.

By default, the iterator produces pointers into the arrays provided, which may be aligned or unaligned, and with any byte order. If copying or buffering is not enabled and the operand data doesn't satisfy the constraints, an error will be raised.

The contiguous constraint applies only to the inner loop, successive inner loops may have arbitrary pointer changes.

If the requested data type is in non-native byte order, the NBO flag overrides it and the requested data type is converted to be in native byte order.

NPY_ITER_ALLOCATE

This is for output arrays, and requires that the flag *NPY_ITER_WRITEONLY* or *NPY_ITER_READWRITE* be set. If `op[i]` is NULL, creates a new array with the final broadcast dimensions, and a layout matching the iteration order of the iterator.

When `op[i]` is NULL, the requested data type `op_dtypes[i]` may be NULL as well, in which case it is automatically generated from the dtypes of the arrays which are flagged as readable. The rules for generating the dtype are the same is for UFuncs. Of special note is handling of byte order in the selected dtype. If there is exactly one input, the input's dtype is used as is. Otherwise, if more than one input dtypes are combined together, the output will be in native byte order.

After being allocated with this flag, the caller may retrieve the new array by calling *NpyIter_GetOperandArray* and getting the i-th object in the returned C array. The caller must call Py_INCREF on it to claim a reference to the array.

NPY_ITER_NO_SUBTYPE

For use with *NPY_ITER_ALLOCATE*, this flag disables allocating an array subtype for the output, forcing it to be a straight ndarray.

TODO: Maybe it would be better to introduce a function `NpyIter_GetWrappedOutput` and remove this flag?

NPY_ITER_NO_BROADCAST

Ensures that the input or output matches the iteration dimensions exactly.

NPY_ITER_ARRAYMASK

Indicates that this operand is the mask to use for selecting elements when writing to operands which have the *NPY_ITER_WRITEMASKED* flag applied to them. Only one operand may have *NPY_ITER_ARRAYMASK* flag applied to it.

The data type of an operand with this flag should be either *NPY_BOOL*, *NPY_MASK*, or a struct dtype whose fields are all valid mask dtypes. In the latter case, it must match up with a struct operand being WRITEMASKED, as it is specifying a mask for each field of that array.

This flag only affects writing from the buffer back to the array. This means that if the operand is also *NPY_ITER_READWRITE* or *NPY_ITER_WRITEONLY*, code doing iteration can write to this operand to control which elements will be untouched and which ones will be modified. This is useful when the mask should be a combination of input masks.

NPY_ITER_WRITEMASKED

This array is the mask for all *writemasked* operands. Code uses the `writemasked` flag which indicates that only elements where the chosen ARRAYMASK operand is True will be written to. In general, the iterator does not enforce this, it is up to the code doing the iteration to follow that promise.

When `writemasked` flag is used, and this operand is buffered, this changes how data is copied from the buffer into the array. A masked copying routine is used, which only copies the elements in the buffer for which `writemasked` returns true from the corresponding element in the ARRAYMASK operand.

NPY_ITER_OVERLAP_ASSUME_ELEMENTWISE

In memory overlap checks, assume that operands with `NPY_ITER_OVERLAP_ASSUME_ELEMENTWISE` enabled are accessed only in the iterator order.

This enables the iterator to reason about data dependency, possibly avoiding unnecessary copies.

This flag has effect only if `NPY_ITER_COPY_IF_OVERLAP` is enabled on the iterator.

NpyIter ***NpyIter_AdvancedNew**(*npy_intp* nop, *PyArrayObject* **op, *npy_uint32* flags, *NPY_ORDER* order, *NPY_CASTING* casting, *npy_uint32* *op_flags, *PyArray_Descr* **op_dtypes, int oa_ndim, int **op_axes, *npy_intp* const *itershape, *npy_intp* buffersize)

Extends *NpyIter_MultiNew* with several advanced options providing more control over broadcasting and buffering.

If -1/NULL values are passed to `oa_ndim`, `op_axes`, `itershape`, and `buffersize`, it is equivalent to *NpyIter_MultiNew*.

The parameter `oa_ndim`, when not zero or -1, specifies the number of dimensions that will be iterated with customized broadcasting. If it is provided, `op_axes` must and `itershape` can also be provided. The `op_axes` parameter let you control in detail how the axes of the operand arrays get matched together and iterated. In `op_axes`, you must provide an array of `nop` pointers to `oa_ndim`-sized arrays of type `npy_intp`. If an entry in `op_axes` is NULL, normal broadcasting rules will apply. In `op_axes[j][i]` is stored either a valid axis of `op[j]`, or -1 which means `newaxis`. Within each `op_axes[j]` array, axes may not be repeated. The following example is how normal broadcasting applies to a 3-D array, a 2-D array, a 1-D array and a scalar.

Note: Before NumPy 1.8 `oa_ndim == 0` was used for signalling that `op_axes` and `itershape` are unused. This is deprecated and should be replaced with -1. Better backward compatibility may be achieved by using *NpyIter_MultiNew* for this case.

```
int oa_ndim = 3;                /* # iteration axes */
int op0_axes[] = {0, 1, 2};     /* 3-D operand */
int op1_axes[] = {-1, 0, 1};    /* 2-D operand */
int op2_axes[] = {-1, -1, 0};   /* 1-D operand */
int op3_axes[] = {-1, -1, -1}   /* 0-D (scalar) operand */
int* op_axes[] = {op0_axes, op1_axes, op2_axes, op3_axes};
```

The `itershape` parameter allows you to force the iterator to have a specific iteration shape. It is an array of length `oa_ndim`. When an entry is negative, its value is determined from the operands. This parameter allows automatically allocated outputs to get additional dimensions which don't match up with any dimension of an input.

If `buffersize` is zero, a default buffer size is used, otherwise it specifies how big of a buffer to use. Buffers which are powers of 2 such as 4096 or 8192 are recommended.

Returns NULL if there is an error, otherwise returns the allocated iterator.

NpyIter ***NpyIter_Copy**(*NpyIter* *iter)

Makes a copy of the given iterator. This function is provided primarily to enable multi-threaded iteration of the data.

TODO: Move this to a section about multithreaded iteration.

The recommended approach to multithreaded iteration is to first create an iterator with the flags *NPY_ITER_EXTERNAL_LOOP*, *NPY_ITER_RANGED*, *NPY_ITER_BUFFERED*, *NPY_ITER_DELAY_BUFALLOC*, and possibly *NPY_ITER_GROWINNER*. Create a copy of this iterator for each thread (minus one for the first iterator). Then, take the iteration index range `[0,`

`NpyIter_GetIterSize(iter)` and split it up into tasks, for example using a TBB parallel_for loop. When a thread gets a task to execute, it then uses its copy of the iterator by calling *`NpyIter_ResetToIterIndexRange`* and iterating over the full range.

When using the iterator in multi-threaded code or in code not holding the Python GIL, care must be taken to only call functions which are safe in that context. *`NpyIter_Copy`* cannot be safely called without the Python GIL, because it increments Python references. The `Reset*` and some other functions may be safely called by passing in the `errmsg` parameter as non-NULL, so that the functions will pass back errors through it instead of setting a Python exception.

`NpyIter_Deallocate` must be called for each copy.

int **NpyIter_RemoveAxis**(*NpyIter* *iter, int axis)

Removes an axis from iteration. This requires that *`NPY_ITER_MULTI_INDEX`* was set for iterator creation, and does not work if buffering is enabled or an index is being tracked. This function also resets the iterator to its initial state.

This is useful for setting up an accumulation loop, for example. The iterator can first be created with all the dimensions, including the accumulation axis, so that the output gets created correctly. Then, the accumulation axis can be removed, and the calculation done in a nested fashion.

WARNING: This function may change the internal memory layout of the iterator. Any cached functions or pointers from the iterator must be retrieved again! The iterator range will be reset as well.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

int **NpyIter_RemoveMultiIndex**(*NpyIter* *iter)

If the iterator is tracking a multi-index, this strips support for them, and does further iterator optimizations that are possible if multi-indices are not needed. This function also resets the iterator to its initial state.

WARNING: This function may change the internal memory layout of the iterator. Any cached functions or pointers from the iterator must be retrieved again!

After calling this function, *`NpyIter_HasMultiIndex`*`(iter)` will return false.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

int **NpyIter_EnableExternalLoop**(*NpyIter* *iter)

If *`NpyIter_RemoveMultiIndex`* was called, you may want to enable the flag *`NPY_ITER_EXTERNAL_LOOP`*. This flag is not permitted together with *`NPY_ITER_MULTI_INDEX`*, so this function is provided to enable the feature after *`NpyIter_RemoveMultiIndex`* is called. This function also resets the iterator to its initial state.

WARNING: This function changes the internal logic of the iterator. Any cached functions or pointers from the iterator must be retrieved again!

Returns `NPY_SUCCEED` or `NPY_FAIL`.

int **NpyIter_Deallocate**(*NpyIter* *iter)

Deallocates the iterator object and resolves any needed writebacks.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

int **NpyIter_Reset**(*NpyIter* *iter, char **errmsg)

Resets the iterator back to its initial state, at the beginning of the iteration range.

Returns `NPY_SUCCEED` or `NPY_FAIL`. If errmsg is non-NULL, no Python exception is set when `NPY_FAIL` is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

int **NpyIter_ResetToIterIndexRange**(*NpyIter* *iter, *npy_intp* istart, *npy_intp* iend, char **errmsg)

Resets the iterator and restricts it to the `iterindex` range `[istart, iend)`. See *NpyIter_Copy* for an explanation of how to use this for multi-threaded iteration. This requires that the flag *NPY_ITER_RANGED* was passed to the iterator constructor.

If you want to reset both the `iterindex` range and the base pointers at the same time, you can do the following to avoid extra buffer copying (be sure to add the return code error checks when you copy this code).

```
/* Set to a trivial empty range */
NpyIter_ResetToIterIndexRange(iter, 0, 0);
/* Set the base pointers */
NpyIter_ResetBasePointers(iter, baseptrs);
/* Set to the desired range */
NpyIter_ResetToIterIndexRange(iter, istart, iend);
```

Returns `NPY_SUCCEED` or `NPY_FAIL`. If errmsg is non-NULL, no Python exception is set when `NPY_FAIL` is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

int **NpyIter_ResetBasePointers**(*NpyIter* *iter, char **baseptrs, char **errmsg)

Resets the iterator back to its initial state, but using the values in `baseptrs` for the data instead of the pointers from the arrays being iterated. This functions is intended to be used, together with the `op_axes` parameter, by nested iteration code with two or more iterators.

Returns `NPY_SUCCEED` or `NPY_FAIL`. If errmsg is non-NULL, no Python exception is set when `NPY_FAIL` is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

TODO: Move the following into a special section on nested iterators.

Creating iterators for nested iteration requires some care. All the iterator operands must match exactly, or the calls to *NpyIter_ResetBasePointers* will be invalid. This means that automatic copies and output allocation should not be used haphazardly. It is possible to still use the automatic data conversion and casting features of the iterator by creating one of the iterators with all the conversion parameters enabled, then grabbing the allocated operands with the *NpyIter_GetOperandArray* function and passing them into the constructors for the rest of the iterators.

WARNING: When creating iterators for nested iteration, the code must not use a dimension more than once in the different iterators. If this is done, nested iteration will produce out-of-bounds pointers during iteration.

WARNING: When creating iterators for nested iteration, buffering can only be applied to the innermost iterator. If a buffered iterator is used as the source for `baseptrs`, it will point into a small buffer instead of the array and the inner iteration will be invalid.

The pattern for using nested iterators is as follows.

```
NpyIter *iter1, *iter1;
NpyIter_IterNextFunc *iternext1, *iternext2;
char **dataptrs1;

/*
 * With the exact same operands, no copies allowed, and
 * no axis in op_axes used both in iter1 and iter2.
 * Buffering may be enabled for iter2, but not for iter1.
 */
iter1 = ...; iter2 = ...;

iternext1 = NpyIter_GetIterNext(iter1);
iternext2 = NpyIter_GetIterNext(iter2);
```

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```
dataptrs1 = NpyIter_GetDataPtrArray(iter1);

do {
    NpyIter_ResetBasePointers(iter2, dataptrs1);
    do {
        /* Use the iter2 values */
    } while (iternext2(iter2));
} while (iternext1(iter1));
```

int **NpyIter_GotoMultiIndex**(*NpyIter* *iter, *npy_intp* const *multi_index)

Adjusts the iterator to point to the `ndim` indices pointed to by `multi_index`. Returns an error if a multi-index is not being tracked, the indices are out of bounds, or inner loop iteration is disabled.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

int **NpyIter_GotoIndex**(*NpyIter* *iter, *npy_intp* index)

Adjusts the iterator to point to the `index` specified. If the iterator was constructed with the flag *NPY_ITER_C_INDEX*, `index` is the C-order index, and if the iterator was constructed with the flag *NPY_ITER_F_INDEX*, `index` is the Fortran-order index. Returns an error if there is no index being tracked, the index is out of bounds, or inner loop iteration is disabled.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

npy_intp **NpyIter_GetIterSize**(*NpyIter* *iter)

Returns the number of elements being iterated. This is the product of all the dimensions in the shape. When a multi index is being tracked (and *NpyIter_RemoveAxis* may be called) the size may be `-1` to indicate an iterator is too large. Such an iterator is invalid, but may become valid after *NpyIter_RemoveAxis* is called. It is not necessary to check for this case.

npy_intp **NpyIter_GetIterIndex**(*NpyIter* *iter)

Gets the `iterindex` of the iterator, which is an index matching the iteration order of the iterator.

void **NpyIter_GetIterIndexRange**(*NpyIter* *iter, *npy_intp* *istart, *npy_intp* *iend)

Gets the `iterindex` sub-range that is being iterated. If *NPY_ITER_RANGED* was not specified, this always returns the range `[0, NpyIter_IterSize(iter))`.

int **NpyIter_GotoIterIndex**(*NpyIter* *iter, *npy_intp* iterindex)

Adjusts the iterator to point to the `iterindex` specified. The IterIndex is an index matching the iteration order of the iterator. Returns an error if the `iterindex` is out of bounds, buffering is enabled, or inner loop iteration is disabled.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

npy_bool **NpyIter_HasDelayedBufAlloc**(*NpyIter* *iter)

Returns 1 if the flag *NPY_ITER_DELAY_BUFALLOC* was passed to the iterator constructor, and no call to one of the Reset functions has been done yet, 0 otherwise.

npy_bool **NpyIter_HasExternalLoop**(*NpyIter* *iter)

Returns 1 if the caller needs to handle the inner-most 1-dimensional loop, or 0 if the iterator handles all looping. This is controlled by the constructor flag *NPY_ITER_EXTERNAL_LOOP* or *NpyIter_EnableExternalLoop*.

npy_bool **NpyIter_HasMultiIndex**(*NpyIter* *iter)

Returns 1 if the iterator was created with the *NPY_ITER_MULTI_INDEX* flag, 0 otherwise.

npy_bool **NpyIter_HasIndex**(*NpyIter* *iter)

Returns 1 if the iterator was created with the *NPY_ITER_C_INDEX* or *NPY_ITER_F_INDEX* flag, 0 otherwise.

npy_bool **NpyIter_RequiresBuffering**(*NpyIter* *iter)

Returns 1 if the iterator requires buffering, which occurs when an operand needs conversion or alignment and so cannot be used directly.

npy_bool **NpyIter_IsBuffered**(*NpyIter* *iter)

Returns 1 if the iterator was created with the *NPY_ITER_BUFFERED* flag, 0 otherwise.

npy_bool **NpyIter_IsGrowInner**(*NpyIter* *iter)

Returns 1 if the iterator was created with the *NPY_ITER_GROWINNER* flag, 0 otherwise.

npy_intp **NpyIter_GetBufferSize**(*NpyIter* *iter)

If the iterator is buffered, returns the size of the buffer being used, otherwise returns 0.

int **NpyIter_GetNDim**(*NpyIter* *iter)

Returns the number of dimensions being iterated. If a multi-index was not requested in the iterator constructor, this value may be smaller than the number of dimensions in the original objects.

int **NpyIter_GetNOp**(*NpyIter* *iter)

Returns the number of operands in the iterator.

npy_intp ***NpyIter_GetAxisStrideArray**(*NpyIter* *iter, int axis)

Gets the array of strides for the specified axis. Requires that the iterator be tracking a multi-index, and that buffering not be enabled.

This may be used when you want to match up operand axes in some fashion, then remove them with *NpyIter_RemoveAxis* to handle their processing manually. By calling this function before removing the axes, you can get the strides for the manual processing.

Returns `NULL` on error.

int **NpyIter_GetShape**(*NpyIter* *iter, *npy_intp* *outshape)

Returns the broadcast shape of the iterator in `outshape`. This can only be called on an iterator which is tracking a multi-index.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

PyArray_Descr ****NpyIter_GetDescrArray**(*NpyIter* *iter)

This gives back a pointer to the `nop` data type Descrs for the objects being iterated. The result points into `iter`, so the caller does not gain any references to the Descrs.

This pointer may be cached before the iteration loop, calling `iternext` will not change it.

PyObject ****NpyIter_GetOperandArray**(*NpyIter* *iter)

This gives back a pointer to the `nop` operand PyObjects that are being iterated. The result points into `iter`, so the caller does not gain any references to the PyObjects.

PyObject ***NpyIter_GetIterView**(*NpyIter* *iter, *npy_intp* i)

This gives back a reference to a new ndarray view, which is a view into the i-th object in the array *NpyIter_GetOperandArray*, whose dimensions and strides match the internal optimized iteration pattern. A C-order iteration of this view is equivalent to the iterator's iteration order.

For example, if an iterator was created with a single array as its input, and it was possible to rearrange all its axes and then collapse it into a single strided iteration, this would return a view that is a one-dimensional array.

void **NpyIter_GetReadFlags**(*NpyIter* *iter, char *outreadflags)

Fills `nop` flags. Sets `outreadflags[i]` to 1 if `op[i]` can be read from, and to 0 if not.

void **NpyIter_GetWriteFlags**(*NpyIter* *iter, char *outwriteflags)

Fills `nop` flags. Sets `outwriteflags[i]` to 1 if `op[i]` can be written to, and to 0 if not.

int **NpyIter_CreateCompatibleStrides**(*NpyIter* *iter, *npy_intp* itemsize, *npy_intp* *outstrides)

Builds a set of strides which are the same as the strides of an output array created using the *NPY_ITER_ALLOCATE* flag, where NULL was passed for op_axes. This is for data packed contiguously, but not necessarily in C or Fortran order. This should be used together with *NpyIter_GetShape* and *NpyIter_GetNDim* with the flag *NPY_ITER_MULTI_INDEX* passed into the constructor.

A use case for this function is to match the shape and layout of the iterator and tack on one or more dimensions. For example, in order to generate a vector per input value for a numerical gradient, you pass in ndim*itemsize for itemsize, then add another dimension to the end with size ndim and stride itemsize. To do the Hessian matrix, you do the same thing but add two dimensions, or take advantage of the symmetry and pack it into 1 dimension with a particular encoding.

This function may only be called if the iterator is tracking a multi-index and if *NPY_ITER_DONT_NEGATE_STRIDES* was used to prevent an axis from being iterated in reverse order.

If an array is created with this method, simply adding 'itemsize' for each iteration will traverse the new array matching the iterator.

Returns `NPY_SUCCEED` or `NPY_FAIL`.

npy_bool **NpyIter_IsFirstVisit**(*NpyIter* *iter, int iop)

Checks to see whether this is the first time the elements of the specified reduction operand which the iterator points at are being seen for the first time. The function returns a reasonable answer for reduction operands and when buffering is disabled. The answer may be incorrect for buffered non-reduction operands.

This function is intended to be used in EXTERNAL_LOOP mode only, and will produce some wrong answers when that mode is not enabled.

If this function returns true, the caller should also check the inner loop stride of the operand, because if that stride is 0, then only the first element of the innermost external loop is being visited for the first time.

WARNING: For performance reasons, 'iop' is not bounds-checked, it is not confirmed that 'iop' is actually a reduction operand, and it is not confirmed that EXTERNAL_LOOP mode is enabled. These checks are the responsibility of the caller, and should be done outside of any inner loops.

Functions for iteration

NpyIter_IterNextFunc ***NpyIter_GetIterNext**(*NpyIter* *iter, char **errmsg)

Returns a function pointer for iteration. A specialized version of the function pointer may be calculated by this function instead of being stored in the iterator structure. Thus, to get good performance, it is required that the function pointer be saved in a variable rather than retrieved for each loop iteration.

Returns NULL if there is an error. If errmsg is non-NULL, no Python exception is set when `NPY_FAIL` is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

The typical looping construct is as follows.

```
NpyIter_IterNextFunc *iternext = NpyIter_GetIterNext(iter, NULL);
char** dataptr = NpyIter_GetDataPtrArray(iter);

do {
    /* use the addresses dataptr[0], ... dataptr[nop-1] */
} while(iternext(iter));
```

When *NPY_ITER_EXTERNAL_LOOP* is specified, the typical inner loop construct is as follows.

```
NpyIter_IterNextFunc *iternext = NpyIter_GetIterNext(iter, NULL);
char** dataptr = NpyIter_GetDataPtrArray(iter);
npy_intp* stride = NpyIter_GetInnerStrideArray(iter);
npy_intp* size_ptr = NpyIter_GetInnerLoopSizePtr(iter), size;
npy_intp iop, nop = NpyIter_GetNOp(iter);

do {
    size = *size_ptr;
    while (size--) {
        /* use the addresses dataptr[0], ... dataptr[nop-1] */
        for (iop = 0; iop < nop; ++iop) {
            dataptr[iop] += stride[iop];
        }
    }
} while (iternext());
```

Observe that we are using the dataptr array inside the iterator, not copying the values to a local temporary. This is possible because when `iternext()` is called, these pointers will be overwritten with fresh values, not incrementally updated.

If a compile-time fixed buffer is being used (both flags *NPY_ITER_BUFFERED* and *NPY_ITER_EXTERNAL_LOOP*), the inner size may be used as a signal as well. The size is guaranteed to become zero when `iternext()` returns false, enabling the following loop construct. Note that if you use this construct, you should not pass *NPY_ITER_GROWINNER* as a flag, because it will cause larger sizes under some circumstances.

```
/* The constructor should have buffersize passed as this value */
#define FIXED_BUFFER_SIZE 1024

NpyIter_IterNextFunc *iternext = NpyIter_GetIterNext(iter, NULL);
char **dataptr = NpyIter_GetDataPtrArray(iter);
npy_intp *stride = NpyIter_GetInnerStrideArray(iter);
npy_intp *size_ptr = NpyIter_GetInnerLoopSizePtr(iter), size;
npy_intp i, iop, nop = NpyIter_GetNOp(iter);

/* One loop with a fixed inner size */
size = *size_ptr;
while (size == FIXED_BUFFER_SIZE) {
    /*
     * This loop could be manually unrolled by a factor
     * which divides into FIXED_BUFFER_SIZE
     */
    for (i = 0; i < FIXED_BUFFER_SIZE; ++i) {
        /* use the addresses dataptr[0], ... dataptr[nop-1] */
        for (iop = 0; iop < nop; ++iop) {
            dataptr[iop] += stride[iop];
        }
    }
    iternext();
    size = *size_ptr;
}

/* Finish-up loop with variable inner size */
if (size > 0) do {
    size = *size_ptr;
    while (size--) {
        /* use the addresses dataptr[0], ... dataptr[nop-1] */
```

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```
        for (iop = 0; iop < nop; ++iop) {
            dataptr[iop] += stride[iop];
        }
    }
} while (iternext());
```

NpyIter_GetMultiIndexFunc ***NpyIter_GetGetMultiIndex**(*NpyIter* *iter, char **errmsg)

Returns a function pointer for getting the current multi-index of the iterator. Returns NULL if the iterator is not tracking a multi-index. It is recommended that this function pointer be cached in a local variable before the iteration loop.

Returns NULL if there is an error. If errmsg is non-NULL, no Python exception is set when `NPY_FAIL` is returned. Instead, *errmsg is set to an error message. When errmsg is non-NULL, the function may be safely called without holding the Python GIL.

char ***NpyIter_GetDataPtrArray**(*NpyIter* *iter)

This gives back a pointer to the `nop` data pointers. If *NPY_ITER_EXTERNAL_LOOP* was not specified, each data pointer points to the current data item of the iterator. If no inner iteration was specified, it points to the first data item of the inner loop.

This pointer may be cached before the iteration loop, calling `iternext` will not change it. This function may be safely called without holding the Python GIL.

char ***NpyIter_GetInitialDataPtrArray**(*NpyIter* *iter)

Gets the array of data pointers directly into the arrays (never into the buffers), corresponding to iteration index 0.

These pointers are different from the pointers accepted by `NpyIter_ResetBasePointers`, because the direction along some axes may have been reversed.

This function may be safely called without holding the Python GIL.

npy_intp ***NpyIter_GetIndexPtr**(*NpyIter* *iter)

This gives back a pointer to the index being tracked, or NULL if no index is being tracked. It is only usable if one of the flags *NPY_ITER_C_INDEX* or *NPY_ITER_F_INDEX* were specified during construction.

When the flag *NPY_ITER_EXTERNAL_LOOP* is used, the code needs to know the parameters for doing the inner loop. These functions provide that information.

npy_intp ***NpyIter_GetInnerStrideArray**(*NpyIter* *iter)

Returns a pointer to an array of the `nop` strides, one for each iterated object, to be used by the inner loop.

This pointer may be cached before the iteration loop, calling `iternext` will not change it. This function may be safely called without holding the Python GIL.

WARNING: While the pointer may be cached, its values may change if the iterator is buffered.

npy_intp ***NpyIter_GetInnerLoopSizePtr**(*NpyIter* *iter)

Returns a pointer to the number of iterations the inner loop should execute.

This address may be cached before the iteration loop, calling `iternext` will not change it. The value itself may change during iteration, in particular if buffering is enabled. This function may be safely called without holding the Python GIL.

void **NpyIter_GetInnerFixedStrideArray**(*NpyIter* *iter, *npy_intp* *out_strides)

Gets an array of strides which are fixed, or will not change during the entire iteration. For strides that may change, the value NPY_MAX_INTP is placed in the stride.

Once the iterator is prepared for iteration (after a reset if *NPY_ITER_DELAY_BUFALLOC* was used), call this to get the strides which may be used to select a fast inner loop function. For example, if the stride is 0, that means the

inner loop can always load its value into a variable once, then use the variable throughout the loop, or if the stride equals the itemsize, a contiguous version for that operand may be used.

This function may be safely called without holding the Python GIL.

Converting from previous NumPy iterators

The old iterator API includes functions like PyArrayIter_Check, PyArray_Iter* and PyArray_ITER_*. The multi-iterator array includes PyArray_MultiIter*, PyArray_Broadcast, and PyArray_RemoveSmallest. The new iterator design replaces all of this functionality with a single object and associated API. One goal of the new API is that all uses of the existing iterator should be replaceable with the new iterator without significant effort. In 1.6, the major exception to this is the neighborhood iterator, which does not have corresponding features in this iterator.

Here is a conversion table for which functions to use with the new iterator:

Iterator Functions	
PyArray_IterNew	*NpyIter_New*
PyArray_IterAllButAxis	*NpyIter_New* + `axes` parameter **or** Iterator flag *NPY_ITER_EXTERNAL_LOOP*
PyArray_BroadcastToShape	**NOT SUPPORTED** (Use the support for multiple operands instead.)
PyArrayIter_Check	Will need to add this in Python exposure
PyArray_ITER_RESET	*NpyIter_Reset*
PyArray_ITER_NEXT	Function pointer from *NpyIter_GetIterNext*
PyArray_ITER_DATA	*NpyIter_GetDataPtrArray*
PyArray_ITER_GOTO	*NpyIter_GotoMultiIndex*
PyArray_ITER_GOTO1D	*NpyIter_GotoIndex* or *NpyIter_GotoIterIndex*
PyArray_ITER_NOTDONE	Return value of `iternext` function pointer
Multi-iterator Functions	
PyArray_MultiIterNew	*NpyIter_MultiNew*
PyArray_MultiIter_RESET	*NpyIter_Reset*
PyArray_MultiIter_NEXT	Function pointer from *NpyIter_GetIterNext*
PyArray_MultiIter_DATA	*NpyIter_GetDataPtrArray*
PyArray_MultiIter_NEXTi	**NOT SUPPORTED** (always lock-step iteration)
PyArray_MultiIter_GOTO	*NpyIter_GotoMultiIndex*
PyArray_MultiIter_GOTO1D	*NpyIter_GotoIndex* or *NpyIter_GotoIterIndex*
PyArray_MultiIter_NOTDONE	Return value of `iternext` function pointer
PyArray_Broadcast	Handled by *NpyIter_MultiNew*
PyArray_RemoveSmallest	Iterator flag *NPY_ITER_EXTERNAL_LOOP*
Other Functions	
PyArray_ConvertToCommonTy	Iterator flag *NPY_ITER_COMMON_DTYPE*

2.1.6 ufunc API

Constants

UFUNC_{THING}_{ERR}

UFUNC_FPE_DIVIDEBYZERO

UFUNC_FPE_OVERFLOW

UFUNC_FPE_UNDERFLOW

UFUNC_FPE_INVALID

PyUFunc_{VALUE}

PyUFunc_One

PyUFunc_Zero

PyUFunc_MinusOne

PyUFunc_ReorderableNone

PyUFunc_None

PyUFunc_IdentityValue

Macros

NPY_LOOP_BEGIN_THREADS

Used in universal function code to only release the Python GIL if loop->obj is not true (*i.e.* this is not an OBJECT array loop). Requires use of *NPY_BEGIN_THREADS_DEF* in variable declaration area.

NPY_LOOP_END_THREADS

Used in universal function code to re-acquire the Python GIL if it was released (because loop->obj was not true).

Types

type **PyUFuncGenericFunction**

Pointers to functions that actually implement the underlying (element-by-element) function N times with the following signature:

void **loopfunc**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *data)

Parameters

- **args** – An array of pointers to the actual data for the input and output arrays. The input arguments are given first followed by the output arguments.
- **dimensions** – A pointer to the size of the dimension over which this function is looping.
- **steps** – A pointer to the number of bytes to jump to get to the next element in this dimension for each of the input and output arguments.
- **data** – Arbitrary data (extra arguments, function names, *etc.*) that can be stored with the ufunc and will be passed in when it is called. May be `NULL`.

  Changed in version 1.23.0: Accepts `NULL` *data* in addition to array of `NULL` values.

This is an example of a func specialized for addition of doubles returning doubles.

```
static void
double_add(char **args,
           npy_intp const *dimensions,
           npy_intp const *steps,
           void *extra)
{
    npy_intp i;
    npy_intp is1 = steps[0], is2 = steps[1];
```

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```
    npy_intp os = steps[2], n = dimensions[0];
    char *i1 = args[0], *i2 = args[1], *op = args[2];
    for (i = 0; i < n; i++) {
        *((double *)op) = *((double *)i1) +
                          *((double *)i2);
        i1 += is1;
        i2 += is2;
        op += os;
     }
}
```

Functions

PyObject ***PyUFunc_FromFuncAndData**(*PyUFuncGenericFunction* *func, void *const *data, const char *types, int ntypes, int nin, int nout, int identity, const char *name, const char *doc, int unused)

Create a new broadcasting universal function from required variables. Each ufunc builds around the notion of an element-by-element operation. Each ufunc object contains pointers to 1-d loops implementing the basic functionality for each supported type.

Note: The *func*, *data*, *types*, *name*, and *doc* arguments are not copied by *PyUFunc_FromFuncAndData*. The caller must ensure that the memory used by these arrays is not freed as long as the ufunc object is alive.

Parameters

- **func** – Must point to an array containing *ntypes* *PyUFuncGenericFunction* elements.
- **data** – Should be `NULL` or a pointer to an array of size *ntypes*. This array may contain arbitrary extra-data to be passed to the corresponding loop function in the func array, including `NULL`.
- **types** – Length `(nin + nout) * ntypes` array of `char` encoding the *numpy.dtype.num* (built-in only) that the corresponding function in the `func` array accepts. For instance, for a comparison ufunc with three `ntypes`, two `nin` and one `nout`, where the first function accepts *numpy.int32* and the second *numpy.int64*, with both returning *numpy.bool_*, `types` would be `(char[]) {5, 5, 0, 7, 7, 0}` since `NPY_INT32` is 5, `NPY_INT64` is 7, and `NPY_BOOL` is 0.

  The bit-width names can also be used (e.g. *NPY_INT32*, *NPY_COMPLEX128*) if desired.

  ufuncs.casting will be used at runtime to find the first `func` callable by the input/output provided.
- **ntypes** – How many different data-type-specific functions the ufunc has implemented.
- **nin** – The number of inputs to this operation.
- **nout** – The number of outputs
- **identity** – Either *PyUFunc_One*, *PyUFunc_Zero*, *PyUFunc_MinusOne*, or *PyUFunc_None*. This specifies what should be returned when an empty array is passed to the reduce method of the ufunc. The special value *PyUFunc_IdentityValue* may only be used with the *PyUFunc_FromFuncAndDataAndSignatureAndIdentity* method, to allow an arbitrary python object to be used as the identity.

- **name** – The name for the ufunc as a `NULL` terminated string. Specifying a name of 'add' or 'multiply' enables a special behavior for integer-typed reductions when no dtype is given. If the input type is an integer (or boolean) data type smaller than the size of the *numpy.int_* data type, it will be internally upcast to the *numpy.int_* (or *numpy.uint*) data type.
- **doc** – Allows passing in a documentation string to be stored with the ufunc. The documentation string should not contain the name of the function or the calling signature as that will be dynamically determined from the object and available when accessing the **__doc__** attribute of the ufunc.
- **unused** – Unused and present for backwards compatibility of the C-API.

PyObject ***PyUFunc_FromFuncAndDataAndSignature**(*PyUFuncGenericFunction* *func, void *const *data, const char *types, int ntypes, int nin, int nout, int identity, const char *name, const char *doc, int unused, const char *signature)

This function is very similar to PyUFunc_FromFuncAndData above, but has an extra *signature* argument, to define a *generalized universal functions*. Similarly to how ufuncs are built around an element-by-element operation, gufuncs are around subarray-by-subarray operations, the *signature* defining the subarrays to operate on.

Parameters

- **signature** – The signature for the new gufunc. Setting it to NULL is equivalent to calling PyUFunc_FromFuncAndData. A copy of the string is made, so the passed in buffer can be freed.

PyObject ***PyUFunc_FromFuncAndDataAndSignatureAndIdentity**(*PyUFuncGenericFunction* *func, void **data, char *types, int ntypes, int nin, int nout, int identity, char *name, char *doc, int unused, char *signature, PyObject *identity_value)

This function is very similar to *PyUFunc_FromFuncAndDataAndSignature* above, but has an extra *identity_value* argument, to define an arbitrary identity for the ufunc when `identity` is passed as `PyUFunc_IdentityValue`.

Parameters

- **identity_value** – The identity for the new gufunc. Must be passed as `NULL` unless the `identity` argument is `PyUFunc_IdentityValue`. Setting it to NULL is equivalent to calling PyUFunc_FromFuncAndDataAndSignature.

int **PyUFunc_RegisterLoopForType**(*PyUFuncObject* *ufunc, int usertype, *PyUFuncGenericFunction* function, int *arg_types, void *data)

This function allows the user to register a 1-d loop with an already- created ufunc to be used whenever the ufunc is called with any of its input arguments as the user-defined data-type. This is needed in order to make ufuncs work with built-in data-types. The data-type must have been previously registered with the numpy system. The loop is passed in as *function*. This loop can take arbitrary data which should be passed in as *data*. The data-types the loop requires are passed in as *arg_types* which must be a pointer to memory at least as large as ufunc->nargs.

int **PyUFunc_RegisterLoopForDescr**(*PyUFuncObject* *ufunc, *PyArray_Descr* *userdtype, *PyUFuncGenericFunction* function, *PyArray_Descr* **arg_dtypes, void *data)

This function behaves like PyUFunc_RegisterLoopForType above, except that it allows the user to register a 1-d loop using PyArray_Descr objects instead of dtype type num values. This allows a 1-d loop to be registered for structured array data-dtypes and custom data-types instead of scalar data-types.

int **PyUFunc_ReplaceLoopBySignature**(*PyUFuncObject* *ufunc, *PyUFuncGenericFunction* newfunc, int *signature, *PyUFuncGenericFunction* *oldfunc)

Replace a 1-d loop matching the given *signature* in the already-created *ufunc* with the new 1-d loop newfunc. Return the old 1-d loop function in *oldfunc*. Return 0 on success and -1 on failure. This function works only with built-in types (use *PyUFunc_RegisterLoopForType* for user-defined types). A signature is an array of data-type numbers indicating the inputs followed by the outputs assumed by the 1-d loop.

void **PyUFunc_clearfperr**()

Clear the IEEE error flags.

Generic functions

At the core of every ufunc is a collection of type-specific functions that defines the basic functionality for each of the supported types. These functions must evaluate the underlying function $N \geq 1$ times. Extra-data may be passed in that may be used during the calculation. This feature allows some general functions to be used as these basic looping functions. The general function has all the code needed to point variables to the right place and set up a function call. The general function assumes that the actual function to call is passed in as the extra data and calls it with the correct values. All of these functions are suitable for placing directly in the array of functions stored in the functions member of the PyUFuncObject structure.

void **PyUFunc_f_f_As_d_d**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_d_d**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_f_f**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_g_g**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_F_F_As_D_D**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_F_F**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_D_D**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_G_G**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_e_e**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_e_e_As_f_f**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_e_e_As_d_d**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

Type specific, core 1-d functions for ufuncs where each calculation is obtained by calling a function taking one input argument and returning one output. This function is passed in `func`. The letters correspond to dtypechar's of the supported data types (`e` - half, `f` - float, `d` - double, `g` - long double, `F` - cfloat, `D` - cdouble, `G` - clongdouble). The argument *func* must support the same signature. The _As_X_X variants assume ndarray's of one data type but cast the values to use an underlying function that takes a different data type. Thus, *PyUFunc_f_f_As_d_d* uses ndarrays of data type *NPY_FLOAT* but calls out to a C-function that takes double and returns double.

void **PyUFunc_ff_f_As_dd_d**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_ff_f**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_dd_d**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_gg_g**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_FF_F_As_DD_D**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_DD_D**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_FF_F**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_GG_G**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_ee_e**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_ee_e_As_ff_f**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_ee_e_As_dd_d**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

Type specific, core 1-d functions for ufuncs where each calculation is obtained by calling a function taking two input arguments and returning one output. The underlying function to call is passed in as *func*. The letters correspond to dtypechar's of the specific data type supported by the general-purpose function. The argument `func` must support the corresponding signature. The `_As_XX_X` variants assume ndarrays of one data type but cast the values at each iteration of the loop to use the underlying function that takes a different data type.

void **PyUFunc_O_O**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

void **PyUFunc_OO_O**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

One-input, one-output, and two-input, one-output core 1-d functions for the *NPY_OBJECT* data type. These functions handle reference count issues and return early on error. The actual function to call is *func* and it must accept calls with the signature `(PyObject*) (PyObject*)` for *PyUFunc_O_O* or `(PyObject*)(PyObject *, PyObject *)` for *PyUFunc_OO_O*.

void **PyUFunc_O_O_method**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

This general purpose 1-d core function assumes that *func* is a string representing a method of the input object. For each iteration of the loop, the Python object is extracted from the array and its *func* method is called returning the result to the output array.

void **PyUFunc_OO_O_method**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

This general purpose 1-d core function assumes that *func* is a string representing a method of the input object that takes one argument. The first argument in *args* is the method whose function is called, the second argument in *args* is the argument passed to the function. The output of the function is stored in the third entry of *args*.

void **PyUFunc_On_Om**(char **args, *npy_intp* const *dimensions, *npy_intp* const *steps, void *func)

This is the 1-d core function used by the dynamic ufuncs created by umath.frompyfunc(function, nin, nout). In this case *func* is a pointer to a *PyUFunc_PyFuncData* structure which has definition

type **PyUFunc_PyFuncData**

```
typedef struct {
    int nin;
    int nout;
    PyObject *callable;
} PyUFunc_PyFuncData;
```

At each iteration of the loop, the *nin* input objects are extracted from their object arrays and placed into an argument tuple, the Python *callable* is called with the input arguments, and the nout outputs are placed into their object arrays.

Importing the API

PY_UFUNC_UNIQUE_SYMBOL

NO_IMPORT_UFUNC

int **PyUFunc_ImportUFuncAPI**(void)

Ensures that the UFunc C-API is imported and usable. It returns `0` on success and `-1` with an error set if NumPy couldn't be imported. While preferable to call it once at module initialization, this function is very light-weight if called multiple times.

New in version 2.0: This function mainly checks for `PyUFunc_API == NULL` so it can be manually backported if desired.

import_ufunc(void)

These are the constants and functions for accessing the ufunc C-API from extension modules in precisely the same way as the array C-API can be accessed. The `import_ufunc` () function must always be called (in the initialization subroutine of the extension module). If your extension module is in one file then that is all that is required. The other two constants are useful if your extension module makes use of multiple files. In that case, define *PY_UFUNC_UNIQUE_SYMBOL* to something unique to your code and then in source files that do not contain the module initialization function but still need access to the UFUNC API, define *PY_UFUNC_UNIQUE_SYMBOL* to the same name used previously and also define *NO_IMPORT_UFUNC*.

The C-API is actually an array of function pointers. This array is created (and pointed to by a global variable) by import_ufunc. The global variable is either statically defined or allowed to be seen by other files depending on the state of *PY_UFUNC_UNIQUE_SYMBOL* and *NO_IMPORT_UFUNC*.

2.1.7 Generalized universal function API

There is a general need for looping over not only functions on scalars but also over functions on vectors (or arrays). This concept is realized in NumPy by generalizing the universal functions (ufuncs). In regular ufuncs, the elementary function is limited to element-by-element operations, whereas the generalized version (gufuncs) supports "sub-array" by "sub-array" operations. The Perl vector library PDL provides a similar functionality and its terms are re-used in the following.

Each generalized ufunc has information associated with it that states what the "core" dimensionality of the inputs is, as well as the corresponding dimensionality of the outputs (the element-wise ufuncs have zero core dimensions). The list of the core dimensions for all arguments is called the "signature" of a ufunc. For example, the ufunc `numpy.add` has signature `(),()->()` defining two scalar inputs and one scalar output.

Another example is the function `inner1d(a, b)` with a signature of `(i),(i)->()`. This applies the inner product along the last axis of each input, but keeps the remaining indices intact. For example, where `a` is of shape `(3, 5, N)` and `b` is of shape `(5, N)`, this will return an output of shape `(3,5)`. The underlying elementary function is called `3 * 5` times. In the signature, we specify one core dimension `(i)` for each input and zero core dimensions `()` for the output, since it takes two 1-d arrays and returns a scalar. By using the same name `i`, we specify that the two corresponding dimensions should be of the same size.

The dimensions beyond the core dimensions are called "loop" dimensions. In the above example, this corresponds to `(3, 5)`.

The signature determines how the dimensions of each input/output array are split into core and loop dimensions:

1. Each dimension in the signature is matched to a dimension of the corresponding passed-in array, starting from the end of the shape tuple. These are the core dimensions, and they must be present in the arrays, or an error will be raised.
2. Core dimensions assigned to the same label in the signature (e.g. the `i` in `inner1d`'s `(i),(i)->()`) must have exactly matching sizes, no broadcasting is performed.

3. The core dimensions are removed from all inputs and the remaining dimensions are broadcast together, defining the loop dimensions.
4. The shape of each output is determined from the loop dimensions plus the output's core dimensions

Typically, the size of all core dimensions in an output will be determined by the size of a core dimension with the same label in an input array. This is not a requirement, and it is possible to define a signature where a label comes up for the first time in an output, although some precautions must be taken when calling such a function. An example would be the function `euclidean_pdist(a)`, with signature `(n,d)->(p)`, that given an array of `n` `d`-dimensional vectors, computes all unique pairwise Euclidean distances among them. The output dimension `p` must therefore be equal to `n * (n - 1) / 2`, but by default, it is the caller's responsibility to pass in an output array of the right size. If the size of a core dimension of an output cannot be determined from a passed in input or output array, an error will be raised. This can be changed by defining a `PyUFunc_ProcessCoreDimsFunc` function and assigning it to the `proces_core_dims_func` field of the `PyUFuncObject` structure. See below for more details.

Note: Prior to NumPy 1.10.0, less strict checks were in place: missing core dimensions were created by prepending 1's to the shape as necessary, core dimensions with the same label were broadcast together, and undetermined dimensions were created with size 1.

Definitions

Elementary Function
: Each ufunc consists of an elementary function that performs the most basic operation on the smallest portion of array arguments (e.g. adding two numbers is the most basic operation in adding two arrays). The ufunc applies the elementary function multiple times on different parts of the arrays. The input/output of elementary functions can be vectors; e.g., the elementary function of `inner1d` takes two vectors as input.

Signature
: A signature is a string describing the input/output dimensions of the elementary function of a ufunc. See section below for more details.

Core Dimension
: The dimensionality of each input/output of an elementary function is defined by its core dimensions (zero core dimensions correspond to a scalar input/output). The core dimensions are mapped to the last dimensions of the input/output arrays.

Dimension Name
: A dimension name represents a core dimension in the signature. Different dimensions may share a name, indicating that they are of the same size.

Dimension Index
: A dimension index is an integer representing a dimension name. It enumerates the dimension names according to the order of the first occurrence of each name in the signature.

Details of signature

The signature defines "core" dimensionality of input and output variables, and thereby also defines the contraction of the dimensions. The signature is represented by a string of the following format:

- Core dimensions of each input or output array are represented by a list of dimension names in parentheses, `(i_1, ...,i_N)`; a scalar input/output is denoted by `()`. Instead of `i_1`, `i_2`, etc, one can use any valid Python variable name.
- Dimension lists for different arguments are separated by `","`. Input/output arguments are separated by `"->"`.
- If one uses the same dimension name in multiple locations, this enforces the same size of the corresponding dimensions.

The formal syntax of signatures is as follows:

```
<Signature>            ::= <Input arguments> "->" <Output arguments>
<Input arguments>      ::= <Argument list>
<Output arguments>     ::= <Argument list>
<Argument list>        ::= nil | <Argument> | <Argument> "," <Argument list>
<Argument>             ::= "(" <Core dimension list> ")"
<Core dimension list>  ::= nil | <Core dimension> |
                           <Core dimension> "," <Core dimension list>
<Core dimension>       ::= <Dimension name> <Dimension modifier>
<Dimension name>       ::= valid Python variable name | valid integer
<Dimension modifier>   ::= nil | "?"
```

Notes:

1. All quotes are for clarity.
2. Unmodified core dimensions that share the same name must have the same size. Each dimension name typically corresponds to one level of looping in the elementary function's implementation.
3. White spaces are ignored.
4. An integer as a dimension name freezes that dimension to the value.
5. If the name is suffixed with the "?" modifier, the dimension is a core dimension only if it exists on all inputs and outputs that share it; otherwise it is ignored (and replaced by a dimension of size 1 for the elementary function).

Here are some examples of signatures:

name	signature	common usage
add	`(),()->()`	binary ufunc
sum1d	`(i)->()`	reduction
inner1d	`(i),(i)->()`	vector-vector multiplication
matmat	`(m,n),(n,p)->(m,p)`	matrix multiplication
vecmat	`(n),(n,p)->(p)`	vector-matrix multiplication
matvec	`(m,n),(n)->(m)`	matrix-vector multiplication
matmul	`(m?,n),(n,p?)->(m?,p?)`	combination of the four above
outer_inne	`(i,t),(j,t)->(i,j)`	inner over the last dimension, outer over the second to last, and loop/broadcast over the rest.
cross1d	`(3),(3)->(3)`	cross product where the last dimension is frozen and must be 3

The last is an instance of freezing a core dimension and can be used to improve ufunc performance

C-API for implementing elementary functions

The current interface remains unchanged, and `PyUFunc_FromFuncAndData` can still be used to implement (specialized) ufuncs, consisting of scalar elementary functions.

One can use `PyUFunc_FromFuncAndDataAndSignature` to declare a more general ufunc. The argument list is the same as `PyUFunc_FromFuncAndData`, with an additional argument specifying the signature as C string.

Furthermore, the callback function is of the same type as before, `void (*foo)(char **args, intp *dimensions, intp *steps, void *func)`. When invoked, `args` is a list of length `nargs` containing the data of all input/output arguments. For a scalar elementary function, `steps` is also of length `nargs`, denoting

the strides used for the arguments. `dimensions` is a pointer to a single integer defining the size of the axis to be looped over.

For a non-trivial signature, `dimensions` will also contain the sizes of the core dimensions as well, starting at the second entry. Only one size is provided for each unique dimension name and the sizes are given according to the first occurrence of a dimension name in the signature.

The first `nargs` elements of `steps` remain the same as for scalar ufuncs. The following elements contain the strides of all core dimensions for all arguments in order.

For example, consider a ufunc with signature `(i,j),(i)->()`. In this case, `args` will contain three pointers to the data of the input/output arrays `a`, `b`, `c`. Furthermore, `dimensions` will be `[N, I, J]` to define the size of `N` of the loop and the sizes `I` and `J` for the core dimensions `i` and `j`. Finally, `steps` will be `[a_N, b_N, c_N, a_i, a_j, b_i]`, containing all necessary strides.

Customizing core dimension size processing

The optional function of type `PyUFunc_ProcessCoreDimsFunc`, stored on the `process_core_dims_func` attribute of the ufunc, provides the author of the ufunc a "hook" into the processing of the core dimensions of the arrays that were passed to the ufunc. The two primary uses of this "hook" are:

- Check that constraints on the core dimensions required by the ufunc are satisfied (and set an exception if they are not).
- Compute output shapes for any output core dimensions that were not determined by the input arrays.

As an example of the first use, consider the generalized ufunc `minmax` with signature `(n)->(2)` that simultaneously computes the minimum and maximum of a sequence. It should require that `n > 0`, because the minimum and maximum of a sequence with length 0 is not meaningful. In this case, the ufunc author might define the function like this:

```
int minmax_process_core_dims(PyUFuncObject ufunc,
                             npy_intp *core_dim_sizes)
{
    npy_intp n = core_dim_sizes[0];
    if (n == 0) {
        PyExc_SetString("minmax requires the core dimension "
                        "to be at least 1.");
        return -1;
    }
    return 0;
}
```

In this case, the length of the array `core_dim_sizes` will be 2. The second value in the array will always be 2, so there is no need for the function to inspect it. The core dimension `n` is stored in the first element. The function sets an exception and returns -1 if it finds that `n` is 0.

The second use for the "hook" is to compute the size of output arrays when the output arrays are not provided by the caller and one or more core dimension of the output is not also an input core dimension. If the ufunc does not have a function defined on the `process_core_dims_func` attribute, an unspecified output core dimension size will result in an exception being raised. With the "hook" provided by `process_core_dims_func`, the author of the ufunc can set the output size to whatever is appropriate for the ufunc.

In the array passed to the "hook" function, core dimensions that were not determined by the input are indicating by having the value -1 in the `core_dim_sizes` array. The function can replace the -1 with whatever value is appropriate for the ufunc, based on the core dimensions that occurred in the input arrays.

Warning: The function must never change a value in `core_dim_sizes` that is not -1 on input. Changing a value that was not -1 will generally result in incorrect output from the ufunc, and could result in the Python interpreter crashing.

For example, consider the generalized ufunc `conv1d` for which the elementary function computes the "full" convolution of two one-dimensional arrays `x` and `y` with lengths `m` and `n`, respectively. The output of this convolution has length `m + n - 1`. To implement this as a generalized ufunc, the signature is set to `(m),(n)->(p)`, and in the "hook" function, if the core dimension `p` is found to be -1, it is replaced with `m + n - 1`. If `p` is *not* -1, it must be verified that the given value equals `m + n - 1`. If it does not, the function must set an exception and return -1. For a meaningful result, the operation also requires that `m + n` is at least 1, i.e. both inputs can't have length 0.

Here's how that might look in code:

```
int conv1d_process_core_dims(PyUFuncObject *ufunc,
                             npy_intp *core_dim_sizes)
{
    // core_dim_sizes will hold the core dimensions [m, n, p].
    // p will be -1 if the caller did not provide the out argument.
    npy_intp m = core_dim_sizes[0];
    npy_intp n = core_dim_sizes[1];
    npy_intp p = core_dim_sizes[2];
    npy_intp required_p = m + n - 1;

    if (m == 0 && n == 0) {
        // Disallow both inputs having length 0.
        PyErr_SetString(PyExc_ValueError,
            "conv1d: both inputs have core dimension 0; the function "
            "requires that at least one input has size greater than 0.");
        return -1;
    }
    if (p == -1) {
        // Output array was not given in the call of the ufunc.
        // Set the correct output size here.
        core_dim_sizes[2] = required_p;
        return 0;
    }
    // An output array *was* given.  Validate its core dimension.
    if (p != required_p) {
        PyErr_Format(PyExc_ValueError,
                "conv1d: the core dimension p of the out parameter "
                "does not equal m + n - 1, where m and n are the "
                "core dimensions of the inputs x and y; got m=%zd "
                "and n=%zd so p must be %zd, but got p=%zd.",
                m, n, required_p, p);
        return -1;
    }
    return 0;
}
```

2.1.8 NpyString API

New in version 2.0.

This API allows access to the UTF-8 string data stored in NumPy StringDType arrays. See NEP-55 for more in-depth details into the design of StringDType.

Examples

Loading a String

Say we are writing a ufunc implementation for `StringDType`. If we are given `const char *buf` pointer to the beginning of a `StringDType` array entry, and a `PyArray_Descr *` pointer to the array descriptor, one can access the underlying string data like so:

```
npy_string_allocator *allocator = NpyString_acquire_allocator(
        (PyArray_StringDTypeObject *)descr);

npy_static_string sdata = {0, NULL};
npy_packed_static_string *packed_string = (npy_packed_static_string *)buf;
int is_null = 0;

is_null = NpyString_load(allocator, packed_string, &sdata);

if (is_null == -1) {
    // failed to load string, set error
    return -1;
}
else if (is_null) {
    // handle missing string
    // sdata->buf is NULL
    // sdata->size is 0
}
else {
    // sdata->buf is a pointer to the beginning of a string
    // sdata->size is the size of the string
}
NpyString_release_allocator(allocator);
```

Packing a String

This example shows how to pack a new string entry into an array:

```
char *str = "Hello world";
size_t size = 11;
npy_packed_static_string *packed_string = (npy_packed_static_string *)buf;

npy_string_allocator *allocator = NpyString_acquire_allocator(
        (PyArray_StringDTypeObject *)descr);

// copy contents of str into packed_string
if (NpyString_pack(allocator, packed_string, str, size) == -1) {
    // string packing failed, set error
    return -1;
}

// packed_string contains a copy of "Hello world"
```

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```
NpyString_release_allocator(allocator);
```

Types

type **npy_packed_static_string**

An opaque struct that represents "packed" encoded strings. Individual entries in array buffers are instances of this struct. Direct access to the data in the struct is undefined and future version of the library may change the packed representation of strings.

type **npy_static_string**

An unpacked string allowing access to the UTF-8 string data.

```
typedef struct npy_unpacked_static_string {
    size_t size;
    const char *buf;
} npy_static_string;
```

size_t **size**

The size of the string, in bytes.

const char ***buf**

The string buffer. Holds UTF-8-encoded bytes. Does not currently end in a null string but we may decide to add null termination in the future, so do not rely on the presence or absence of null-termination.

Note that this is a `const` buffer. If you want to alter an entry in an array, you should create a new string and pack it into the array entry.

type **npy_string_allocator**

An opaque pointer to an object that handles string allocation. Before using the allocator, you must acquire the allocator lock and release the lock after you are done interacting with strings managed by the allocator.

type **PyArray_StringDTypeObject**

The C struct backing instances of StringDType in Python. Attributes store the settings the object was created with, an instance of `npy_string_allocator` that manages string allocations for arrays associated with the DType instance, and several attributes caching information about the missing string object that is commonly needed in cast and ufunc loop implementations.

```
typedef struct {
    PyArray_Descr base;
    PyObject *na_object;
    char coerce;
    char has_nan_na;
    char has_string_na;
    char array_owned;
    npy_static_string default_string;
    npy_static_string na_name;
    npy_string_allocator *allocator;
} PyArray_StringDTypeObject;
```

PyArray_Descr **base**

The base object. Use this member to access fields common to all descriptor objects.

PyObject ***na_object**

A reference to the object representing the null value. If there is no null value (the default) this will be NULL.

char **coerce**

1 if string coercion is enabled, 0 otherwise.

char **has_nan_na**

1 if the missing string object (if any) is NaN-like, 0 otherwise.

char **has_string_na**

1 if the missing string object (if any) is a string, 0 otherwise.

char **array_owned**

1 if an array owns the StringDType instance, 0 otherwise.

npy_static_string **default_string**

The default string to use in operations. If the missing string object is a string, this will contain the string data for the missing string.

npy_static_string **na_name**

The name of the missing string object, if any. An empty string otherwise.

npy_string_allocator **allocator**

The allocator instance associated with the array that owns this descriptor instance. The allocator should only be directly accessed after acquiring the allocator_lock and the lock should be released immediately after the allocator is no longer needed

Functions

npy_string_allocator ***NpyString_acquire_allocator**(const *PyArray_StringDTypeObject* *descr)

Acquire the mutex locking the allocator attached to `descr`. `NpyString_release_allocator` must be called on the allocator returned by this function exactly once. Note that functions requiring the GIL should not be called while the allocator mutex is held, as doing so may cause deadlocks.

void **NpyString_acquire_allocators**(size_t n_descriptors, *PyArray_Descr* *const descrs[], *npy_string_allocator* *allocators[])

Simultaneously acquire the mutexes locking the allocators attached to multiple descriptors. Writes a pointer to the associated allocator in the allocators array for each StringDType descriptor in the array. If any of the descriptors are not StringDType instances, write NULL to the allocators array for that entry.

`n_descriptors` is the number of descriptors in the descrs array that should be examined. Any descriptor after `n_descriptors` elements is ignored. A buffer overflow will happen if the `descrs` array does not contain n_descriptors elements.

If pointers to the same descriptor are passed multiple times, only acquires the allocator mutex once but sets identical allocator pointers appropriately. The allocator mutexes must be released after this function returns, see `NpyString_release_allocators`.

Note that functions requiring the GIL should not be called while the allocator mutex is held, as doing so may cause deadlocks.

void **NpyString_release_allocator**(*npy_string_allocator* *allocator)

Release the mutex locking an allocator. This must be called exactly once after acquiring the allocator mutex and all operations requiring the allocator are done.

If you need to release multiple allocators, see NpyString_release_allocators, which can correctly handle releasing the allocator once when given several references to the same allocator.

void **NpyString_release_allocators**(size_t length, *npy_string_allocator* *allocators[])

Release the mutexes locking N allocators. `length` is the length of the allocators array. NULL entries are ignored.

If pointers to the same allocator are passed multiple times, only releases the allocator mutex once.

int **NpyString_load**(*npy_string_allocator* *allocator, const *npy_packed_static_string* *packed_string, *npy_static_string* *unpacked_string)

Extract the packed contents of `packed_string` into `unpacked_string`.

The `unpacked_string` is a read-only view onto the `packed_string` data and should not be used to modify the string data. If `packed_string` is the null string, sets `unpacked_string.buf` to the NULL pointer. Returns -1 if unpacking the string fails, returns 1 if `packed_string` is the null string, and returns 0 otherwise.

A useful pattern is to define a stack-allocated npy_static_string instance initialized to `{0, NULL}` and pass a pointer to the stack-allocated unpacked string to this function. This function can be used to simultaneously unpack a string and determine if it is a null string.

int **NpyString_pack_null**(*npy_string_allocator* *allocator, *npy_packed_static_string* *packed_string)

Pack the null string into `packed_string`. Returns 0 on success and -1 on failure.

int **NpyString_pack**(*npy_string_allocator* *allocator, *npy_packed_static_string* *packed_string, const char *buf, size_t size)

Copy and pack the first `size` entries of the buffer pointed to by `buf` into the `packed_string`. Returns 0 on success and -1 on failure.

2.1.9 NumPy core math library

The numpy core math library (`npymath`) is a first step in this direction. This library contains most math-related C99 functionality, which can be used on platforms where C99 is not well supported. The core math functions have the same API as the C99 ones, except for the `npy_*` prefix.

The available functions are defined in `<numpy/npy_math.h>` - please refer to this header when in doubt.

Note: An effort is underway to make `npymath` smaller (since C99 compatibility of compilers has improved over time) and more easily vendorable or usable as a header-only dependency. That will avoid problems with shipping a static library built with a compiler which may not match the compiler used by a downstream package or end user. See gh-20880 for details.

Floating point classification

NPY_NAN

This macro is defined to a NaN (Not a Number), and is guaranteed to have the signbit unset ('positive' NaN). The corresponding single and extension precision macro are available with the suffix F and L.

NPY_INFINITY

This macro is defined to a positive inf. The corresponding single and extension precision macro are available with the suffix F and L.

NPY_PZERO

This macro is defined to positive zero. The corresponding single and extension precision macro are available with the suffix F and L.

NPY_NZERO

This macro is defined to negative zero (that is with the sign bit set). The corresponding single and extension precision macro are available with the suffix F and L.

npy_isnan(x)

This is an alias for C99 isnan: works for single, double and extended precision, and return a non 0 value if x is a NaN.

npy_isfinite(x)

This is an alias for C99 isfinite: works for single, double and extended precision, and return a non 0 value if x is neither a NaN nor an infinity.

npy_isinf(x)

This is an alias for C99 isinf: works for single, double and extended precision, and return a non 0 value if x is infinite (positive and negative).

npy_signbit(x)

This is an alias for C99 signbit: works for single, double and extended precision, and return a non 0 value if x has the signbit set (that is the number is negative).

npy_copysign(x, y)

This is an alias for C99 copysign: return x with the same sign as y. Works for any value, including inf and nan. Single and extended precisions are available with suffix f and l.

Useful math constants

The following math constants are available in `npy_math.h`. Single and extended precision are also available by adding the `f` and `l` suffixes respectively.

NPY_E

Base of natural logarithm (e)

NPY_LOG2E

Logarithm to base 2 of the Euler constant ($\frac{\ln(e)}{\ln(2)}$)

NPY_LOG10E

Logarithm to base 10 of the Euler constant ($\frac{\ln(e)}{\ln(10)}$)

NPY_LOGE2

Natural logarithm of 2 ($\ln(2)$)

NPY_LOGE10

Natural logarithm of 10 ($\ln(10)$)

NPY_PI

Pi (π)

NPY_PI_2

Pi divided by 2 ($\frac{\pi}{2}$)

NPY_PI_4

Pi divided by 4 ($\frac{\pi}{4}$)

NPY_1_PI

Reciprocal of pi ($\frac{1}{\pi}$)

NPY_2_PI

Two times the reciprocal of pi ($\frac{2}{\pi}$)

NPY_EULER

The Euler constant

$\lim_{n\to\infty}(\sum_{k=1}^{n}\frac{1}{k} - \ln n)$

Low-level floating point manipulation

Those can be useful for precise floating point comparison.

double **npy_nextafter**(double x, double y)

This is an alias to C99 nextafter: return next representable floating point value from x in the direction of y. Single and extended precisions are available with suffix f and l.

double **npy_spacing**(double x)

This is a function equivalent to Fortran intrinsic. Return distance between x and next representable floating point value from x, e.g. spacing(1) == eps. spacing of nan and +/- inf return nan. Single and extended precisions are available with suffix f and l.

void **npy_set_floatstatus_divbyzero**()

Set the divide by zero floating point exception

void **npy_set_floatstatus_overflow**()

Set the overflow floating point exception

void **npy_set_floatstatus_underflow**()

Set the underflow floating point exception

void **npy_set_floatstatus_invalid**()

Set the invalid floating point exception

int **npy_get_floatstatus**()

Get floating point status. Returns a bitmask with following possible flags:

- NPY_FPE_DIVIDEBYZERO
- NPY_FPE_OVERFLOW
- NPY_FPE_UNDERFLOW
- NPY_FPE_INVALID

Note that *npy_get_floatstatus_barrier* is preferable as it prevents aggressive compiler optimizations reordering the call relative to the code setting the status, which could lead to incorrect results.

int **npy_get_floatstatus_barrier**(char*)

Get floating point status. A pointer to a local variable is passed in to prevent aggressive compiler optimizations from reordering this function call relative to the code setting the status, which could lead to incorrect results.

Returns a bitmask with following possible flags:

- NPY_FPE_DIVIDEBYZERO
- NPY_FPE_OVERFLOW
- NPY_FPE_UNDERFLOW
- NPY_FPE_INVALID

int **npy_clear_floatstatus**()

Clears the floating point status. Returns the previous status mask.

Note that *npy_clear_floatstatus_barrier* is preferable as it prevents aggressive compiler optimizations reordering the call relative to the code setting the status, which could lead to incorrect results.

int **npy_clear_floatstatus_barrier**(char*)

Clears the floating point status. A pointer to a local variable is passed in to prevent aggressive compiler optimizations from reordering this function call. Returns the previous status mask.

Support for complex numbers

C99-like complex functions have been added. Those can be used if you wish to implement portable C extensions. Since NumPy 2.0 we use C99 complex types as the underlying type:

```
typedef double _Complex npy_cdouble;
typedef float _Complex npy_cfloat;
typedef long double _Complex npy_clongdouble;
```

MSVC does not support the `_Complex` type itself, but has added support for the C99 `complex.h` header by providing its own implementation. Thus, under MSVC, the equivalent MSVC types will be used:

```
typedef _Dcomplex npy_cdouble;
typedef _Fcomplex npy_cfloat;
typedef _Lcomplex npy_clongdouble;
```

Because MSVC still does not support C99 syntax for initializing a complex number, you need to restrict to C90-compatible syntax, e.g.:

```
/* a = 1 + 2i \*/
npy_complex a = npy_cpack(1, 2);
npy_complex b;

b = npy_log(a);
```

A few utilities have also been added in `numpy/npy_math.h`, in order to retrieve or set the real or the imaginary part of a complex number:

```
npy_cdouble c;
npy_csetreal(&c, 1.0);
npy_csetimag(&c, 0.0);
printf("%d + %di\n", npy_creal(c), npy_cimag(c));
```

Changed in version 2.0.0: The underlying C types for all of numpy's complex types have been changed to use C99 complex types. Up until now the following was being used to represent complex types:

```
typedef struct { double real, imag; } npy_cdouble;
typedef struct { float real, imag; } npy_cfloat;
typedef struct {npy_longdouble real, imag;} npy_clongdouble;
```

Using the `struct` representation ensured that complex numbers could be used on all platforms, even the ones without support for built-in complex types. It also meant that a static library had to be shipped together with NumPy to provide a C99 compatibility layer for downstream packages to use. In recent years however, support for native complex types has been improved immensely, with MSVC adding built-in support for the `complex.h` header in 2019.

To ease cross-version compatibility, macros that use the new set APIs have been added.

```
#define NPY_CSETREAL(z, r) npy_csetreal(z, r)
#define NPY_CSETIMAG(z, i) npy_csetimag(z, i)
```

A compatibility layer is also provided in `numpy/npy_2_complexcompat.h`. It checks whether the macros exist, and falls back to the 1.x syntax in case they don't.

```
#include <numpy/npy_math.h>

#ifndef NPY_CSETREALF
#define NPY_CSETREALF(c, r) (c)->real = (r)
#endif
#ifndef NPY_CSETIMAGF
#define NPY_CSETIMAGF(c, i) (c)->imag = (i)
#endif
```

We suggest all downstream packages that need this functionality to copy-paste the compatibility layer code into their own sources and use that, so that they can continue to support both NumPy 1.x and 2.x without issues. Note also that the `complex.h` header is included in `numpy/npy_common.h`, which makes `complex` a reserved keyword.

Linking against the core math library in an extension

To use the core math library that NumPy ships as a static library in your own Python extension, you need to add the `npymath` compile and link options to your extension. The exact steps to take will depend on the build system you are using. The generic steps to take are:

1. Add the numpy include directory (= the value of `np.get_include()`) to your include directories,
2. The `npymath` static library resides in the `lib` directory right next to numpy's include directory (i.e., `pathlib.Path(np.get_include()) / '..' / 'lib'`). Add that to your library search directories,
3. Link with `libnpymath` and `libm`.

Note: Keep in mind that when you are cross compiling, you must use the `numpy` for the platform you are building for, not the native one for the build machine. Otherwise you pick up a static library built for the wrong architecture.

When you build with `numpy.distutils` (deprecated), then use this in your `setup.py`:

```
>>> from numpy.distutils.misc_util import get_info
>>> info = get_info('npymath')
>>> _ = config.add_extension('foo', sources=['foo.c'], extra_info=info)
```

In other words, the usage of `info` is exactly the same as when using `blas_info` and co.

When you are building with Meson, use:

```
# Note that this will get easier in the future, when Meson has
# support for numpy built in; most of this can then be replaced
# by `dependency('numpy')`.
incdir_numpy = run_command(py3,
  [
    '-c',
    'import os; os.chdir(".."); import numpy; print(numpy.get_include())'
  ],
  check: true
).stdout().strip()
```

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```
inc_np = include_directories(incdir_numpy)

cc = meson.get_compiler('c')
npymath_path = incdir_numpy / '..' / 'lib'
npymath_lib = cc.find_library('npymath', dirs: npymath_path)

py3.extension_module('module_name',
  ...
  include_directories: inc_np,
  dependencies: [npymath_lib],
```

Half-precision functions

The header file <numpy/halffloat.h> provides functions to work with IEEE 754-2008 16-bit floating point values. While this format is not typically used for numerical computations, it is useful for storing values which require floating point but do not need much precision. It can also be used as an educational tool to understand the nature of floating point round-off error.

Like for other types, NumPy includes a typedef npy_half for the 16 bit float. Unlike for most of the other types, you cannot use this as a normal type in C, since it is a typedef for npy_uint16. For example, 1.0 looks like 0x3c00 to C, and if you do an equality comparison between the different signed zeros, you will get -0.0 != 0.0 (0x8000 != 0x0000), which is incorrect.

For these reasons, NumPy provides an API to work with npy_half values accessible by including <numpy/halffloat.h> and linking to npymath. For functions that are not provided directly, such as the arithmetic operations, the preferred method is to convert to float or double and back again, as in the following example.

```
npy_half sum(int n, npy_half *array) {
    float ret = 0;
    while(n--) {
        ret += npy_half_to_float(*array++);
    }
    return npy_float_to_half(ret);
}
```

External Links:

- 754-2008 IEEE Standard for Floating-Point Arithmetic
- Half-precision Float Wikipedia Article.
- OpenGL Half Float Pixel Support
- The OpenEXR image format.

NPY_HALF_ZERO

This macro is defined to positive zero.

NPY_HALF_PZERO

This macro is defined to positive zero.

NPY_HALF_NZERO

This macro is defined to negative zero.

NPY_HALF_ONE

This macro is defined to 1.0.

NPY_HALF_NEGONE

This macro is defined to -1.0.

NPY_HALF_PINF

This macro is defined to +inf.

NPY_HALF_NINF

This macro is defined to -inf.

NPY_HALF_NAN

This macro is defined to a NaN value, guaranteed to have its sign bit unset.

float **npy_half_to_float**(*npy_half* h)

Converts a half-precision float to a single-precision float.

double **npy_half_to_double**(*npy_half* h)

Converts a half-precision float to a double-precision float.

npy_half **npy_float_to_half**(float f)

Converts a single-precision float to a half-precision float. The value is rounded to the nearest representable half, with ties going to the nearest even. If the value is too small or too big, the system's floating point underflow or overflow bit will be set.

npy_half **npy_double_to_half**(double d)

Converts a double-precision float to a half-precision float. The value is rounded to the nearest representable half, with ties going to the nearest even. If the value is too small or too big, the system's floating point underflow or overflow bit will be set.

int **npy_half_eq**(*npy_half* h1, *npy_half* h2)

Compares two half-precision floats (h1 == h2).

int **npy_half_ne**(*npy_half* h1, *npy_half* h2)

Compares two half-precision floats (h1 != h2).

int **npy_half_le**(*npy_half* h1, *npy_half* h2)

Compares two half-precision floats (h1 <= h2).

int **npy_half_lt**(*npy_half* h1, *npy_half* h2)

Compares two half-precision floats (h1 < h2).

int **npy_half_ge**(*npy_half* h1, *npy_half* h2)

Compares two half-precision floats (h1 >= h2).

int **npy_half_gt**(*npy_half* h1, *npy_half* h2)

Compares two half-precision floats (h1 > h2).

int **npy_half_eq_nonan**(*npy_half* h1, *npy_half* h2)

Compares two half-precision floats that are known to not be NaN (h1 == h2). If a value is NaN, the result is undefined.

int **npy_half_lt_nonan**(*npy_half* h1, *npy_half* h2)

Compares two half-precision floats that are known to not be NaN (h1 < h2). If a value is NaN, the result is undefined.

int **npy_half_le_nonan**(*npy_half* h1, *npy_half* h2)

Compares two half-precision floats that are known to not be NaN (h1 <= h2). If a value is NaN, the result is undefined.

int **npy_half_iszero** (*npy_half* h)

Tests whether the half-precision float has a value equal to zero. This may be slightly faster than calling npy_half_eq(h, NPY_ZERO).

int **npy_half_isnan** (*npy_half* h)

Tests whether the half-precision float is a NaN.

int **npy_half_isinf** (*npy_half* h)

Tests whether the half-precision float is plus or minus Inf.

int **npy_half_isfinite** (*npy_half* h)

Tests whether the half-precision float is finite (not NaN or Inf).

int **npy_half_signbit** (*npy_half* h)

Returns 1 is h is negative, 0 otherwise.

npy_half **npy_half_copysign** (*npy_half* x, *npy_half* y)

Returns the value of x with the sign bit copied from y. Works for any value, including Inf and NaN.

npy_half **npy_half_spacing** (*npy_half* h)

This is the same for half-precision float as npy_spacing and npy_spacingf described in the low-level floating point section.

npy_half **npy_half_nextafter** (*npy_half* x, *npy_half* y)

This is the same for half-precision float as npy_nextafter and npy_nextafterf described in the low-level floating point section.

npy_uint16 **npy_floatbits_to_halfbits** (*npy_uint32* f)

Low-level function which converts a 32-bit single-precision float, stored as a uint32, into a 16-bit half-precision float.

npy_uint16 **npy_doublebits_to_halfbits** (*npy_uint64* d)

Low-level function which converts a 64-bit double-precision float, stored as a uint64, into a 16-bit half-precision float.

npy_uint32 **npy_halfbits_to_floatbits** (*npy_uint16* h)

Low-level function which converts a 16-bit half-precision float into a 32-bit single-precision float, stored as a uint32.

npy_uint64 **npy_halfbits_to_doublebits** (*npy_uint16* h)

Low-level function which converts a 16-bit half-precision float into a 64-bit double-precision float, stored as a uint64.

2.1.10 Datetime API

NumPy represents dates internally using an int64 counter and a unit metadata struct. Time differences are represented similarly using an int64 and a unit metadata struct. The functions described below are available to to facilitate converting between ISO 8601 date strings, NumPy datetimes, and Python datetime objects in C.

Data types

In addition to the *npy_datetime* and *npy_timedelta* typedefs for *npy_int64*, NumPy defines two additional structs that represent time unit metadata and an "exploded" view of a datetime.

type **PyArray_DatetimeMetaData**

Represents datetime unit metadata.

```
typedef struct {
    NPY_DATETIMEUNIT base;
    int num;
} PyArray_DatetimeMetaData;
```

NPY_DATETIMEUNIT **base**

The unit of the datetime.

int **num**

A multiplier for the unit.

type **npy_datetimestruct**

An "exploded" view of a datetime value

```
typedef struct {
    npy_int64 year;
    npy_int32 month, day, hour, min, sec, us, ps, as;
} npy_datetimestruct;
```

enum **NPY_DATETIMEUNIT**

Time units supported by NumPy. The "FR" in the names of the enum variants is short for frequency.

enumerator **NPY_FR_ERROR**

Error or undetermined units.

enumerator **NPY_FR_Y**

Years

enumerator **NPY_FR_M**

Months

enumerator **NPY_FR_W**

Weeks

enumerator **NPY_FR_D**

Days

enumerator **NPY_FR_h**

Hours

enumerator **NPY_FR_m**

Minutes

enumerator **NPY_FR_s**

Seconds

enumerator **NPY_FR_ms**

Milliseconds

enumerator **NPY_FR_us**
Microseconds

enumerator **NPY_FR_ns**
Nanoseconds

enumerator **NPY_FR_ps**
Picoseconds

enumerator **NPY_FR_fs**
Femtoseconds

enumerator **NPY_FR_as**
Attoseconds

enumerator **NPY_FR_GENERIC**
Unbound units, can convert to anything

Conversion functions

int **NpyDatetime_ConvertDatetimeStructToDatetime64**(*PyArray_DatetimeMetaData* *meta, const *npy_datetimestruct* *dts, *npy_datetime* *out)

Converts a datetime from a datetimestruct to a datetime in the units specified by the unit metadata. The date is assumed to be valid.

If the `num` member of the metadata struct is large, there may be integer overflow in this function.

Returns 0 on success and -1 on failure.

int **NpyDatetime_ConvertDatetime64ToDatetimeStruct**(*PyArray_DatetimeMetaData* *meta, *npy_datetime* dt, *npy_datetimestruct* *out)

Converts a datetime with units specified by the unit metadata to an exploded datetime struct.

Returns 0 on success and -1 on failure.

int **NpyDatetime_ConvertPyDateTimeToDatetimeStruct**(PyObject *obj, *npy_datetimestruct* *out, *NPY_DATETIMEUNIT* *out_bestunit, int apply_tzinfo)

Tests for and converts a Python `datetime.datetime` or `datetime.date` object into a NumPy `npy_datetimestruct`.

`out_bestunit` gives a suggested unit based on whether the object was a `datetime.date` or `datetime.datetime` object.

If `apply_tzinfo` is 1, this function uses the tzinfo to convert to UTC time, otherwise it returns the struct with the local time.

Returns -1 on error, 0 on success, and 1 (with no error set) if obj doesn't have the needed date or datetime attributes.

int **NpyDatetime_ParseISO8601Datetime**(char const *str, Py_ssize_t len, *NPY_DATETIMEUNIT* unit, *NPY_CASTING* casting, *npy_datetimestruct* *out, *NPY_DATETIMEUNIT* *out_bestunit, *npy_bool* *out_special)

Parses (almost) standard ISO 8601 date strings. The differences are:

- The date "20100312" is parsed as the year 20100312, not as equivalent to "2010-03-12". The '-' in the dates are not optional.
- Only seconds may have a decimal point, with up to 18 digits after it (maximum attoseconds precision).

- Either a 'T' as in ISO 8601 or a ' ' may be used to separate the date and the time. Both are treated equivalently.
- Doesn't (yet) handle the "YYYY-DDD" or "YYYY-Www" formats.
- Doesn't handle leap seconds (seconds value has 60 in these cases).
- Doesn't handle 24:00:00 as synonym for midnight (00:00:00) tomorrow
- Accepts special values "NaT" (not a time), "Today", (current day according to local time) and "Now" (current time in UTC).

`str` must be a NULL-terminated string, and `len` must be its length.

`unit` should contain -1 if the unit is unknown, or the unit which will be used if it is.

`casting` controls how the detected unit from the string is allowed to be cast to the 'unit' parameter.

`out` gets filled with the parsed date-time.

`out_bestunit` gives a suggested unit based on the amount of resolution provided in the string, or -1 for NaT.

`out_special` gets set to 1 if the parsed time was 'today', 'now', empty string, or 'NaT'. For 'today', the unit recommended is 'D', for 'now', the unit recommended is 's', and for 'NaT' the unit recommended is 'Y'.

Returns 0 on success, -1 on failure.

int **NpyDatetime_GetDatetimeISO8601StrLen**(int local, *NPY_DATETIMEUNIT* base)

Returns the string length to use for converting datetime objects with the given local time and unit settings to strings. Use this when constructing strings to supply to `NpyDatetime_MakeISO8601Datetime`.

int **NpyDatetime_MakeISO8601Datetime**(*npy_datetimestruct* *dts, char *outstr, *npy_intp* outlen, int local, int utc, *NPY_DATETIMEUNIT* base, int tzoffset, *NPY_CASTING* casting)

Converts an `npy_datetimestruct` to an (almost) ISO 8601 NULL-terminated string. If the string fits in the space exactly, it leaves out the NULL terminator and returns success.

The differences from ISO 8601 are the 'NaT' string, and the number of year digits is >= 4 instead of strictly 4.

If `local` is non-zero, it produces a string in local time with a +-#### timezone offset. If `local` is zero and `utc` is non-zero, produce a string ending with 'Z' to denote UTC. By default, no time zone information is attached.

`base` restricts the output to that unit. Set `base` to -1 to auto-detect a base after which all the values are zero.

`tzoffset` is used if `local` is enabled, and `tzoffset` is set to a value other than -1. This is a manual override for the local time zone to use, as an offset in minutes.

`casting` controls whether data loss is allowed by truncating the data to a coarser unit. This interacts with `local`, slightly, in order to form a date unit string as a local time, the casting must be unsafe.

Returns 0 on success, -1 on failure (for example if the output string was too short).

2.1.11 C API deprecations

Background

The API exposed by NumPy for third-party extensions has grown over years of releases, and has allowed programmers to directly access NumPy functionality from C. This API can be best described as "organic". It has emerged from multiple competing desires and from multiple points of view over the years, strongly influenced by the desire to make it easy for users to move to NumPy from Numeric and Numarray. The core API originated with Numeric in 1995 and there are patterns such as the heavy use of macros written to mimic Python's C-API as well as account for compiler technology of the late 90's. There is also only a small group of volunteers who have had very little time to spend on improving this API.

There is an ongoing effort to improve the API. It is important in this effort to ensure that code that compiles for NumPy 1.X continues to compile for NumPy 1.X. At the same time, certain API's will be marked as deprecated so that future-looking code can avoid these API's and follow better practices.

Another important role played by deprecation markings in the C API is to move towards hiding internal details of the NumPy implementation. For those needing direct, easy, access to the data of ndarrays, this will not remove this ability. Rather, there are many potential performance optimizations which require changing the implementation details, and NumPy developers have been unable to try them because of the high value of preserving ABI compatibility. By deprecating this direct access, we will in the future be able to improve NumPy's performance in ways we cannot presently.

Deprecation mechanism NPY_NO_DEPRECATED_API

In C, there is no equivalent to the deprecation warnings that Python supports. One way to do deprecations is to flag them in the documentation and release notes, then remove or change the deprecated features in a future major version (NumPy 2.0 and beyond). Minor versions of NumPy should not have major C-API changes, however, that prevent code that worked on a previous minor release. For example, we will do our best to ensure that code that compiled and worked on NumPy 1.4 should continue to work on NumPy 1.7 (but perhaps with compiler warnings).

To use the NPY_NO_DEPRECATED_API mechanism, you need to #define it to the target API version of NumPy before #including any NumPy headers. If you want to confirm that your code is clean against 1.7, use:

```
#define NPY_NO_DEPRECATED_API NPY_1_7_API_VERSION
```

On compilers which support a #warning mechanism, NumPy issues a compiler warning if you do not define the symbol NPY_NO_DEPRECATED_API. This way, the fact that there are deprecations will be flagged for third-party developers who may not have read the release notes closely.

Note that defining NPY_NO_DEPRECATED_API is not sufficient to make your extension ABI compatible with a given NumPy version. See for-downstream-package-authors.

2.1.12 Memory management in NumPy

The *numpy.ndarray* is a python class. It requires additional memory allocations to hold *numpy.ndarray.strides*, *numpy.ndarray.shape* and *numpy.ndarray.data* attributes. These attributes are specially allocated after creating the python object in `__new__`. The `strides` and `shape` are stored in a piece of memory allocated internally.

The `data` allocation used to store the actual array values (which could be pointers in the case of `object` arrays) can be very large, so NumPy has provided interfaces to manage its allocation and release. This document details how those interfaces work.

Historical overview

Since version 1.7.0, NumPy has exposed a set of `PyDataMem_*` functions (*PyDataMem_NEW*, *PyDataMem_FREE*, *PyDataMem_RENEW*) which are backed by *alloc*, *free*, *realloc* respectively.

Since those early days, Python also improved its memory management capabilities, and began providing various management policies beginning in version 3.4. These routines are divided into a set of domains, each domain has a `PyMemAllocatorEx` structure of routines for memory management. Python also added a `tracemalloc` module to trace calls to the various routines. These tracking hooks were added to the NumPy `PyDataMem_*` routines.

NumPy added a small cache of allocated memory in its internal `npy_alloc_cache`, `npy_alloc_cache_zero`, and `npy_free_cache` functions. These wrap `alloc`, `alloc-and-memset(0)` and `free` respectively, but when `npy_free_cache` is called, it adds the pointer to a short list of available blocks marked by size. These blocks can be re-used by subsequent calls to `npy_alloc*`, avoiding memory thrashing.

Configurable memory routines in NumPy (NEP 49)

Users may wish to override the internal data memory routines with ones of their own. Since NumPy does not use the Python domain strategy to manage data memory, it provides an alternative set of C-APIs to change memory routines. There are no Python domain-wide strategies for large chunks of object data, so those are less suited to NumPy's needs. User who wish to change the NumPy data memory management routines can use *PyDataMem_SetHandler*, which uses a *PyDataMem_Handler* structure to hold pointers to functions used to manage the data memory. The calls are still wrapped by internal routines to call PyTraceMalloc_Track, PyTraceMalloc_Untrack. Since the functions may change during the lifetime of the process, each ndarray carries with it the functions used at the time of its instantiation, and these will be used to reallocate or free the data memory of the instance.

type **PyDataMem_Handler**

A struct to hold function pointers used to manipulate memory

```
typedef struct {
    char name[127];  /* multiple of 64 to keep the struct aligned */
    uint8_t version; /* currently 1 */
    PyDataMemAllocator allocator;
} PyDataMem_Handler;
```

where the allocator structure is

```
/* The declaration of free differs from PyMemAllocatorEx */
typedef struct {
    void *ctx;
    void* (*malloc) (void *ctx, size_t size);
    void* (*calloc) (void *ctx, size_t nelem, size_t elsize);
    void* (*realloc) (void *ctx, void *ptr, size_t new_size);
    void (*free) (void *ctx, void *ptr, size_t size);
} PyDataMemAllocator;
```

PyObject ***PyDataMem_SetHandler**(PyObject *handler)

Set a new allocation policy. If the input value is NULL, will reset the policy to the default. Return the previous policy, or return NULL if an error has occurred. We wrap the user-provided functions so they will still call the python and numpy memory management callback hooks.

PyObject ***PyDataMem_GetHandler**()

Return the current policy that will be used to allocate data for the next PyArrayObject. On failure, return NULL.

For an example of setting up and using the PyDataMem_Handler, see the test in numpy/_core/tests/test_mem_policy.py

What happens when deallocating if there is no policy set

A rare but useful technique is to allocate a buffer outside NumPy, use *PyArray_NewFromDescr* to wrap the buffer in a ndarray, then switch the OWNDATA flag to true. When the ndarray is released, the appropriate function from the ndarray's PyDataMem_Handler should be called to free the buffer. But the PyDataMem_Handler field was never set, it will be NULL. For backward compatibility, NumPy will call free() to release the buffer. If NUMPY_WARN_IF_NO_MEM_POLICY is set to 1, a warning will be emitted. The current default is not to emit a warning, this may change in a future version of NumPy.

A better technique would be to use a PyCapsule as a base object:

```
/* define a PyCapsule_Destructor, using the correct deallocator for buff */
void free_wrap(void *capsule){
    void * obj = PyCapsule_GetPointer(capsule, PyCapsule_GetName(capsule));
    free(obj);
};

/* then inside the function that creates arr from buff */
...
arr = PyArray_NewFromDescr(... buf, ...);
if (arr == NULL) {
    return NULL;
}
capsule = PyCapsule_New(buf, "my_wrapped_buffer",
                        (PyCapsule_Destructor)&free_wrap);
if (PyArray_SetBaseObject(arr, capsule) == -1) {
    Py_DECREF(arr);
    return NULL;
}
...
```

Example of memory tracing with `np.lib.tracemalloc_domain`

Note that since Python 3.6 (or newer), the builtin `tracemalloc` module can be used to track allocations inside NumPy. NumPy places its CPU memory allocations into the `np.lib.tracemalloc_domain` domain. For additional information, check: https://docs.python.org/3/library/tracemalloc.html.

Here is an example on how to use `np.lib.tracemalloc_domain`:

```
"""
   The goal of this example is to show how to trace memory
   from an application that has NumPy and non-NumPy sections.
   We only select the sections using NumPy related calls.
"""

import tracemalloc
import numpy as np

# Flag to determine if we select NumPy domain
use_np_domain = True

nx = 300
ny = 500

# Start to trace memory
tracemalloc.start()

# Section 1
# ---------

# NumPy related call
a = np.zeros((nx,ny))

# non-NumPy related call
b = [i**2 for i in range(nx*ny)]

snapshot1 = tracemalloc.take_snapshot()
```

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```
# We filter the snapshot to only select NumPy related calls
np_domain = np.lib.tracemalloc_domain
dom_filter = tracemalloc.DomainFilter(inclusive=use_np_domain,
                                      domain=np_domain)
snapshot1 = snapshot1.filter_traces([dom_filter])
top_stats1 = snapshot1.statistics('traceback')

print("================ SNAPSHOT 1 =================")
for stat in top_stats1:
    print(f"{stat.count} memory blocks: {stat.size / 1024:.1f} KiB")
    print(stat.traceback.format()[-1])

# Clear traces of memory blocks allocated by Python
# before moving to the next section.
tracemalloc.clear_traces()

# Section 2
#----------

# We are only using NumPy
c = np.sum(a*a)

snapshot2 = tracemalloc.take_snapshot()
top_stats2 = snapshot2.statistics('traceback')

print()
print("================ SNAPSHOT 2 =================")
for stat in top_stats2:
    print(f"{stat.count} memory blocks: {stat.size / 1024:.1f} KiB")
    print(stat.traceback.format()[-1])

tracemalloc.stop()

print()
print("=============================================")
print("\nTracing Status : ", tracemalloc.is_tracing())

try:
    print("\nTrying to Take Snapshot After Tracing is Stopped.")
    snap = tracemalloc.take_snapshot()
except Exception as e:
    print("Exception : ", e)
```

CHAPTER

THREE

OTHER TOPICS

3.1 Array API standard compatibility

NumPy's main namespace as well as the *numpy.fft* and *numpy.linalg* namespaces are compatible[1] with the 2022.12 version of the Python array API standard.

NumPy aims to implement support for the 2023.12 version and future versions of the standard - assuming that those future versions can be upgraded to given NumPy's backwards compatibility policy.

For usage guidelines for downstream libraries and end users who want to write code that will work with both NumPy and other array libraries, we refer to the documentation of the array API standard itself and to code and developer-focused documentation in SciPy and scikit-learn.

Note that in order to use standard-complaint code with older NumPy versions (< 2.0), the array-api-compat package may be useful. For testing whether NumPy-using code is only using standard-compliant features rather than anything NumPy-specific, the array-api-strict package can be used.

History

NumPy 1.22.0 was the first version to include support for the array API standard, via a separate `numpy.array_api` submodule. This module was marked as experimental (it emitted a warning on import) and removed in NumPy 2.0 because full support was included in the main namespace. NEP 47 and NEP 56 describe the motivation and scope for implementing the array API standard in NumPy.

3.1.1 Entry point

NumPy installs an entry point that can be used for discovery purposes:

```
>>> from importlib.metadata import entry_points
>>> entry_points(group='array_api', name='numpy')
[EntryPoint(name='numpy', value='numpy', group='array_api')]
```

Note that leaving out `name='numpy'` will cause a list of entry points to be returned for all array API standard compatible implementations that installed an entry point.

[1] With a few very minor exceptions, as documented in NEP 56. The `sum`, `prod` and `trace` behavior adheres to the 2023.12 version instead, as do function signatures; the only known incompatibility that may remain is that the standard forbids unsafe casts for in-place operators while NumPy supports those.

3.1.2 Inspection

NumPy implements the array API inspection utilities. These functions can be accessed via the `__array_namespace_info__()` function, which returns a namespace containing the inspection utilities.

__array_namespace_info__()	Get the array API inspection namespace for NumPy.

class numpy.**__array_namespace_info__**

Get the array API inspection namespace for NumPy.

The array API inspection namespace defines the following functions:

- capabilities()
- default_device()
- default_dtypes()
- dtypes()
- devices()

See https://data-apis.org/array-api/latest/API_specification/inspection.html for more details.

Returns

info
[ModuleType] The array API inspection namespace for NumPy.

Examples

```
>>> info = np.__array_namespace_info__()
>>> info.default_dtypes()
{'real floating': numpy.float64,
 'complex floating': numpy.complex128,
 'integral': numpy.int64,
 'indexing': numpy.int64}
```

Methods

capabilities()	Return a dictionary of array API library capabilities.
default_device()	The default device used for new NumPy arrays.
default_dtypes(*[, device])	The default data types used for new NumPy arrays.
devices()	The devices supported by NumPy.
dtypes(*[, device, kind])	The array API data types supported by NumPy.

method

__array_namespace_info__.**capabilities**()

Return a dictionary of array API library capabilities.

The resulting dictionary has the following keys:

- **"boolean indexing"**: boolean indicating whether an array library supports boolean indexing. Always `True` for NumPy.

- **"data-dependent shapes"**: boolean indicating whether an array library supports data-dependent output shapes. Always `True` for NumPy.

See https://data-apis.org/array-api/latest/API_specification/generated/array_api.info.capabilities.html for more details.

Returns

capabilities
[dict] A dictionary of array API library capabilities.

See also:

__array_namespace_info__.default_device
__array_namespace_info__.default_dtypes
__array_namespace_info__.dtypes
__array_namespace_info__.devices

Examples

```
>>> info = np.__array_namespace_info__()
>>> info.capabilities()
{'boolean indexing': True,
 'data-dependent shapes': True}
```

method

__array_namespace_info__.**default_device**()

The default device used for new NumPy arrays.

For NumPy, this always returns `'cpu'`.

Returns

device
[str] The default device used for new NumPy arrays.

See also:

__array_namespace_info__.capabilities
__array_namespace_info__.default_dtypes
__array_namespace_info__.dtypes
__array_namespace_info__.devices

Examples

```
>>> info = np.__array_namespace_info__()
>>> info.default_device()
'cpu'
```

method

__array_namespace_info__.**default_dtypes**(*, *device=None*)

The default data types used for new NumPy arrays.

For NumPy, this always returns the following dictionary:

- **"real floating"**: `numpy.float64`

- **“complex floating”**: `numpy.complex128`
- **“integral”**: `numpy.intp`
- **“indexing”**: `numpy.intp`

Parameters

device
[str, optional] The device to get the default data types for. For NumPy, only `'cpu'` is allowed.

Returns

dtypes
[dict] A dictionary describing the default data types used for new NumPy arrays.

See also:

__array_namespace_info__.capabilities
__array_namespace_info__.default_device
__array_namespace_info__.dtypes
__array_namespace_info__.devices

Examples

```
>>> info = np.__array_namespace_info__()
>>> info.default_dtypes()
{'real floating': numpy.float64,
 'complex floating': numpy.complex128,
 'integral': numpy.int64,
 'indexing': numpy.int64}
```

method

`__array_namespace_info__.`**`devices`**`()`

The devices supported by NumPy.

For NumPy, this always returns `['cpu']`.

Returns

devices
[list of str] The devices supported by NumPy.

See also:

__array_namespace_info__.capabilities
__array_namespace_info__.default_device
__array_namespace_info__.default_dtypes
__array_namespace_info__.dtypes

Examples

```
>>> info = np.__array_namespace_info__()
>>> info.devices()
['cpu']
```

method

__array_namespace_info__.**dtypes**(*, *device=None*, *kind=None*)

The array API data types supported by NumPy.

Note that this function only returns data types that are defined by the array API.

Parameters

device
[str, optional] The device to get the data types for. For NumPy, only `'cpu'` is allowed.

kind
[str or tuple of str, optional] The kind of data types to return. If `None`, all data types are returned. If a string, only data types of that kind are returned. If a tuple, a dictionary containing the union of the given kinds is returned. The following kinds are supported:

- `'bool'`: boolean data types (i.e., `bool`).
- `'signed integer'`: signed integer data types (i.e., `int8`, `int16`, `int32`, `int64`).
- `'unsigned integer'`: unsigned integer data types (i.e., `uint8`, `uint16`, `uint32`, `uint64`).
- `'integral'`: integer data types. Shorthand for `('signed integer', 'unsigned integer')`.
- `'real floating'`: real-valued floating-point data types (i.e., `float32`, `float64`).
- `'complex floating'`: complex floating-point data types (i.e., `complex64`, `complex128`).
- `'numeric'`: numeric data types. Shorthand for `('integral', 'real floating', 'complex floating')`.

Returns

dtypes
[dict] A dictionary mapping the names of data types to the corresponding NumPy data types.

See also:

__array_namespace_info__.capabilities
__array_namespace_info__.default_device
__array_namespace_info__.default_dtypes
__array_namespace_info__.devices

Examples

```
>>> info = np.__array_namespace_info__()
>>> info.dtypes(kind='signed integer')
{'int8': numpy.int8,
 'int16': numpy.int16,
 'int32': numpy.int32,
 'int64': numpy.int64}
```

3.2 CPU/SIMD optimizations

NumPy comes with a flexible working mechanism that allows it to harness the SIMD features that CPUs own, in order to provide faster and more stable performance on all popular platforms. Currently, NumPy supports the X86, IBM/Power, ARM7 and ARM8 architectures.

The optimization process in NumPy is carried out in three layers:

- Code is *written* using the universal intrinsics which is a set of types, macros and functions that are mapped to each supported instruction-sets by using guards that will enable use of the them only when the compiler recognizes them. This allow us to generate multiple kernels for the same functionality, in which each generated kernel represents a set of instructions that related one or multiple certain CPU features. The first kernel represents the minimum (baseline) CPU features, and the other kernels represent the additional (dispatched) CPU features.
- At *compile* time, CPU build options are used to define the minimum and additional features to support, based on user choice and compiler support. The appropriate intrinsics are overlaid with the platform / architecture intrinsics, and multiple kernels are compiled.
- At *runtime import*, the CPU is probed for the set of supported CPU features. A mechanism is used to grab the pointer to the most appropriate kernel, and this will be the one called for the function.

Note: NumPy community had a deep discussion before implementing this work, please check NEP-38 for more clarification.

3.2.1 CPU build options

Description

The following options are mainly used to change the default behavior of optimizations that target certain CPU features:

- **`cpu-baseline`: minimal set of required CPU features.**
  Default value is `min` which provides the minimum CPU features that can safely run on a wide range of platforms within the processor family.

  Note: During the runtime, NumPy modules will fail to load if any of specified features are not supported by the target CPU (raises Python runtime error).

- **`cpu-dispatch`: dispatched set of additional CPU features.**
  Default value is `max -xop -fma4` which enables all CPU features, except for AMD legacy features (in case of X86).

Note: During the runtime, NumPy modules will skip any specified features that are not available in the target CPU.

These options are accessible at build time by passing setup arguments to meson-python via the build frontend (e.g., `pip` or `build`). They accept a set of *CPU features* or groups of features that gather several features or *special options* that perform a series of procedures.

To customize CPU/build options:

```
pip install . -Csetup-args=-Dcpu-baseline="avx2 fma3" -Csetup-args=-Dcpu-dispatch="max
↪"
```

Quick start

In general, the default settings tend to not impose certain CPU features that may not be available on some older processors. Raising the ceiling of the baseline features will often improve performance and may also reduce binary size.

The following are the most common scenarios that may require changing the default settings:

I am building NumPy for my local use

And I do not intend to export the build to other users or target a different CPU than what the host has.

Set `native` for baseline, or manually specify the CPU features in case of option `native` isn't supported by your platform:

```
python -m build --wheel -Csetup-args=-Dcpu-baseline="native"
```

Building NumPy with extra CPU features isn't necessary for this case, since all supported features are already defined within the baseline features:

```
python -m build --wheel -Csetup-args=-Dcpu-baseline="native" \
-Csetup-args=-Dcpu-dispatch="none"
```

Note: A fatal error will be raised if `native` isn't supported by the host platform.

I do not want to support the old processors of the x86 architecture

Since most of the CPUs nowadays support at least `AVX`, `F16C` features, you can use:

```
python -m build --wheel -Csetup-args=-Dcpu-baseline="avx f16c"
```

Note: `cpu-baseline` force combine all implied features, so there's no need to add SSE features.

I'm facing the same case above but with ppc64 architecture

Then raise the ceiling of the baseline features to Power8:

```
python -m build --wheel -Csetup-args=-Dcpu-baseline="vsx2"
```

Having issues with AVX512 features?

You may have some reservations about including of `AVX512` or any other CPU feature and you want to exclude from the dispatched features:

```
python -m build --wheel -Csetup-args=-Dcpu-dispatch="max -avx512f -avx512cd \
-avx512_knl -avx512_knm -avx512_skx -avx512_clx -avx512_cnl -avx512_icl"
```

Supported features

The names of the features can express one feature or a group of features, as shown in the following tables supported depend on the lowest interest:

Note: The following features may not be supported by all compilers, also some compilers may produce different set of implied features when it comes to features like `AVX512`, `AVX2`, and `FMA3`. See *Platform differences* for more details.

On x86

Name	Implies	Gathers
SSE	SSE2	
SSE2	SSE	
SSE3	SSE SSE2	
SSSE3	SSE SSE2 SSE3	
SSE41	SSE SSE2 SSE3 SSSE3	
POPCNT	SSE SSE2 SSE3 SSSE3 SSE41	
SSE42	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT	
AVX	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42	
XOP	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX	
FMA4	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX	
F16C	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX	
FMA3	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C	
AVX2	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C	
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2	
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F	
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD	AVX512ER AVX512PF
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_KNL	AVX5124FMAPS AVX5124VNNIW AVX512VPOPCNTDQ
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD	AVX512VL AVX512BW AVX512DQ
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_SKX	AVX512VNNI
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_SKX	AVX512IFMA AVX512VBMI
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_SKX AVX512_CLX AVX512_CNL	AVX512VBMI2 AVX512BITALG AVX512VPOPCNTDQ
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_SKX AVX512_CLX AVX512_CNL AVX512_ICL	AVX512FP16

On IBM/POWER big-endian

Name	Implies
VSX	
VSX2	VSX
VSX3	VSX VSX2
VSX4	VSX VSX2 VSX3

On IBM/POWER little-endian

Name	Implies
VSX	VSX2
VSX2	VSX
VSX3	VSX VSX2
VSX4	VSX VSX2 VSX3

On ARMv7/A32

Name	Implies
NEON	
NEON_FP16	NEON
NEON_VFPV4	NEON NEON_FP16
ASIMD	NEON NEON_FP16 NEON_VFPV4
ASIMDHP	NEON NEON_FP16 NEON_VFPV4 ASIMD
ASIMDDP	NEON NEON_FP16 NEON_VFPV4 ASIMD
ASIMDFHM	NEON NEON_FP16 NEON_VFPV4 ASIMD ASIMDHP

On ARMv8/A64

Name	Implies
NEON	NEON_FP16 NEON_VFPV4 ASIMD
NEON_FP16	NEON NEON_VFPV4 ASIMD
NEON_VFPV4	NEON NEON_FP16 ASIMD
ASIMD	NEON NEON_FP16 NEON_VFPV4
ASIMDHP	NEON NEON_FP16 NEON_VFPV4 ASIMD
ASIMDDP	NEON NEON_FP16 NEON_VFPV4 ASIMD
ASIMDFHM	NEON NEON_FP16 NEON_VFPV4 ASIMD ASIMDHP

On IBM/ZSYSTEM(S390X)

Name	Implies
VX	
VXE	VX
VXE2	VX VXE

Special options

- `NONE`: enable no features.
- `NATIVE`: Enables all CPU features that supported by the host CPU, this operation is based on the compiler flags (`-march=native`, `-xHost`, `/QxHost`)
- `MIN`: Enables the minimum CPU features that can safely run on a wide range of platforms:

For Arch	Implies
x86 (32-bit mode)	`SSE SSE2`
x86_64	`SSE SSE2 SSE3`
IBM/POWER (big-endian mode)	`NONE`
IBM/POWER (little-endian mode)	`VSX VSX2`
ARMHF	`NONE`
ARM64 A.K. AARCH64	`NEON NEON_FP16 NEON_VFPV4 ASIMD`
IBM/ZSYSTEM(S390X)	`NONE`

- `MAX`: Enables all supported CPU features by the compiler and platform.
- `Operators-/+`: remove or add features, useful with options `MAX`, `MIN` and `NATIVE`.

Behaviors

- CPU features and other options are case-insensitive, for example:

```
python -m build --wheel -Csetup-args=-Dcpu-dispatch="SSE41 avx2 FMA3"
```

- The order of the requested optimizations doesn't matter:

```
python -m build --wheel -Csetup-args=-Dcpu-dispatch="SSE41 AVX2 FMA3"
# equivalent to
python -m build --wheel -Csetup-args=-Dcpu-dispatch="FMA3 AVX2 SSE41"
```

- Either commas or spaces or '+' can be used as a separator, for example:

```
python -m build --wheel -Csetup-args=-Dcpu-dispatch="avx2 avx512f"
# or
python -m build --wheel -Csetup-args=-Dcpu-dispatch=avx2,avx512f
# or
python -m build --wheel -Csetup-args=-Dcpu-dispatch="avx2+avx512f"
```

  all works but arguments should be enclosed in quotes or escaped by backslash if any spaces are used.

- `cpu-baseline` combines all implied CPU features, for example:

```
python -m build --wheel -Csetup-args=-Dcpu-baseline=sse42
# equivalent to
python -m build --wheel -Csetup-args=-Dcpu-baseline="sse sse2 sse3 ssse3 sse41␣
↪popcnt sse42"
```

- `cpu-baseline` will be treated as "native" if compiler native flag `-march=native` or `-xHost` or `/QxHost` is enabled through environment variable `CFLAGS`:

```
export CFLAGS="-march=native"
pip install .
# is equivalent to
pip install . -Csetup-args=-Dcpu-baseline=native
```

- `cpu-baseline` escapes any specified features that aren't supported by the target platform or compiler rather than raising fatal errors.

Note: Since `cpu-baseline` combines all implied features, the maximum supported of implied features will be enabled rather than escape all of them. For example:

```
# Requesting `AVX2,FMA3` but the compiler only support **SSE** features
python -m build --wheel -Csetup-args=-Dcpu-baseline="avx2 fma3"
# is equivalent to
python -m build --wheel -Csetup-args=-Dcpu-baseline="sse sse2 sse3 ssse3 sse41␣
↪popcnt sse42"
```

- `cpu-dispatch` does not combine any of implied CPU features, so you must add them unless you want to disable one or all of them:

```
# Only dispatches AVX2 and FMA3
python -m build --wheel -Csetup-args=-Dcpu-dispatch=avx2,fma3
# Dispatches AVX and SSE features
python -m build --wheel -Csetup-args=-Dcpu-dispatch=ssse3,sse41,sse42,avx,avx2,
↪fma3
```

- `cpu-dispatch` escapes any specified baseline features and also escapes any features not supported by the target platform or compiler without raising fatal errors.

Eventually, you should always check the final report through the build log to verify the enabled features. See *Build report* for more details.

Platform differences

Some exceptional conditions force us to link some features together when it come to certain compilers or architectures, resulting in the impossibility of building them separately.

These conditions can be divided into two parts, as follows:

Architectural compatibility

The need to align certain CPU features that are assured to be supported by successive generations of the same architecture, some cases:

- On ppc64le `VSX(ISA 2.06)` and `VSX2(ISA 2.07)` both imply one another since the first generation that supports little-endian mode is Power-8`(ISA 2.07)`
- On AArch64 `NEON NEON_FP16 NEON_VFPV4 ASIMD` implies each other since they are part of the hardware baseline.

For example:

```
# On ARMv8/A64, specify NEON is going to enable Advanced SIMD
# and all predecessor extensions
python -m build --wheel -Csetup-args=-Dcpu-baseline=neon
# which is equivalent to
python -m build --wheel -Csetup-args=-Dcpu-baseline="neon neon_fp16 neon_vfpv4 asimd"
```

Note: Please take a deep look at *Supported features*, in order to determine the features that imply one another.

Compilation compatibility

Some compilers don't provide independent support for all CPU features. For instance **Intel**'s compiler doesn't provide separated flags for `AVX2` and `FMA3`, it makes sense since all Intel CPUs that comes with `AVX2` also support `FMA3`, but this approach is incompatible with other **x86** CPUs from **AMD** or **VIA**.

For example:

```
# Specify AVX2 will force enables FMA3 on Intel compilers
python -m build --wheel -Csetup-args=-Dcpu-baseline=avx2
# which is equivalent to
python -m build --wheel -Csetup-args=-Dcpu-baseline="avx2 fma3"
```

The following tables only show the differences imposed by some compilers from the general context that been shown in the *Supported features* tables:

Note: Features names with strikeout represent the unsupported CPU features.

On x86::Intel Compiler

Name	Implies	Gathers
FMA3	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C AVX2	
AVX2	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3	
AVX512F	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512CD	
XOP	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX	
FMA4	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX	
AVX512_	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_SKX AVX512_CLX AVX512_CNL AVX512_ICL	AVX512FP16

On x86::Microsoft Visual C/C++

Name	Implies	Gathers
FMA3	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C AVX2	
AVX2	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3	
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512CD AVX512_SKX	
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512_SKX	
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD	AVX512ER AVX512PF
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_KNL	AVX5124FMAPS AVX5124VNNIW AVX512VPOPCNTDQ
AVX512	SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_SKX AVX512_CLX AVX512_CNL AVX512_ICL	AVX512FP16

Build report

In most cases, the CPU build options do not produce any fatal errors that lead to hanging the build. Most of the errors that may appear in the build log serve as heavy warnings due to the lack of some expected CPU features by the compiler.

So we strongly recommend checking the final report log, to be aware of what kind of CPU features are enabled and what are not.

You can find the final report of CPU optimizations at the end of the build log, and here is how it looks on x86_64/gcc:

```
########### EXT COMPILER OPTIMIZATION ###########
Platform      :
  Architecture: x64
  Compiler    : gcc

CPU baseline  :
  Requested   : 'min'
  Enabled     : SSE SSE2 SSE3
  Flags       : -msse -msse2 -msse3
  Extra checks: none

CPU dispatch  :
  Requested   : 'max -xop -fma4'
  Enabled     : SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_
↪KNL AVX512_KNM AVX512_SKX AVX512_CLX AVX512_CNL AVX512_ICL
  Generated   :
              :
  SSE41       : SSE SSE2 SSE3 SSSE3
  Flags       : -msse -msse2 -msse3 -mssse3 -msse4.1
  Extra checks: none
  Detect      : SSE SSE2 SSE3 SSSE3 SSE41
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_arithmetic.
↪dispatch.c
              : numpy/_core/src/umath/_umath_tests.dispatch.c
              :
  SSE42       : SSE SSE2 SSE3 SSSE3 SSE41 POPCNT
  Flags       : -msse -msse2 -msse3 -mssse3 -msse4.1 -mpopcnt -msse4.2
  Extra checks: none
  Detect      : SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42
              : build/src.linux-x86_64-3.9/numpy/_core/src/_simd/_simd.dispatch.c
              :
  AVX2        : SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C
  Flags       : -msse -msse2 -msse3 -mssse3 -msse4.1 -mpopcnt -msse4.2 -mavx -mf16c -
↪mavx2
  Extra checks: none
  Detect      : AVX F16C AVX2
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_arithm_fp.
↪dispatch.c
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_arithmetic.
↪dispatch.c
              : numpy/_core/src/umath/_umath_tests.dispatch.c
              :
  (FMA3 AVX2) : SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C
  Flags       : -msse -msse2 -msse3 -mssse3 -msse4.1 -mpopcnt -msse4.2 -mavx -mf16c -
↪mfma -mavx2
  Extra checks: none
  Detect      : AVX F16C FMA3 AVX2
              : build/src.linux-x86_64-3.9/numpy/_core/src/_simd/_simd.dispatch.c
```

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```
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_exponent_log.
↪dispatch.c
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_trigonometric.
↪dispatch.c
              :
  AVX512F     : SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2
  Flags       : -msse -msse2 -msse3 -mssse3 -msse4.1 -mpopcnt -msse4.2 -mavx -mf16c -
↪mfma -mavx2 -mavx512f
  Extra checks: AVX512F_REDUCE
  Detect      : AVX512F
              : build/src.linux-x86_64-3.9/numpy/_core/src/_simd/_simd.dispatch.c
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_arithm_fp.
↪dispatch.c
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_arithmetic.
↪dispatch.c
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_exponent_log.
↪dispatch.c
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_trigonometric.
↪dispatch.c
              :
  AVX512_SKX  : SSE SSE2 SSE3 SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F␣
↪AVX512CD
  Flags       : -msse -msse2 -msse3 -mssse3 -msse4.1 -mpopcnt -msse4.2 -mavx -mf16c -
↪mfma -mavx2 -mavx512f -mavx512cd -mavx512vl -mavx512bw -mavx512dq
  Extra checks: AVX512BW_MASK AVX512DQ_MASK
  Detect      : AVX512_SKX
              : build/src.linux-x86_64-3.9/numpy/_core/src/_simd/_simd.dispatch.c
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_arithmetic.
↪dispatch.c
              : build/src.linux-x86_64-3.9/numpy/_core/src/umath/loops_exponent_log.
↪dispatch.c
CCompilerOpt.cache_flush[804] : write cache to path -> /home/seiko/work/repos/numpy/
↪build/temp.linux-x86_64-3.9/ccompiler_opt_cache_ext.py

########### CLIB COMPILER OPTIMIZATION ###########
Platform      :
  Architecture: x64
  Compiler    : gcc

CPU baseline  :
  Requested   : 'min'
  Enabled     : SSE SSE2 SSE3
  Flags       : -msse -msse2 -msse3
  Extra checks: none

CPU dispatch  :
  Requested   : 'max -xop -fma4'
  Enabled     : SSSE3 SSE41 POPCNT SSE42 AVX F16C FMA3 AVX2 AVX512F AVX512CD AVX512_
↪KNL AVX512_KNM AVX512_SKX AVX512_CLX AVX512_CNL AVX512_ICL
  Generated   : none
```

There is a separate report for each of `build_ext` and `build_clib` that includes several sections, and each section has several values, representing the following:

Platform:

- Architecture: The architecture name of target CPU. It should be one of `x86`, `x64`, `ppc64`, `ppc64le`, `armhf`, `aarch64`, `s390x` or `unknown`.

- Compiler: The compiler name. It should be one of gcc, clang, msvc, icc, iccw or unix-like.

CPU baseline:

- Requested: The specific features and options to `cpu-baseline` as-is.
- Enabled: The final set of enabled CPU features.
- Flags: The compiler flags that were used to all NumPy C/C++ sources during the compilation except for temporary sources that have been used for generating the binary objects of dispatched features.
- Extra checks: list of internal checks that activate certain functionality or intrinsics related to the enabled features, useful for debugging when it comes to developing SIMD kernels.

CPU dispatch:

- Requested: The specific features and options to `cpu-dispatch` as-is.
- Enabled: The final set of enabled CPU features.
- Generated: At the beginning of the next row of this property, the features for which optimizations have been generated are shown in the form of several sections with similar properties explained as follows:
  - One or multiple dispatched feature: The implied CPU features.
  - Flags: The compiler flags that been used for these features.
  - Extra checks: Similar to the baseline but for these dispatched features.
  - Detect: Set of CPU features that need be detected in runtime in order to execute the generated optimizations.
  - The lines that come after the above property and end with a ':' on a separate line, represent the paths of c/c++ sources that define the generated optimizations.

Runtime dispatch

Importing NumPy triggers a scan of the available CPU features from the set of dispatchable features. This can be further restricted by setting the environment variable `NPY_DISABLE_CPU_FEATURES` to a comma-, tab-, or space-separated list of features to disable. This will raise an error if parsing fails or if the feature was not enabled. For instance, on `x86_64` this will disable `AVX2` and `FMA3`:

```
NPY_DISABLE_CPU_FEATURES="AVX2,FMA3"
```

If the feature is not available, a warning will be emitted.

Tracking dispatched functions

Discovering which CPU targets are enabled for different optimized functions is achievable through the Python function `numpy.lib.introspect.opt_func_info`. This function offers the flexibility of applying filters using two optional arguments: one for refining function names and the other for specifying data types in the signatures.

For example:

```
>> func_info = numpy.lib.introspect.opt_func_info(func_name='add|abs', signature=
↪'float64|complex64')
>> print(json.dumps(func_info, indent=2))
{
  "absolute": {
    "dd": {
      "current": "SSE41",
```

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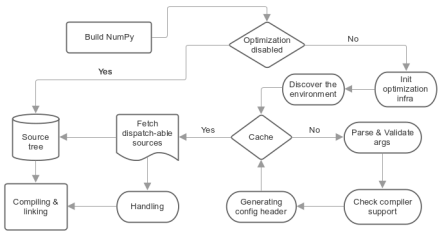
```
      "available": "SSE41 baseline(SSE SSE2 SSE3)"
    },
    "Ff": {
      "current": "FMA3__AVX2",
      "available": "AVX512F FMA3__AVX2 baseline(SSE SSE2 SSE3)"
    },
    "Dd": {
      "current": "FMA3__AVX2",
      "available": "AVX512F FMA3__AVX2 baseline(SSE SSE2 SSE3)"
    }
  },
  "add": {
    "ddd": {
      "current": "FMA3__AVX2",
      "available": "FMA3__AVX2 baseline(SSE SSE2 SSE3)"
    },
    "FFF": {
      "current": "FMA3__AVX2",
      "available": "FMA3__AVX2 baseline(SSE SSE2 SSE3)"
    }
  }
}
```

3.2.2 How does the CPU dispatcher work?

NumPy dispatcher is based on multi-source compiling, which means taking a certain source and compiling it multiple times with different compiler flags and also with different **C** definitions that affect the code paths. This enables certain instruction-sets for each compiled object depending on the required optimizations and ends with linking the returned objects together.



This mechanism should support all compilers and it doesn't require any compiler-specific extension, but at the same time it adds a few steps to normal compilation that are explained as follows.

1- Configuration

Configuring the required optimization by the user before starting to build the source files via the two command arguments as explained above:

- `--cpu-baseline`: minimal set of required optimizations.
- `--cpu-dispatch`: dispatched set of additional optimizations.

2- Discovering the environment

In this part, we check the compiler and platform architecture and cache some of the intermediary results to speed up rebuilding.

3- Validating the requested optimizations

By testing them against the compiler, and seeing what the compiler can support according to the requested optimizations.

4- Generating the main configuration header

The generated header `_cpu_dispatch.h` contains all the definitions and headers of instruction-sets for the required optimizations that have been validated during the previous step.

It also contains extra C definitions that are used for defining NumPy's Python-level module attributes `__cpu_baseline__` and `__cpu_dispatch__`.

What is in this header?

The example header was dynamically generated by gcc on an X86 machine. The compiler supports `--cpu-baseline="sse sse2 sse3"` and `--cpu-dispatch="ssse3 sse41"`, and the result is below.

```
// The header should be located at numpy/numpy/_core/src/common/_cpu_dispatch.h
/**NOTE
 ** C definitions prefixed with "NPY_HAVE_" represent
 ** the required optimizations.
 **
 ** C definitions prefixed with 'NPY__CPU_TARGET_' are protected and
 ** shouldn't be used by any NumPy C sources.
 */
/******* baseline features *******/
/** SSE **/
#define NPY_HAVE_SSE 1
#include <xmmintrin.h>
/** SSE2 **/
#define NPY_HAVE_SSE2 1
#include <emmintrin.h>
/** SSE3 **/
#define NPY_HAVE_SSE3 1
#include <pmmintrin.h>

/******* dispatch-able features *******/
#ifdef NPY__CPU_TARGET_SSSE3
  /** SSSE3 **/
  #define NPY_HAVE_SSSE3 1
  #include <tmmintrin.h>
#endif
#ifdef NPY__CPU_TARGET_SSE41
  /** SSE41 **/
  #define NPY_HAVE_SSE41 1
  #include <smmintrin.h>
#endif
```

Baseline features are the minimal set of required optimizations configured via `--cpu-baseline`. They have no preprocessor guards and they're always on, which means they can be used in any source.

Does this mean NumPy's infrastructure passes the compiler's flags of baseline features to all sources?

Definitely, yes. But the *dispatch-able sources* are treated differently.

What if the user specifies certain **baseline features** during the build but at runtime the machine doesn't support even these features? Will the compiled code be called via one of these definitions, or maybe the compiler itself auto-generated/vectorized certain piece of code based on the provided command line compiler flags?

During the loading of the NumPy module, there's a validation step which detects this behavior. It will raise a Python runtime error to inform the user. This is to prevent the CPU reaching an illegal instruction error causing a segfault.

Dispatch-able features are our dispatched set of additional optimizations that were configured via `--cpu-dispatch`. They are not activated by default and are always guarded by other C definitions prefixed with `NPY__CPU_TARGET_`. C definitions `NPY__CPU_TARGET_` are only enabled within **dispatch-able sources**.

5- Dispatch-able sources and configuration statements

Dispatch-able sources are special **C** files that can be compiled multiple times with different compiler flags and also with different **C** definitions. These affect code paths to enable certain instruction-sets for each compiled object according to "**the configuration statements**" that must be declared between a **C** comment `(/**/)` and start with a special mark **@targets** at the top of each dispatch-able source. At the same time, dispatch-able sources will be treated as normal **C** sources if the optimization was disabled by the command argument `--disable-optimization`.

What are configuration statements?

Configuration statements are sort of keywords combined together to determine the required optimization for the dispatch-able source.

Example:

```
/*@targets avx2 avx512f vsx2 vsx3 asimd asimdhp */
// C code
```

The keywords mainly represent the additional optimizations configured through `--cpu-dispatch`, but it can also represent other options such as:

- Target groups: pre-configured configuration statements used for managing the required optimizations from outside the dispatch-able source.
- Policies: collections of options used for changing the default behaviors or forcing the compilers to perform certain things.
- "baseline": a unique keyword represents the minimal optimizations that configured through `--cpu-baseline`

Numpy's infrastructure handles dispatch-able sources in four steps:

- **(A) Recognition**: Just like source templates and F2PY, the dispatch-able sources requires a special extension `*.dispatch.c` to mark C dispatch-able source files, and for C++ `*.dispatch.cpp` or `*.dispatch.cxx` **NOTE**: C++ not supported yet.
- **(B) Parsing and validating**: In this step, the dispatch-able sources that had been filtered by the previous step are parsed and validated by the configuration statements for each one of them one by one in order to determine the required optimizations.
- **(C) Wrapping**: This is the approach taken by NumPy's infrastructure, which has proved to be sufficiently flexible in order to compile a single source multiple times with different **C** definitions and flags that affect the code paths. The process is achieved by creating a temporary **C** source for each required optimization that related to the additional optimization, which contains the declarations of the **C** definitions and includes the involved source via the **C** directive **#include**. For more clarification take a look at the following code for AVX512F :

```
/*
 * this definition is used by NumPy utilities as suffixes for the
 * exported symbols
 */
#define NPY__CPU_TARGET_CURRENT AVX512F
/*
 * The following definitions enable
 * definitions of the dispatch-able features that are defined within the main
 * configuration header. These are definitions for the implied features.
 */
#define NPY__CPU_TARGET_SSE
#define NPY__CPU_TARGET_SSE2
#define NPY__CPU_TARGET_SSE3
#define NPY__CPU_TARGET_SSSE3
#define NPY__CPU_TARGET_SSE41
#define NPY__CPU_TARGET_POPCNT
#define NPY__CPU_TARGET_SSE42
#define NPY__CPU_TARGET_AVX
#define NPY__CPU_TARGET_F16C
#define NPY__CPU_TARGET_FMA3
#define NPY__CPU_TARGET_AVX2
#define NPY__CPU_TARGET_AVX512F
// our dispatch-able source
#include "/the/absolute/path/of/hello.dispatch.c"
```

- **(D) Dispatch-able configuration header**: The infrastructure generates a config header for each dispatch-able source, this header mainly contains two abstract **C** macros used for identifying the generated objects, so they can be used for runtime dispatching certain symbols from the generated objects by any **C** source. It is also used for forward declarations.

  The generated header takes the name of the dispatch-able source after excluding the extension and replace it with `.h`, for example assume we have a dispatch-able source called `hello.dispatch.c` and contains the following:

```
// hello.dispatch.c
/*@targets baseline sse42 avx512f */
#include <stdio.h>
#include "numpy/utils.h" // NPY_CAT, NPY_TOSTR

#ifndef NPY__CPU_TARGET_CURRENT
  // wrapping the dispatch-able source only happens to the additional␣
↪optimizations
  // but if the keyword 'baseline' provided within the configuration statements,
  // the infrastructure will add extra compiling for the dispatch-able source by
  // passing it as-is to the compiler without any changes.
  #define CURRENT_TARGET(X) X
  #define NPY__CPU_TARGET_CURRENT baseline // for printing only
#else
  // since we reach to this point, that's mean we're dealing with
    // the additional optimizations, so it could be SSE42 or AVX512F
  #define CURRENT_TARGET(X) NPY_CAT(NPY_CAT(X, _), NPY__CPU_TARGET_CURRENT)
#endif
// Macro 'CURRENT_TARGET' adding the current target as suffix to the exported␣
↪symbols,
// to avoid linking duplications, NumPy already has a macro called
// 'NPY_CPU_DISPATCH_CURFX' similar to it, located at
// numpy/numpy/_core/src/common/npy_cpu_dispatch.h
// NOTE: we tend to not adding suffixes to the baseline exported symbols
```

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```
void CURRENT_TARGET(simd_whoami)(const char *extra_info)
{
    printf("I'm " NPY_TOSTR(NPY__CPU_TARGET_CURRENT) ", %s\n", extra_info);
}
```

Now assume you attached **hello.dispatch.c** to the source tree, then the infrastructure should generate a temporary config header called **hello.dispatch.h** that can be reached by any source in the source tree, and it should contain the following code :

```
#ifndef NPY__CPU_DISPATCH_EXPAND_
  // To expand the macro calls in this header
    #define NPY__CPU_DISPATCH_EXPAND_(X) X
#endif
// Undefining the following macros, due to the possibility of including config␣
↪headers
// multiple times within the same source and since each config header represents
// different required optimizations according to the specified configuration
// statements in the dispatch-able source that derived from it.
#undef NPY__CPU_DISPATCH_BASELINE_CALL
#undef NPY__CPU_DISPATCH_CALL
// nothing strange here, just a normal preprocessor callback
// enabled only if 'baseline' specified within the configuration statements
#define NPY__CPU_DISPATCH_BASELINE_CALL(CB, ...) \
  NPY__CPU_DISPATCH_EXPAND_(CB(__VA_ARGS__))
// 'NPY__CPU_DISPATCH_CALL' is an abstract macro is used for dispatching
// the required optimizations that specified within the configuration statements.
//
// @param CHK, Expected a macro that can be used to detect CPU features
// in runtime, which takes a CPU feature name without string quotes and
// returns the testing result in a shape of boolean value.
// NumPy already has macro called "NPY_CPU_HAVE", which fits this requirement.
//
// @param CB, a callback macro that expected to be called multiple times depending
// on the required optimizations, the callback should receive the following␣
↪arguments:
//  1- The pending calls of @param CHK filled up with the required CPU features,
//     that need to be tested first in runtime before executing call belong to
//     the compiled object.
//  2- The required optimization name, same as in 'NPY__CPU_TARGET_CURRENT'
//  3- Extra arguments in the macro itself
//
// By default the callback calls are sorted depending on the highest interest
// unless the policy "$keep_sort" was in place within the configuration statements
// see "Dive into the CPU dispatcher" for more clarification.
#define NPY__CPU_DISPATCH_CALL(CHK, CB, ...) \
  NPY__CPU_DISPATCH_EXPAND_(CB((CHK(AVX512F)), AVX512F, __VA_ARGS__)) \
  NPY__CPU_DISPATCH_EXPAND_(CB((CHK(SSE)&&CHK(SSE2)&&CHK(SSE3)&&CHK(SSSE3)&&
↪CHK(SSE41)), SSE41, __VA_ARGS__))
```

An example of using the config header in light of the above:

```
// NOTE: The following macros are only defined for demonstration purposes only.
// NumPy already has a collections of macros located at
// numpy/numpy/_core/src/common/npy_cpu_dispatch.h, that covers all dispatching
// and declarations scenarios.
```

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```
#include "numpy/npy_cpu_features.h" // NPY_CPU_HAVE
#include "numpy/utils.h" // NPY_CAT, NPY_EXPAND

// An example for setting a macro that calls all the exported symbols at once
// after checking if they're supported by the running machine.
#define DISPATCH_CALL_ALL(FN, ARGS) \
    NPY__CPU_DISPATCH_CALL(NPY_CPU_HAVE, DISPATCH_CALL_ALL_CB, FN, ARGS) \
    NPY__CPU_DISPATCH_BASELINE_CALL(DISPATCH_CALL_BASELINE_ALL_CB, FN, ARGS)
// The preprocessor callbacks.
// The same suffixes as we define it in the dispatch-able source.
#define DISPATCH_CALL_ALL_CB(CHECK, TARGET_NAME, FN, ARGS) \
  if (CHECK) { NPY_CAT(NPY_CAT(FN, _), TARGET_NAME) ARGS; }
#define DISPATCH_CALL_BASELINE_ALL_CB(FN, ARGS) \
  FN NPY_EXPAND(ARGS);

// An example for setting a macro that calls the exported symbols of highest
// interest optimization, after checking if they're supported by the running machine.
#define DISPATCH_CALL_HIGH(FN, ARGS) \
  if (0) {} \
    NPY__CPU_DISPATCH_CALL(NPY_CPU_HAVE, DISPATCH_CALL_HIGH_CB, FN, ARGS) \
    NPY__CPU_DISPATCH_BASELINE_CALL(DISPATCH_CALL_BASELINE_HIGH_CB, FN, ARGS)
// The preprocessor callbacks
// The same suffixes as we define it in the dispatch-able source.
#define DISPATCH_CALL_HIGH_CB(CHECK, TARGET_NAME, FN, ARGS) \
  else if (CHECK) { NPY_CAT(NPY_CAT(FN, _), TARGET_NAME) ARGS; }
#define DISPATCH_CALL_BASELINE_HIGH_CB(FN, ARGS) \
  else { FN NPY_EXPAND(ARGS); }

// NumPy has a macro called 'NPY_CPU_DISPATCH_DECLARE' can be used
// for forward declarations any kind of prototypes based on
// 'NPY__CPU_DISPATCH_CALL' and 'NPY__CPU_DISPATCH_BASELINE_CALL'.
// However in this example, we just handle it manually.
void simd_whoami(const char *extra_info);
void simd_whoami_AVX512F(const char *extra_info);
void simd_whoami_SSE41(const char *extra_info);

void trigger_me(void)
{
    // bring the auto-generated config header
    // which contains config macros 'NPY__CPU_DISPATCH_CALL' and
    // 'NPY__CPU_DISPATCH_BASELINE_CALL'.
    // it is highly recommended to include the config header before executing
  // the dispatching macros in case if there's another header in the scope.
    #include "hello.dispatch.h"
    DISPATCH_CALL_ALL(simd_whoami, ("all"))
    DISPATCH_CALL_HIGH(simd_whoami, ("the highest interest"))
    // An example of including multiple config headers in the same source
    // #include "hello2.dispatch.h"
    // DISPATCH_CALL_HIGH(another_function, ("the highest interest"))
}
```

3.3 Thread Safety

NumPy supports use in a multithreaded context via the `threading` module in the standard library. Many NumPy operations release the GIL, so unlike many situations in Python, it is possible to improve parallel performance by exploiting multithreaded parallelism in Python.

The easiest performance gains happen when each worker thread owns its own array or set of array objects, with no data directly shared between threads. Because NumPy releases the GIL for many low-level operations, threads that spend most of the time in low-level code will run in parallel.

It is possible to share NumPy arrays between threads, but extreme care must be taken to avoid creating thread safety issues when mutating arrays that are shared between multiple threads. If two threads simultaneously read from and write to the same array, they will at best produce inconsistent, racey results that are not reproducible, let alone correct. It is also possible to crash the Python interpreter by, for example, resizing an array while another thread is reading from it to compute a ufunc operation.

In the future, we may add locking to ndarray to make writing multithreaded algorithms using NumPy arrays safer, but for now we suggest focusing on read-only access of arrays that are shared between threads, or adding your own locking if you need to mutation and multithreading.

Note that operations that *do not* release the GIL will see no performance gains from use of the `threading` module, and instead might be better served with `multiprocessing`. In particular, operations on arrays with `dtype=object` do not release the GIL.

3.3.1 Free-threaded Python

New in version 2.1.

Starting with NumPy 2.1 and CPython 3.13, NumPy also has experimental support for python runtimes with the GIL disabled. See https://py-free-threading.github.io for more information about installing and using free-threaded Python, as well as information about supporting it in libraries that depend on NumPy.

Because free-threaded Python does not have a global interpreter lock to serialize access to Python objects, there are more opportunities for threads to mutate shared state and create thread safety issues. In addition to the limitations about locking of the ndarray object noted above, this also means that arrays with `dtype=object` are not protected by the GIL, creating data races for python objects that are not possible outside free-threaded python.

3.4 Global Configuration Options

NumPy has a few import-time, compile-time, or runtime configuration options which change the global behaviour. Most of these are related to performance or for debugging purposes and will not be interesting to the vast majority of users.

3.4.1 Performance-related options

Number of threads used for linear algebra

NumPy itself is normally intentionally limited to a single thread during function calls, however it does support multiple Python threads running at the same time. Note that for performant linear algebra NumPy uses a BLAS backend such as OpenBLAS or MKL, which may use multiple threads that may be controlled by environment variables such as `OMP_NUM_THREADS` depending on what is used. One way to control the number of threads is the package threadpoolctl

madvise hugepage on Linux

When working with very large arrays on modern Linux kernels, you can experience a significant speedup when transparent hugepage is used. The current system policy for transparent hugepages can be seen by:

```
cat /sys/kernel/mm/transparent_hugepage/enabled
```

When set to `madvise` NumPy will typically use hugepages for a performance boost. This behaviour can be modified by setting the environment variable:

```
NUMPY_MADVISE_HUGEPAGE=0
```

or setting it to `1` to always enable it. When not set, the default is to use madvise on Kernels 4.6 and newer. These kernels presumably experience a large speedup with hugepage support. This flag is checked at import time.

SIMD feature selection

Setting `NPY_DISABLE_CPU_FEATURES` will exclude simd features at runtime. See *Runtime dispatch*.

3.4.2 Debugging-related options

Warn if no memory allocation policy when deallocating data

Some users might pass ownership of the data pointer to the `ndarray` by setting the `OWNDATA` flag. If they do this without setting (manually) a memory allocation policy, the default will be to call `free`. If `NUMPY_WARN_IF_NO_MEM_POLICY` is set to `"1"`, a `RuntimeWarning` will be emitted. A better alternative is to use a `PyCapsule` with a deallocator and set the `ndarray.base`.

Changed in version 1.25.2: This variable is only checked on the first import.

3.5 NumPy security

Security issues can be reported privately as described in the project README and when opening a new issue on the issue tracker. The Python security reporting guidelines are a good resource and its notes apply also to NumPy.

NumPy's maintainers are not security experts. However, we are conscientious about security and experts of both the NumPy codebase and how it's used. Please do notify us before creating security advisories against NumPy as we are happy to prioritize issues or help with assessing the severity of a bug. A security advisory we are not aware of beforehand can lead to a lot of work for all involved parties.

3.5.1 Advice for using NumPy on untrusted data

A user who can freely execute NumPy (or Python) functions must be considered to have the same privilege as the process/Python interpreter.

That said, NumPy should be generally safe to use on *data* provided by unprivileged users and read through safe API functions (e.g. loaded from a text file or `.npy` file without pickle support). Malicious *values* or *data sizes* should never lead to privilege escalation. Note that the above refers to array data. We do not currently consider for example `f2py` to be safe: it is typically used to compile a program that is then run. Any `f2py` invocation must thus use the same privilege as the later execution.

The following points may be useful or should be noted when working with untrusted data:

- Exhausting memory can result in an out-of-memory kill, which is a possible denial of service attack. Possible causes could be:
  - Functions reading text files, which may require much more memory than the original input file size.
  - If users can create arbitrarily shaped arrays, NumPy's broadcasting means that intermediate or result arrays can be much larger than the inputs.
- NumPy structured dtypes allow for a large amount of complexity. Fortunately, most code fails gracefully when a structured dtype is provided unexpectedly. However, code should either disallow untrusted users to provide these (e.g. via `.npy` files) or carefully check the fields included for nested structured/subarray dtypes.
- Passing on user input should generally be considered unsafe (except for the data being read). An example would be `np.dtype(user_string)` or `dtype=user_string`.
- The speed of operations can depend on values and memory order can lead to larger temporary memory use and slower execution. This means that operations may be significantly slower or use more memory compared to simple test cases.
- When reading data, consider enforcing a specific shape (e.g. one dimensional) or dtype such as `float64`, `float32`, or `int64` to reduce complexity.

When working with non-trivial untrusted data, it is advisable to sandbox the analysis to guard against potential privilege escalation. This is especially advisable if further libraries based on NumPy are used since these add additional complexity and potential security issues.

3.6 Status of `numpy.distutils` and migration advice

`numpy.distutils` has been deprecated in NumPy `1.23.0`. It will be removed for Python 3.12; for Python <= 3.11 it will not be removed until 2 years after the Python 3.12 release (Oct 2025).

Warning: `numpy.distutils` is only tested with `setuptools < 60.0`, newer versions may break. See *Interaction of numpy.distutils with setuptools* for details.

3.6.1 Migration advice

There are several build systems which are good options to migrate to. Assuming you have compiled code in your package (if not, you have several good options, e.g. the build backends offered by Poetry, Hatch or PDM) and you want to be using a well-designed, modern and reliable build system, we recommend:

1. Meson, and the meson-python build backend
2. CMake, and the scikit-build-core build backend

If you have modest needs (only simple Cython/C extensions; no need for Fortran, BLAS/LAPACK, nested `setup.py` files, or other features of `numpy.distutils`) and have been happy with `numpy.distutils` so far, you can also consider switching to `setuptools`. Note that most functionality of `numpy.distutils` is unlikely to be ported to `setuptools`.

Moving to Meson

SciPy has moved to Meson and meson-python for its 1.9.0 release. During this process, remaining issues with Meson's Python support and feature parity with `numpy.distutils` were resolved. *Note: parity means a large superset (because Meson is a good general-purpose build system); only a few BLAS/LAPACK library selection niceties are missing*. SciPy uses almost all functionality that `numpy.distutils` offers, so if SciPy has successfully made a release with Meson as the build system, there should be no blockers left to migrate, and SciPy will be a good reference for other packages who are migrating. For more details about the SciPy migration, see:

- RFC: switch to Meson as a build system
- Tracking issue for Meson support

NumPy will migrate to Meson for the 1.26 release.

Moving to CMake / scikit-build

The next generation of scikit-build is called scikit-build-core. Where the older `scikit-build` used `setuptools` underneath, the rewrite does not. Like Meson, CMake is a good general-purpose build system.

Moving to `setuptools`

For projects that only use `numpy.distutils` for historical reasons, and do not actually use features beyond those that `setuptools` also supports, moving to `setuptools` is likely the solution which costs the least effort. To assess that, there are the `numpy.distutils` features that are *not* present in `setuptools`:

- Nested `setup.py` files
- Fortran build support
- BLAS/LAPACK library support (OpenBLAS, MKL, ATLAS, Netlib LAPACK/BLAS, BLIS, 64-bit ILP interface, etc.)
- Support for a few other scientific libraries, like FFTW and UMFPACK
- Better MinGW support
- Per-compiler build flag customization (e.g. *-O3* and *SSE2* flags are default)
- a simple user build config system, see site.cfg.example
- SIMD intrinsics support
- Support for the NumPy-specific `.src` templating format for `.c`/`.h` files

The most widely used feature is nested `setup.py` files. This feature may perhaps still be ported to `setuptools` in the future (it needs a volunteer though, see gh-18588 for status). Projects only using that feature could move to `setuptools` after that is done. In case a project uses only a couple of `setup.py` files, it also could make sense to simply aggregate all the content of those files into a single `setup.py` file and then move to `setuptools`. This involves dropping all `Configuration` instances, and using `Extension` instead. E.g.,:

```
from distutils.core import setup
from distutils.extension import Extension
setup(name='foobar',
      version='1.0',
      ext_modules=[
          Extension('foopkg.foo', ['foo.c']),
          Extension('barpkg.bar', ['bar.c']),
```

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```
            ],
        )
```

For more details, see the setuptools documentation

3.6.2 Interaction of `numpy.distutils` with `setuptools`

It is recommended to use `setuptools < 60.0`. Newer versions may work, but are not guaranteed to. The reason for this is that `setuptools` 60.0 enabled a vendored copy of `distutils`, including backwards incompatible changes that affect some functionality in `numpy.distutils`.

If you are using only simple Cython or C extensions with minimal use of `numpy.distutils` functionality beyond nested `setup.py` files (its most popular feature, see *`Configuration`*), then latest `setuptools` is likely to continue working. In case of problems, you can also try `SETUPTOOLS_USE_DISTUTILS=stdlib` to avoid the backwards incompatible changes in `setuptools`.

Whatever you do, it is recommended to put an upper bound on your `setuptools` build requirement in `pyproject.toml` to avoid future breakage - see for-downstream-package-authors.

3.7 `numpy.distutils` user guide

Warning: `numpy.distutils` is deprecated, and will be removed for Python >= 3.12. For more details, see *Status of numpy.distutils and migration advice*

3.7.1 SciPy structure

Currently SciPy project consists of two packages:

- NumPy — it provides packages like:
  - numpy.distutils - extension to Python distutils
  - numpy.f2py - a tool to bind Fortran/C codes to Python
  - numpy._core - future replacement of Numeric and numarray packages
  - numpy.lib - extra utility functions
  - numpy.testing - numpy-style tools for unit testing
  - etc
- SciPy — a collection of scientific tools for Python.

The aim of this document is to describe how to add new tools to SciPy.

3.7.2 Requirements for SciPy packages

SciPy consists of Python packages, called SciPy packages, that are available to Python users via the `scipy` namespace. Each SciPy package may contain other SciPy packages. And so on. Therefore, the SciPy directory tree is a tree of packages with arbitrary depth and width. Any SciPy package may depend on NumPy packages but the dependence on other SciPy packages should be kept minimal or zero.

A SciPy package contains, in addition to its sources, the following files and directories:

- `setup.py` — building script
- `__init__.py` — package initializer
- `tests/` — directory of unittests

Their contents are described below.

3.7.3 The `setup.py` file

In order to add a Python package to SciPy, its build script (`setup.py`) must meet certain requirements. The most important requirement is that the package define a `configuration(parent_package='',top_path=None)` function which returns a dictionary suitable for passing to `numpy.distutils.core.setup(..)`. To simplify the construction of this dictionary, `numpy.distutils.misc_util` provides the `Configuration` class, described below.

SciPy pure Python package example

Below is an example of a minimal `setup.py` file for a pure SciPy package:

```
#!/usr/bin/env python3
def configuration(parent_package='',top_path=None):
    from numpy.distutils.misc_util import Configuration
    config = Configuration('mypackage',parent_package,top_path)
    return config

if __name__ == "__main__":
    from numpy.distutils.core import setup
    #setup(**configuration(top_path='').todict())
    setup(configuration=configuration)
```

The arguments of the `configuration` function specify the name of parent SciPy package (`parent_package`) and the directory location of the main `setup.py` script (`top_path`). These arguments, along with the name of the current package, should be passed to the `Configuration` constructor.

The `Configuration` constructor has a fourth optional argument, `package_path`, that can be used when package files are located in a different location than the directory of the `setup.py` file.

Remaining `Configuration` arguments are all keyword arguments that will be used to initialize attributes of `Configuration` instance. Usually, these keywords are the same as the ones that `setup(..)` function would expect, for example, `packages`, `ext_modules`, `data_files`, `include_dirs`, `libraries`, `headers`, `scripts`, `package_dir`, etc. However, the direct specification of these keywords is not recommended as the content of these keyword arguments will not be processed or checked for the consistency of SciPy building system.

Finally, `Configuration` has `.todict()` method that returns all the configuration data as a dictionary suitable for passing on to the `setup(..)` function.

`Configuration` instance attributes

In addition to attributes that can be specified via keyword arguments to `Configuration` constructor, `Configuration` instance (let us denote as `config`) has the following attributes that can be useful in writing setup scripts:

- `config.name` - full name of the current package. The names of parent packages can be extracted as `config.name.split('.')`.
- `config.local_path` - path to the location of current `setup.py` file.
- `config.top_path` - path to the location of main `setup.py` file.

`Configuration` instance methods

- `config.todict()` — returns configuration dictionary suitable for passing to `numpy.distutils.core.setup(..)` function.
- `config.paths(*paths) --- applies ``glob.glob(..)` to items of `paths` if necessary. Fixes `paths` item that is relative to `config.local_path`.
- `config.get_subpackage(subpackage_name,subpackage_path=None)` — returns a list of subpackage configurations. Subpackage is looked in the current directory under the name `subpackage_name` but the path can be specified also via optional `subpackage_path` argument. If `subpackage_name` is specified as `None` then the subpackage name will be taken the basename of `subpackage_path`. Any `*` used for subpackage names are expanded as wildcards.
- `config.add_subpackage(subpackage_name,subpackage_path=None)` — add SciPy subpackage configuration to the current one. The meaning and usage of arguments is explained above, see `config.get_subpackage()` method.
- `config.add_data_files(*files)` — prepend `files` to `data_files` list. If `files` item is a tuple then its first element defines the suffix of where data files are copied relative to package installation directory and the second element specifies the path to data files. By default data files are copied under package installation directory. For example,

```
config.add_data_files('foo.dat',
                      ('fun',['gun.dat','nun/pun.dat','/tmp/sun.dat']),
                      'bar/car.dat'.
                      '/full/path/to/can.dat',
                      )
```

  will install data files to the following locations

```
<installation path of config.name package>/
  foo.dat
  fun/
    gun.dat
    pun.dat
    sun.dat
  bar/
    car.dat
  can.dat
```

  Path to data files can be a function taking no arguments and returning path(s) to data files – this is a useful when data files are generated while building the package. (XXX: explain the step when this function are called exactly)

- `config.add_data_dir(data_path)` — add directory `data_path` recursively to `data_files`. The whole directory tree starting at `data_path` will be copied under package installation directory. If `data_path` is a tuple then its first element defines the suffix of where data files are copied relative to package installation directory

and the second element specifies the path to data directory. By default, data directory are copied under package installation directory under the basename of `data_path`. For example,

```
config.add_data_dir('fun')  # fun/ contains foo.dat bar/car.dat
config.add_data_dir(('sun','fun'))
config.add_data_dir(('gun','/full/path/to/fun'))
```

will install data files to the following locations

```
<installation path of config.name package>/
  fun/
     foo.dat
     bar/
        car.dat
  sun/
     foo.dat
     bar/
        car.dat
  gun/
     foo.dat
     bar/
        car.dat
```

- `config.add_include_dirs(*paths)` — prepend `paths` to `include_dirs` list. This list will be visible to all extension modules of the current package.
- `config.add_headers(*files)` — prepend `files` to `headers` list. By default, headers will be installed under `<prefix>/include/pythonX.X/<config.name.replace('.','/')>/` directory. If `files` item is a tuple then it's first argument specifies the installation suffix relative to `<prefix>/include/pythonX.X/` path. This is a Python distutils method; its use is discouraged for NumPy and SciPy in favour of `config.add_data_files(*files)`.
- `config.add_scripts(*files)` — prepend `files` to `scripts` list. Scripts will be installed under `<prefix>/bin/` directory.
- `config.add_extension(name,sources,**kw)` — create and add an `Extension` instance to `ext_modules` list. The first argument `name` defines the name of the extension module that will be installed under `config.name` package. The second argument is a list of sources. `add_extension` method takes also keyword arguments that are passed on to the `Extension` constructor. The list of allowed keywords is the following: `include_dirs`, `define_macros`, `undef_macros`, `library_dirs`, `libraries`, `runtime_library_dirs`, `extra_objects`, `extra_compile_args`, `extra_link_args`, `export_symbols`, `swig_opts`, `depends`, `language`, `f2py_options`, `module_dirs`, `extra_info`, `extra_f77_compile_args`, `extra_f90_compile_args`.

  Note that `config.paths` method is applied to all lists that may contain paths. `extra_info` is a dictionary or a list of dictionaries that content will be appended to keyword arguments. The list `depends` contains paths to files or directories that the sources of the extension module depend on. If any path in the `depends` list is newer than the extension module, then the module will be rebuilt.

  The list of sources may contain functions ('source generators') with a pattern `def <funcname>(ext, build_dir): return <source(s) or None>`. If `funcname` returns `None`, no sources are generated. And if the `Extension` instance has no sources after processing all source generators, no extension module will be built. This is the recommended way to conditionally define extension modules. Source generator functions are called by the `build_src` sub-command of `numpy.distutils`.

  For example, here is a typical source generator function:

```
def generate_source(ext,build_dir):
    import os
    from distutils.dep_util import newer
    target = os.path.join(build_dir,'somesource.c')
    if newer(target,__file__):
        # create target file
    return target
```

The first argument contains the Extension instance that can be useful to access its attributes like `depends`, `sources`, etc. lists and modify them during the building process. The second argument gives a path to a build directory that must be used when creating files to a disk.

- `config.add_library(name, sources, **build_info)` — add a library to `libraries` list. Allowed keywords arguments are `depends`, `macros`, `include_dirs`, `extra_compiler_args`, `f2py_options`, `extra_f77_compile_args`, `extra_f90_compile_args`. See `.add_extension()` method for more information on arguments.
- `config.have_f77c()` — return True if Fortran 77 compiler is available (read: a simple Fortran 77 code compiled successfully).
- `config.have_f90c()` — return True if Fortran 90 compiler is available (read: a simple Fortran 90 code compiled successfully).
- `config.get_version()` — return version string of the current package, `None` if version information could not be detected. This methods scans files `__version__.py`, `<packagename>_version.py`, `version.py`, `__svn_version__.py` for string variables `version`, `__version__`, `<packagename>_version`.
- `config.make_svn_version_py()` — appends a data function to `data_files` list that will generate `__svn_version__.py` file to the current package directory. The file will be removed from the source directory when Python exits.
- `config.get_build_temp_dir()` — return a path to a temporary directory. This is the place where one should build temporary files.
- `config.get_distribution()` — return distutils `Distribution` instance.
- `config.get_config_cmd()` — returns `numpy.distutils` config command instance.
- `config.get_info(*names)` —

Conversion of `.src` files using templates

NumPy distutils supports automatic conversion of source files named <somefile>.src. This facility can be used to maintain very similar code blocks requiring only simple changes between blocks. During the build phase of setup, if a template file named <somefile>.src is encountered, a new file named <somefile> is constructed from the template and placed in the build directory to be used instead. Two forms of template conversion are supported. The first form occurs for files named <file>.ext.src where ext is a recognized Fortran extension (f, f90, f95, f77, for, ftn, pyf). The second form is used for all other cases.

Fortran files

This template converter will replicate all **function** and **subroutine** blocks in the file with names that contain '<…>' according to the rules in '<…>'. The number of comma-separated words in '<…>' determines the number of times the block is repeated. What these words are indicates what that repeat rule, '<…>', should be replaced with in each block. All of the repeat rules in a block must contain the same number of comma-separated words indicating the number of times that block should be repeated. If the word in the repeat rule needs a comma, leftarrow, or rightarrow, then prepend it with a backslash ' '. If a word in the repeat rule matches ' \<index>' then it will be replaced with the <index>-th word in the same repeat specification. There are two forms for the repeat rule: named and short.

Named repeat rule

A named repeat rule is useful when the same set of repeats must be used several times in a block. It is specified using <rule1=item1, item2, item3,…, itemN>, where N is the number of times the block should be repeated. On each repeat of the block, the entire expression, '<…>' will be replaced first with item1, and then with item2, and so forth until N repeats are accomplished. Once a named repeat specification has been introduced, the same repeat rule may be used **in the current block** by referring only to the name (i.e. <rule1>).

Short repeat rule

A short repeat rule looks like <item1, item2, item3, …, itemN>. The rule specifies that the entire expression, '<…>' should be replaced first with item1, and then with item2, and so forth until N repeats are accomplished.

Pre-defined names

The following predefined named repeat rules are available:

- <prefix=s,d,c,z>
- <_c=s,d,c,z>
- <_t=real, double precision, complex, double complex>
- <ftype=real, double precision, complex, double complex>
- <ctype=float, double, complex_float, complex_double>
- <ftypereal=float, double precision, \0, \1>
- <ctypereal=float, double, \0, \1>

Other files

Non-Fortran files use a separate syntax for defining template blocks that should be repeated using a variable expansion similar to the named repeat rules of the Fortran-specific repeats.

NumPy Distutils preprocesses C source files (extension: `.c.src`) written in a custom templating language to generate C code. The `@` symbol is used to wrap macro-style variables to empower a string substitution mechanism that might describe (for instance) a set of data types.

The template language blocks are delimited by `/**begin repeat` and `/**end repeat**/` lines, which may also be nested using consecutively numbered delimiting lines such as `/**begin repeat1` and `/**end repeat1**/`:

1. `/**begin repeat` on a line by itself marks the beginning of a segment that should be repeated.
2. Named variable expansions are defined using `#name=item1, item2, item3, ..., itemN#` and placed on successive lines. These variables are replaced in each repeat block with corresponding word. All named variables in the same repeat block must define the same number of words.

3. In specifying the repeat rule for a named variable, `item*N` is short- hand for `item, item, ..., item` repeated N times. In addition, parenthesis in combination with `*N` can be used for grouping several items that should be repeated. Thus, `#name=(item1, item2)*4#` is equivalent to `#name=item1, item2, item1, item2, item1, item2, item1, item2#`.
4. `*/` on a line by itself marks the end of the variable expansion naming. The next line is the first line that will be repeated using the named rules.
5. Inside the block to be repeated, the variables that should be expanded are specified as `@name@`.
6. `/**end repeat**/` on a line by itself marks the previous line as the last line of the block to be repeated.
7. A loop in the NumPy C source code may have a `@TYPE@` variable, targeted for string substitution, which is preprocessed to a number of otherwise identical loops with several strings such as `INT`, `LONG`, `UINT`, `ULONG`. The `@TYPE@` style syntax thus reduces code duplication and maintenance burden by mimicking languages that have generic type support.

The above rules may be clearer in the following template source example:

```
/* TIMEDELTA to non-float types */

/**begin repeat
 *
 * #TOTYPE = BYTE, UBYTE, SHORT, USHORT, INT, UINT, LONG, ULONG,
 *           LONGLONG, ULONGLONG, DATETIME,
 *           TIMEDELTA#
 * #totype = npy_byte, npy_ubyte, npy_short, npy_ushort, npy_int, npy_uint,
 *           npy_long, npy_ulong, npy_longlong, npy_ulonglong,
 *           npy_datetime, npy_timedelta#
 */

/**begin repeat1
 *
 * #FROMTYPE = TIMEDELTA#
 * #fromtype = npy_timedelta#
 */
static void
@FROMTYPE@_to_@TOTYPE@(void *input, void *output, npy_intp n,
        void *NPY_UNUSED(aip), void *NPY_UNUSED(aop))
{
    const @fromtype@ *ip = input;
    @totype@ *op = output;

    while (n--) {
        *op++ = (@totype@)*ip++;
    }
}
/**end repeat1**/

/**end repeat**/
```

The preprocessing of generically-typed C source files (whether in NumPy proper or in any third party package using NumPy Distutils) is performed by conv_template.py. The type-specific C files generated (extension: `.c`) by these modules during the build process are ready to be compiled. This form of generic typing is also supported for C header files (preprocessed to produce `.h` files).

Useful functions in `numpy.distutils.misc_util`

- `get_numpy_include_dirs()` — return a list of NumPy base include directories. NumPy base include directories contain header files such as `numpy/arrayobject.h`, `numpy/funcobject.h` etc. For installed NumPy the returned list has length 1 but when building NumPy the list may contain more directories, for example, a path to `config.h` file that `numpy/base/setup.py` file generates and is used by `numpy` header files.
- `append_path(prefix,path)` — smart append `path` to `prefix`.
- `gpaths(paths, local_path='')` — apply glob to paths and prepend `local_path` if needed.
- `njoin(*path)` — join pathname components + convert `/`-separated path to `os.sep`-separated path and resolve `..`, `.` from paths. Ex. `njoin('a',['b','./c'],'..','g') -> os.path.join('a','b','g')`.
- `minrelpath(path)` — resolves dots in `path`.
- `rel_path(path, parent_path)` — return `path` relative to `parent_path`.
- `def get_cmd(cmdname,_cache={})` — returns `numpy.distutils` command instance.
- `all_strings(lst)`
- `has_f_sources(sources)`
- `has_cxx_sources(sources)`
- `filter_sources(sources)` — return `c_sources, cxx_sources, f_sources, fmodule_sources`
- `get_dependencies(sources)`
- `is_local_src_dir(directory)`
- `get_ext_source_files(ext)`
- `get_script_files(scripts)`
- `get_lib_source_files(lib)`
- `get_data_files(data)`
- `dot_join(*args)` — join non-zero arguments with a dot.
- `get_frame(level=0)` — return frame object from call stack with given level.
- `cyg2win32(path)`
- `mingw32()` — return `True` when using mingw32 environment.
- `terminal_has_colors(), red_text(s), green_text(s), yellow_text(s), blue_text(s), cyan_text(s)`
- `get_path(mod_name,parent_path=None)` — return path of a module relative to parent_path when given. Handles also `__main__` and `__builtin__` modules.
- `allpath(name)` — replaces `/` with `os.sep` in `name`.
- `cxx_ext_match`, `fortran_ext_match`, `f90_ext_match`, `f90_module_name_match`

`numpy.distutils.system_info` module

- `get_info(name,notfound_action=0)`
- `combine_paths(*args,**kws)`
- `show_all()`

`numpy.distutils.cpuinfo` module

- `cpuinfo`

`numpy.distutils.log` module

- `set_verbosity(v)`

`numpy.distutils.exec_command` module

- `get_pythonexe()`
- `find_executable(exe, path=None)`
- `exec_command( command, execute_in='', use_shell=None, use_tee=None, **env )`

3.7.4 The `__init__.py` file

The header of a typical SciPy `__init__.py` is:

```
"""
Package docstring, typically with a brief description and function listing.
"""

# import functions into module namespace
from .subpackage import *
...

__all__ = [s for s in dir() if not s.startswith('_')]

from numpy.testing import Tester
test = Tester().test
bench = Tester().bench
```

3.7.5 Extra features in NumPy Distutils

Specifying config_fc options for libraries in setup.py script

It is possible to specify config_fc options in setup.py scripts. For example, using:

```
config.add_library('library',
                   sources=[...],
                   config_fc={'noopt':(__file__,1)})
```

will compile the `library` sources without optimization flags.

It's recommended to specify only those config_fc options in such a way that are compiler independent.

Getting extra Fortran 77 compiler options from source

Some old Fortran codes need special compiler options in order to work correctly. In order to specify compiler options per source file, `numpy.distutils` Fortran compiler looks for the following pattern:

```
CF77FLAGS(<fcompiler type>) = <fcompiler f77flags>
```

in the first 20 lines of the source and use the `f77flags` for specified type of the fcompiler (the first character `C` is optional).

TODO: This feature can be easily extended for Fortran 90 codes as well. Let us know if you would need such a feature.

3.8 NumPy and SWIG

Introduction

The Simple Wrapper and Interface Generator (or SWIG) is a powerful tool for generating wrapper code for interfacing to a wide variety of scripting languages. SWIG can parse header files, and using only the code prototypes, create an interface to the target language. But SWIG is not omnipotent. For example, it cannot know from the prototype:

```
double rms(double* seq, int n);
```

what exactly `seq` is. Is it a single value to be altered in-place? Is it an array, and if so what is its length? Is it input-only? Output-only? Input-output? SWIG cannot determine these details, and does not attempt to do so.

If we designed `rms`, we probably made it a routine that takes an input-only array of length `n` of `double` values called `seq` and returns the root mean square. The default behavior of SWIG, however, will be to create a wrapper function that compiles, but is nearly impossible to use from the scripting language in the way the C routine was intended.

For Python, the preferred way of handling contiguous (or technically, *strided*) blocks of homogeneous data is with NumPy, which provides full object-oriented access to multidimensial arrays of data. Therefore, the most logical Python interface for the `rms` function would be (including doc string):

```
def rms(seq):
    """
    rms: return the root mean square of a sequence
    rms(numpy.ndarray) -> double
    rms(list) -> double
    rms(tuple) -> double
    """
```

where `seq` would be a NumPy array of `double` values, and its length `n` would be extracted from `seq` internally before being passed to the C routine. Even better, since NumPy supports construction of arrays from arbitrary Python sequences, `seq` itself could be a nearly arbitrary sequence (so long as each element can be converted to a `double`) and the wrapper code would internally convert it to a NumPy array before extracting its data and length.

SWIG allows these types of conversions to be defined via a mechanism called *typemaps*. This document provides information on how to use `numpy.i`, a SWIG interface file that defines a series of typemaps intended to make the type of array-related conversions described above relatively simple to implement. For example, suppose that the `rms` function prototype defined above was in a header file named `rms.h`. To obtain the Python interface discussed above, your SWIG interface file would need the following:

```
%{
#define SWIG_FILE_WITH_INIT
#include "rms.h"
%}

%include "numpy.i"

%init %{
import_array();
%}

%apply (double* IN_ARRAY1, int DIM1) {(double* seq, int n)};
%include "rms.h"
```

Typemaps are keyed off a list of one or more function arguments, either by type or by type and name. We will refer to such lists as *signatures*. One of the many typemaps defined by `numpy.i` is used above and has the signature `(double* IN_ARRAY1, int DIM1)`. The argument names are intended to suggest that the `double*` argument is an input array of one dimension and that the `int` represents the size of that dimension. This is precisely the pattern in the `rms` prototype.

Most likely, no actual prototypes to be wrapped will have the argument names `IN_ARRAY1` and `DIM1`. We use the SWIG `%apply` directive to apply the typemap for one-dimensional input arrays of type `double` to the actual prototype used by `rms`. Using `numpy.i` effectively, therefore, requires knowing what typemaps are available and what they do.

A SWIG interface file that includes the SWIG directives given above will produce wrapper code that looks something like:

```
 1 PyObject *_wrap_rms(PyObject *args) {
 2   PyObject *resultobj = 0;
 3   double *arg1 = (double *) 0 ;
 4   int arg2 ;
 5   double result;
 6   PyArrayObject *array1 = NULL ;
 7   int is_new_object1 = 0 ;
 8   PyObject * obj0 = 0 ;
 9
10   if (!PyArg_ParseTuple(args,(char *)"O:rms",&obj0)) SWIG_fail;
11   {
12     array1 = obj_to_array_contiguous_allow_conversion(
13                  obj0, NPY_DOUBLE, &is_new_object1);
14     npy_intp size[1] = {
15       -1
16     };
17     if (!array1 || !require_dimensions(array1, 1) ||
18         !require_size(array1, size, 1)) SWIG_fail;
19     arg1 = (double*) array1->data;
20     arg2 = (int) array1->dimensions[0];
21   }
22   result = (double)rms(arg1,arg2);
23   resultobj = SWIG_From_double((double)(result));
24   {
25     if (is_new_object1 && array1) Py_DECREF(array1);
26   }
27   return resultobj;
28 fail:
29   {
30     if (is_new_object1 && array1) Py_DECREF(array1);
```

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```
31   }
32   return NULL;
33 }
```

The typemaps from `numpy.i` are responsible for the following lines of code: 12–20, 25 and 30. Line 10 parses the input to the `rms` function. From the format string `"O:rms"`, we can see that the argument list is expected to be a single Python object (specified by the `O` before the colon) and whose pointer is stored in `obj0`. A number of functions, supplied by `numpy.i`, are called to make and check the (possible) conversion from a generic Python object to a NumPy array. These functions are explained in the section *Helper Functions*, but hopefully their names are self-explanatory. At line 12 we use `obj0` to construct a NumPy array. At line 17, we check the validity of the result: that it is non-null and that it has a single dimension of arbitrary length. Once these states are verified, we extract the data buffer and length in lines 19 and 20 so that we can call the underlying C function at line 22. Line 25 performs memory management for the case where we have created a new array that is no longer needed.

This code has a significant amount of error handling. Note the `SWIG_fail` is a macro for `goto fail`, referring to the label at line 28. If the user provides the wrong number of arguments, this will be caught at line 10. If construction of the NumPy array fails or produces an array with the wrong number of dimensions, these errors are caught at line 17. And finally, if an error is detected, memory is still managed correctly at line 30.

Note that if the C function signature was in a different order:

```
double rms(int n, double* seq);
```

that SWIG would not match the typemap signature given above with the argument list for `rms`. Fortunately, `numpy.i` has a set of typemaps with the data pointer given last:

```
%apply (int DIM1, double* IN_ARRAY1) {(int n, double* seq)};
```

This simply has the effect of switching the definitions of `arg1` and `arg2` in lines 3 and 4 of the generated code above, and their assignments in lines 19 and 20.

Using numpy.i

The `numpy.i` file is currently located in the `tools/swig` sub-directory under the `numpy` installation directory. Typically, you will want to copy it to the directory where you are developing your wrappers.

A simple module that only uses a single SWIG interface file should include the following:

```
%{
#define SWIG_FILE_WITH_INIT
%}
%include "numpy.i"
%init %{
import_array();
%}
```

Within a compiled Python module, `import_array()` should only get called once. This could be in a C/C++ file that you have written and is linked to the module. If this is the case, then none of your interface files should `#define SWIG_FILE_WITH_INIT` or call `import_array()`. Or, this initialization call could be in a wrapper file generated by SWIG from an interface file that has the `%init` block as above. If this is the case, and you have more than one SWIG interface file, then only one interface file should `#define SWIG_FILE_WITH_INIT` and call `import_array()`.

Available typemaps

The typemap directives provided by `numpy.i` for arrays of different data types, say `double` and `int`, and dimensions of different types, say `int` or `long`, are identical to one another except for the C and NumPy type specifications. The typemaps are therefore implemented (typically behind the scenes) via a macro:

```
%numpy_typemaps(DATA_TYPE, DATA_TYPECODE, DIM_TYPE)
```

that can be invoked for appropriate `(DATA_TYPE, DATA_TYPECODE, DIM_TYPE)` triplets. For example:

```
%numpy_typemaps(double, NPY_DOUBLE, int)
%numpy_typemaps(int,    NPY_INT   , int)
```

The `numpy.i` interface file uses the `%numpy_typemaps` macro to implement typemaps for the following C data types and `int` dimension types:

- `signed char`
- `unsigned char`
- `short`
- `unsigned short`
- `int`
- `unsigned int`
- `long`
- `unsigned long`
- `long long`
- `unsigned long long`
- `float`
- `double`

In the following descriptions, we reference a generic `DATA_TYPE`, which could be any of the C data types listed above, and `DIM_TYPE` which should be one of the many types of integers.

The typemap signatures are largely differentiated on the name given to the buffer pointer. Names with `FARRAY` are for Fortran-ordered arrays, and names with `ARRAY` are for C-ordered (or 1D arrays).

Input Arrays

Input arrays are defined as arrays of data that are passed into a routine but are not altered in-place or returned to the user. The Python input array is therefore allowed to be almost any Python sequence (such as a list) that can be converted to the requested type of array. The input array signatures are

1D:

- `( DATA_TYPE IN_ARRAY1[ANY] )`
- `( DATA_TYPE* IN_ARRAY1, int DIM1 )`
- `( int DIM1, DATA_TYPE* IN_ARRAY1 )`

2D:

- `( DATA_TYPE IN_ARRAY2[ANY][ANY] )`
- `( DATA_TYPE* IN_ARRAY2, int DIM1, int DIM2 )`

- `( int DIM1, int DIM2, DATA_TYPE* IN_ARRAY2 )`
- `( DATA_TYPE* IN_FARRAY2, int DIM1, int DIM2 )`
- `( int DIM1, int DIM2, DATA_TYPE* IN_FARRAY2 )`

3D:

- `( DATA_TYPE IN_ARRAY3[ANY][ANY][ANY] )`
- `( DATA_TYPE* IN_ARRAY3, int DIM1, int DIM2, int DIM3 )`
- `( int DIM1, int DIM2, int DIM3, DATA_TYPE* IN_ARRAY3 )`
- `( DATA_TYPE* IN_FARRAY3, int DIM1, int DIM2, int DIM3 )`
- `( int DIM1, int DIM2, int DIM3, DATA_TYPE* IN_FARRAY3 )`

4D:

- `(DATA_TYPE IN_ARRAY4[ANY][ANY][ANY][ANY])`
- `(DATA_TYPE* IN_ARRAY4, DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4)`
- `(DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, , DIM_TYPE DIM4, DATA_TYPE* IN_ARRAY4)`
- `(DATA_TYPE* IN_FARRAY4, DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4)`
- `(DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4, DATA_TYPE* IN_FARRAY4)`

The first signature listed, `( DATA_TYPE IN_ARRAY[ANY] )` is for one-dimensional arrays with hard-coded dimensions. Likewise, `( DATA_TYPE IN_ARRAY2[ANY][ANY] )` is for two-dimensional arrays with hard-coded dimensions, and similarly for three-dimensional.

In-Place Arrays

In-place arrays are defined as arrays that are modified in-place. The input values may or may not be used, but the values at the time the function returns are significant. The provided Python argument must therefore be a NumPy array of the required type. The in-place signatures are

1D:

- `( DATA_TYPE INPLACE_ARRAY1[ANY] )`
- `( DATA_TYPE* INPLACE_ARRAY1, int DIM1 )`
- `( int DIM1, DATA_TYPE* INPLACE_ARRAY1 )`

2D:

- `( DATA_TYPE INPLACE_ARRAY2[ANY][ANY] )`
- `( DATA_TYPE* INPLACE_ARRAY2, int DIM1, int DIM2 )`
- `( int DIM1, int DIM2, DATA_TYPE* INPLACE_ARRAY2 )`
- `( DATA_TYPE* INPLACE_FARRAY2, int DIM1, int DIM2 )`
- `( int DIM1, int DIM2, DATA_TYPE* INPLACE_FARRAY2 )`

3D:

- `( DATA_TYPE INPLACE_ARRAY3[ANY][ANY][ANY] )`

- `( DATA_TYPE* INPLACE_ARRAY3, int DIM1, int DIM2, int DIM3 )`
- `( int DIM1, int DIM2, int DIM3, DATA_TYPE* INPLACE_ARRAY3 )`
- `( DATA_TYPE* INPLACE_FARRAY3, int DIM1, int DIM2, int DIM3 )`
- `( int DIM1, int DIM2, int DIM3, DATA_TYPE* INPLACE_FARRAY3 )`

4D:

- `(DATA_TYPE INPLACE_ARRAY4[ANY][ANY][ANY][ANY])`
- `(DATA_TYPE* INPLACE_ARRAY4, DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4)`
- `(DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, , DIM_TYPE DIM4, DATA_TYPE* INPLACE_ARRAY4)`
- `(DATA_TYPE* INPLACE_FARRAY4, DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4)`
- `(DIM_TYPE DIM1, DIM_TYPE DIM2, DIM_TYPE DIM3, DIM_TYPE DIM4, DATA_TYPE* INPLACE_FARRAY4)`

These typemaps now check to make sure that the `INPLACE_ARRAY` arguments use native byte ordering. If not, an exception is raised.

There is also a "flat" in-place array for situations in which you would like to modify or process each element, regardless of the number of dimensions. One example is a "quantization" function that quantizes each element of an array in-place, be it 1D, 2D or whatever. This form checks for continuity but allows either C or Fortran ordering.

ND:

- `(DATA_TYPE* INPLACE_ARRAY_FLAT, DIM_TYPE DIM_FLAT)`

Argout Arrays

Argout arrays are arrays that appear in the input arguments in C, but are in fact output arrays. This pattern occurs often when there is more than one output variable and the single return argument is therefore not sufficient. In Python, the conventional way to return multiple arguments is to pack them into a sequence (tuple, list, etc.) and return the sequence. This is what the argout typemaps do. If a wrapped function that uses these argout typemaps has more than one return argument, they are packed into a tuple or list, depending on the version of Python. The Python user does not pass these arrays in, they simply get returned. For the case where a dimension is specified, the python user must provide that dimension as an argument. The argout signatures are

1D:

- `( DATA_TYPE ARGOUT_ARRAY1[ANY] )`
- `( DATA_TYPE* ARGOUT_ARRAY1, int DIM1 )`
- `( int DIM1, DATA_TYPE* ARGOUT_ARRAY1 )`

2D:

- `( DATA_TYPE ARGOUT_ARRAY2[ANY][ANY] )`

3D:

- `( DATA_TYPE ARGOUT_ARRAY3[ANY][ANY][ANY] )`

4D:

- `( DATA_TYPE ARGOUT_ARRAY4[ANY][ANY][ANY][ANY] )`

These are typically used in situations where in C/C++, you would allocate a(n) array(s) on the heap, and call the function to fill the array(s) values. In Python, the arrays are allocated for you and returned as new array objects.

Note that we support `DATA_TYPE*` argout typemaps in 1D, but not 2D or 3D. This is because of a quirk with the SWIG typemap syntax and cannot be avoided. Note that for these types of 1D typemaps, the Python function will take a single argument representing `DIM1`.

Argout View Arrays

Argoutview arrays are for when your C code provides you with a view of its internal data and does not require any memory to be allocated by the user. This can be dangerous. There is almost no way to guarantee that the internal data from the C code will remain in existence for the entire lifetime of the NumPy array that encapsulates it. If the user destroys the object that provides the view of the data before destroying the NumPy array, then using that array may result in bad memory references or segmentation faults. Nevertheless, there are situations, working with large data sets, where you simply have no other choice.

The C code to be wrapped for argoutview arrays are characterized by pointers: pointers to the dimensions and double pointers to the data, so that these values can be passed back to the user. The argoutview typemap signatures are therefore

1D:

- `( DATA_TYPE** ARGOUTVIEW_ARRAY1, DIM_TYPE* DIM1 )`
- `( DIM_TYPE* DIM1, DATA_TYPE** ARGOUTVIEW_ARRAY1 )`

2D:

- `( DATA_TYPE** ARGOUTVIEW_ARRAY2, DIM_TYPE* DIM1, DIM_TYPE* DIM2 )`
- `( DIM_TYPE* DIM1, DIM_TYPE* DIM2, DATA_TYPE** ARGOUTVIEW_ARRAY2 )`
- `( DATA_TYPE** ARGOUTVIEW_FARRAY2, DIM_TYPE* DIM1, DIM_TYPE* DIM2 )`
- `( DIM_TYPE* DIM1, DIM_TYPE* DIM2, DATA_TYPE** ARGOUTVIEW_FARRAY2 )`

3D:

- `( DATA_TYPE** ARGOUTVIEW_ARRAY3, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3)`
- `( DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DATA_TYPE** ARGOUTVIEW_ARRAY3)`
- `( DATA_TYPE** ARGOUTVIEW_FARRAY3, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3)`
- `( DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DATA_TYPE** ARGOUTVIEW_FARRAY3)`

4D:

- `(DATA_TYPE** ARGOUTVIEW_ARRAY4, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4)`
- `(DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4, DATA_TYPE** ARGOUTVIEW_ARRAY4)`
- `(DATA_TYPE** ARGOUTVIEW_FARRAY4, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4)`
- `(DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4, DATA_TYPE** ARGOUTVIEW_FARRAY4)`

Note that arrays with hard-coded dimensions are not supported. These cannot follow the double pointer signatures of these typemaps.

Memory Managed Argout View Arrays

A recent addition to `numpy.i` are typemaps that permit argout arrays with views into memory that is managed.

1D:

- `(DATA_TYPE** ARGOUTVIEWM_ARRAY1, DIM_TYPE* DIM1)`
- `(DIM_TYPE* DIM1, DATA_TYPE** ARGOUTVIEWM_ARRAY1)`

2D:

- `(DATA_TYPE** ARGOUTVIEWM_ARRAY2, DIM_TYPE* DIM1, DIM_TYPE* DIM2)`
- `(DIM_TYPE* DIM1, DIM_TYPE* DIM2, DATA_TYPE** ARGOUTVIEWM_ARRAY2)`
- `(DATA_TYPE** ARGOUTVIEWM_FARRAY2, DIM_TYPE* DIM1, DIM_TYPE* DIM2)`
- `(DIM_TYPE* DIM1, DIM_TYPE* DIM2, DATA_TYPE** ARGOUTVIEWM_FARRAY2)`

3D:

- `(DATA_TYPE** ARGOUTVIEWM_ARRAY3, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3)`
- `(DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DATA_TYPE** ARGOUTVIEWM_ARRAY3)`
- `(DATA_TYPE** ARGOUTVIEWM_FARRAY3, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3)`
- `(DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DATA_TYPE** ARGOUTVIEWM_FARRAY3)`

4D:

- `(DATA_TYPE** ARGOUTVIEWM_ARRAY4, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4)`
- `(DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4, DATA_TYPE** ARGOUTVIEWM_ARRAY4)`
- `(DATA_TYPE** ARGOUTVIEWM_FARRAY4, DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4)`
- `(DIM_TYPE* DIM1, DIM_TYPE* DIM2, DIM_TYPE* DIM3, DIM_TYPE* DIM4, DATA_TYPE** ARGOUTVIEWM_FARRAY4)`

Output Arrays

The `numpy.i` interface file does not support typemaps for output arrays, for several reasons. First, C/C++ return arguments are limited to a single value. This prevents obtaining dimension information in a general way. Second, arrays with hard-coded lengths are not permitted as return arguments. In other words:

```
double[3] newVector(double x, double y, double z);
```

is not legal C/C++ syntax. Therefore, we cannot provide typemaps of the form:

```
%typemap(out) (TYPE[ANY]);
```

If you run into a situation where a function or method is returning a pointer to an array, your best bet is to write your own version of the function to be wrapped, either with `%extend` for the case of class methods or `%ignore` and `%rename` for the case of functions.

Other Common Types: bool

Note that C++ type `bool` is not supported in the list in the *Available Typemaps* section. NumPy bools are a single byte, while the C++ `bool` is four bytes (at least on my system). Therefore:

```
%numpy_typemaps(bool, NPY_BOOL, int)
```

will result in typemaps that will produce code that reference improper data lengths. You can implement the following macro expansion:

```
%numpy_typemaps(bool, NPY_UINT, int)
```

to fix the data length problem, and *Input Arrays* will work fine, but *In-Place Arrays* might fail type-checking.

Other Common Types: complex

Typemap conversions for complex floating-point types is also not supported automatically. This is because Python and NumPy are written in C, which does not have native complex types. Both Python and NumPy implement their own (essentially equivalent) `struct` definitions for complex variables:

```
/* Python */
typedef struct {double real; double imag;} Py_complex;

/* NumPy */
typedef struct {float  real, imag;} npy_cfloat;
typedef struct {double real, imag;} npy_cdouble;
```

We could have implemented:

```
%numpy_typemaps(Py_complex , NPY_CDOUBLE, int)
%numpy_typemaps(npy_cfloat , NPY_CFLOAT , int)
%numpy_typemaps(npy_cdouble, NPY_CDOUBLE, int)
```

which would have provided automatic type conversions for arrays of type `Py_complex`, `npy_cfloat` and `npy_cdouble`. However, it seemed unlikely that there would be any independent (non-Python, non-NumPy) application code that people would be using SWIG to generate a Python interface to, that also used these definitions for complex types. More likely, these application codes will define their own complex types, or in the case of C++, use `std::complex`. Assuming these data structures are compatible with Python and NumPy complex types, `%numpy_typemap` expansions as above (with the user's complex type substituted for the first argument) should work.

NumPy array scalars and SWIG

SWIG has sophisticated type checking for numerical types. For example, if your C/C++ routine expects an integer as input, the code generated by SWIG will check for both Python integers and Python long integers, and raise an overflow error if the provided Python integer is too big to cast down to a C integer. With the introduction of NumPy scalar arrays into your Python code, you might conceivably extract an integer from a NumPy array and attempt to pass this to a SWIG-wrapped C/C++ function that expects an `int`, but the SWIG type checking will not recognize the NumPy array scalar as an integer. (Often, this does in fact work – it depends on whether NumPy recognizes the integer type you are using as inheriting from the Python integer type on the platform you are using. Sometimes, this means that code that works on a 32-bit machine will fail on a 64-bit machine.)

If you get a Python error that looks like the following:

```
TypeError: in method 'MyClass_MyMethod', argument 2 of type 'int'
```

and the argument you are passing is an integer extracted from a NumPy array, then you have stumbled upon this problem. The solution is to modify the SWIG type conversion system to accept NumPy array scalars in addition to the standard integer types. Fortunately, this capability has been provided for you. Simply copy the file:

```
pyfragments.swg
```

to the working build directory for you project, and this problem will be fixed. It is suggested that you do this anyway, as it only increases the capabilities of your Python interface.

Why is There a Second File?

The SWIG type checking and conversion system is a complicated combination of C macros, SWIG macros, SWIG typemaps and SWIG fragments. Fragments are a way to conditionally insert code into your wrapper file if it is needed, and not insert it if not needed. If multiple typemaps require the same fragment, the fragment only gets inserted into your wrapper code once.

There is a fragment for converting a Python integer to a C `long`. There is a different fragment that converts a Python integer to a C `int`, that calls the routine defined in the `long` fragment. We can make the changes we want here by changing the definition for the `long` fragment. SWIG determines the active definition for a fragment using a "first come, first served" system. That is, we need to define the fragment for `long` conversions prior to SWIG doing it internally. SWIG allows us to do this by putting our fragment definitions in the file `pyfragments.swg`. If we were to put the new fragment definitions in `numpy.i`, they would be ignored.

Helper functions

The `numpy.i` file contains several macros and routines that it uses internally to build its typemaps. However, these functions may be useful elsewhere in your interface file. These macros and routines are implemented as fragments, which are described briefly in the previous section. If you try to use one or more of the following macros or functions, but your compiler complains that it does not recognize the symbol, then you need to force these fragments to appear in your code using:

```
%fragment("NumPy_Fragments");
```

in your SWIG interface file.

Macros

is_array(a)
: Evaluates as true if `a` is non-`NULL` and can be cast to a `PyArrayObject*`.

array_type(a)
: Evaluates to the integer data type code of `a`, assuming `a` can be cast to a `PyArrayObject*`.

array_numdims(a)
: Evaluates to the integer number of dimensions of `a`, assuming `a` can be cast to a `PyArrayObject*`.

array_dimensions(a)
: Evaluates to an array of type `npy_intp` and length `array_numdims(a)`, giving the lengths of all of the dimensions of `a`, assuming `a` can be cast to a `PyArrayObject*`.

array_size(a,i)
: Evaluates to the `i`-th dimension size of `a`, assuming `a` can be cast to a `PyArrayObject*`.

array_strides(a)
: Evaluates to an array of type `npy_intp` and length `array_numdims(a)`, giving the stridess of all of the dimensions of `a`, assuming `a` can be cast to a `PyArrayObject*`. A stride is the distance in bytes between an element and its immediate neighbor along the same axis.

array_stride(a,i)
Evaluates to the `i`-th stride of `a`, assuming `a` can be cast to a `PyArrayObject*`.

array_data(a)
Evaluates to a pointer of type `void*` that points to the data buffer of `a`, assuming `a` can be cast to a `PyArrayObject*`.

array_descr(a)
Returns a borrowed reference to the dtype property (`PyArray_Descr*`) of `a`, assuming `a` can be cast to a `PyArrayObject*`.

array_flags(a)
Returns an integer representing the flags of `a`, assuming `a` can be cast to a `PyArrayObject*`.

array_enableflags(a,f)
Sets the flag represented by `f` of `a`, assuming `a` can be cast to a `PyArrayObject*`.

array_is_contiguous(a)
Evaluates as true if `a` is a contiguous array. Equivalent to `(PyArray_ISCONTIGUOUS(a))`.

array_is_native(a)
Evaluates as true if the data buffer of `a` uses native byte order. Equivalent to `(PyArray_ISNOTSWAPPED(a))`.

array_is_fortran(a)
Evaluates as true if `a` is FORTRAN ordered.

Routines

pytype_string()
Return type: `const char*`

Arguments:

- `PyObject* py_obj`, a general Python object.

Return a string describing the type of `py_obj`.

typecode_string()
Return type: `const char*`

Arguments:

- `int typecode`, a NumPy integer typecode.

Return a string describing the type corresponding to the NumPy `typecode`.

type_match()
Return type: `int`

Arguments:

- `int actual_type`, the NumPy typecode of a NumPy array.
- `int desired_type`, the desired NumPy typecode.

Make sure that `actual_type` is compatible with `desired_type`. For example, this allows character and byte types, or int and long types, to match. This is now equivalent to `PyArray_EquivTypenums()`.

obj_to_array_no_conversion()
Return type: `PyArrayObject*`

Arguments:

- `PyObject* input`, a general Python object.
- `int typecode`, the desired NumPy typecode.

Cast `input` to a `PyArrayObject*` if legal, and ensure that it is of type `typecode`. If `input` cannot be cast, or the `typecode` is wrong, set a Python error and return `NULL`.

obj_to_array_allow_conversion()
Return type: `PyArrayObject*`

Arguments:

- `PyObject* input`, a general Python object.
- `int typecode`, the desired NumPy typecode of the resulting array.
- `int* is_new_object`, returns a value of 0 if no conversion performed, else 1.

Convert `input` to a NumPy array with the given `typecode`. On success, return a valid `PyArrayObject*` with the correct type. On failure, the Python error string will be set and the routine returns `NULL`.

make_contiguous()
Return type: `PyArrayObject*`

Arguments:

- `PyArrayObject* ary`, a NumPy array.
- `int* is_new_object`, returns a value of 0 if no conversion performed, else 1.
- `int min_dims`, minimum allowable dimensions.
- `int max_dims`, maximum allowable dimensions.

Check to see if `ary` is contiguous. If so, return the input pointer and flag it as not a new object. If it is not contiguous, create a new `PyArrayObject*` using the original data, flag it as a new object and return the pointer.

make_fortran()
Return type: `PyArrayObject*`

Arguments

- `PyArrayObject* ary`, a NumPy array.
- `int* is_new_object`, returns a value of 0 if no conversion performed, else 1.

Check to see if `ary` is Fortran contiguous. If so, return the input pointer and flag it as not a new object. If it is not Fortran contiguous, create a new `PyArrayObject*` using the original data, flag it as a new object and return the pointer.

obj_to_array_contiguous_allow_conversion()
Return type: `PyArrayObject*`

Arguments:

- `PyObject* input`, a general Python object.
- `int typecode`, the desired NumPy typecode of the resulting array.
- `int* is_new_object`, returns a value of 0 if no conversion performed, else 1.

Convert `input` to a contiguous `PyArrayObject*` of the specified type. If the input object is not a contiguous `PyArrayObject*`, a new one will be created and the new object flag will be set.

obj_to_array_fortran_allow_conversion()
Return type: `PyArrayObject*`

Arguments:

- `PyObject* input`, a general Python object.
- `int typecode`, the desired NumPy typecode of the resulting array.

- `int* is_new_object`, returns a value of 0 if no conversion performed, else 1.

Convert `input` to a Fortran contiguous `PyArrayObject*` of the specified type. If the input object is not a Fortran contiguous `PyArrayObject*`, a new one will be created and the new object flag will be set.

require_contiguous()
Return type: `int`

Arguments:

- `PyArrayObject* ary`, a NumPy array.

Test whether `ary` is contiguous. If so, return 1. Otherwise, set a Python error and return 0.

require_native()
Return type: `int`

Arguments:

- `PyArray_Object* ary`, a NumPy array.

Require that `ary` is not byte-swapped. If the array is not byte-swapped, return 1. Otherwise, set a Python error and return 0.

require_dimensions()
Return type: `int`

Arguments:

- `PyArrayObject* ary`, a NumPy array.
- `int exact_dimensions`, the desired number of dimensions.

Require `ary` to have a specified number of dimensions. If the array has the specified number of dimensions, return 1. Otherwise, set a Python error and return 0.

require_dimensions_n()
Return type: `int`

Arguments:

- `PyArrayObject* ary`, a NumPy array.
- `int* exact_dimensions`, an array of integers representing acceptable numbers of dimensions.
- `int n`, the length of `exact_dimensions`.

Require `ary` to have one of a list of specified number of dimensions. If the array has one of the specified number of dimensions, return 1. Otherwise, set the Python error string and return 0.

require_size()
Return type: `int`

Arguments:

- `PyArrayObject* ary`, a NumPy array.
- `npy_int* size`, an array representing the desired lengths of each dimension.
- `int n`, the length of `size`.

Require `ary` to have a specified shape. If the array has the specified shape, return 1. Otherwise, set the Python error string and return 0.

require_fortran()
Return type: `int`

Arguments:

- `PyArrayObject* ary`, a NumPy array.

Require the given `PyArrayObject` to be Fortran ordered. If the `PyArrayObject` is already Fortran ordered, do nothing. Else, set the Fortran ordering flag and recompute the strides.

Beyond the provided typemaps

There are many C or C++ array/NumPy array situations not covered by a simple `%include "numpy.i"` and subsequent `%apply` directives.

A Common Example

Consider a reasonable prototype for a dot product function:

```
double dot(int len, double* vec1, double* vec2);
```

The Python interface that we want is:

```
def dot(vec1, vec2):
    """
    dot(PyObject,PyObject) -> double
    """
```

The problem here is that there is one dimension argument and two array arguments, and our typemaps are set up for dimensions that apply to a single array (in fact, SWIG does not provide a mechanism for associating `len` with `vec2` that takes two Python input arguments). The recommended solution is the following:

```
%apply (int DIM1, double* IN_ARRAY1) {(int len1, double* vec1),
                                      (int len2, double* vec2)}
%rename (dot) my_dot;
%exception my_dot {
    $action
    if (PyErr_Occurred()) SWIG_fail;
}
%inline %{
double my_dot(int len1, double* vec1, int len2, double* vec2) {
    if (len1 != len2) {
        PyErr_Format(PyExc_ValueError,
                     "Arrays of lengths (%d,%d) given",
                     len1, len2);
        return 0.0;
    }
    return dot(len1, vec1, vec2);
}
%}
```

If the header file that contains the prototype for `double dot()` also contains other prototypes that you want to wrap, so that you need to `%include` this header file, then you will also need a `%ignore dot;` directive, placed after the `%rename` and before the `%include` directives. Or, if the function in question is a class method, you will want to use `%extend` rather than `%inline` in addition to `%ignore`.

A note on error handling: Note that `my_dot` returns a `double` but that it can also raise a Python error. The resulting wrapper function will return a Python float representation of 0.0 when the vector lengths do not match. Since this is not `NULL`, the Python interpreter will not know to check for an error. For this reason, we add the `%exception` directive above for `my_dot` to get the behavior we want (note that `$action` is a macro that gets expanded to a valid call to `my_dot`). In general, you will probably want to write a SWIG macro to perform this task.

Other Situations

There are other wrapping situations in which `numpy.i` may be helpful when you encounter them.

- In some situations, it is possible that you could use the `%numpy_typemaps` macro to implement typemaps for your own types. See the *Other Common Types: bool* or *Other Common Types: complex* sections for examples. Another situation is if your dimensions are of a type other than `int` (say `long` for example):

```
%numpy_typemaps(double, NPY_DOUBLE, long)
```

- You can use the code in `numpy.i` to write your own typemaps. For example, if you had a five-dimensional array as a function argument, you could cut-and-paste the appropriate four-dimensional typemaps into your interface file. The modifications for the fourth dimension would be trivial.
- Sometimes, the best approach is to use the `%extend` directive to define new methods for your classes (or overload existing ones) that take a `PyObject*` (that either is or can be converted to a `PyArrayObject*`) instead of a pointer to a buffer. In this case, the helper routines in `numpy.i` can be very useful.
- Writing typemaps can be a bit nonintuitive. If you have specific questions about writing SWIG typemaps for NumPy, the developers of `numpy.i` do monitor the Numpy-discussion and Swig-user mail lists.

A Final Note

When you use the `%apply` directive, as is usually necessary to use `numpy.i`, it will remain in effect until you tell SWIG that it shouldn't be. If the arguments to the functions or methods that you are wrapping have common names, such as `length` or `vector`, these typemaps may get applied in situations you do not expect or want. Therefore, it is always a good idea to add a `%clear` directive after you are done with a specific typemap:

```
%apply (double* IN_ARRAY1, int DIM1) {(double* vector, int length)}
%include "my_header.h"
%clear (double* vector, int length);
```

In general, you should target these typemap signatures specifically where you want them, and then clear them after you are done.

Summary

Out of the box, `numpy.i` provides typemaps that support conversion between NumPy arrays and C arrays:

- That can be one of 12 different scalar types: `signed char`, `unsigned char`, `short`, `unsigned short`, `int`, `unsigned int`, `long`, `unsigned long`, `long long`, `unsigned long long`, `float` and `double`.
- That support 74 different argument signatures for each data type, including:
  - One-dimensional, two-dimensional, three-dimensional and four-dimensional arrays.
  - Input-only, in-place, argout, argoutview, and memory managed argoutview behavior.
  - Hard-coded dimensions, data-buffer-then-dimensions specification, and dimensions-then-data-buffer specification.
  - Both C-ordering ("last dimension fastest") or Fortran-ordering ("first dimension fastest") support for 2D, 3D and 4D arrays.

The `numpy.i` interface file also provides additional tools for wrapper developers, including:

- A SWIG macro (`%numpy_typemaps`) with three arguments for implementing the 74 argument signatures for the user's choice of (1) C data type, (2) NumPy data type (assuming they match), and (3) dimension type.

- Fourteen C macros and fifteen C functions that can be used to write specialized typemaps, extensions, or inlined functions that handle cases not covered by the provided typemaps. Note that the macros and functions are coded specifically to work with the NumPy C/API regardless of NumPy version number, both before and after the deprecation of some aspects of the API after version 1.6.

3.8.1 Testing the numpy.i typemaps

Introduction

Writing tests for the `numpy.i` SWIG interface file is a combinatorial headache. At present, 12 different data types are supported, each with 74 different argument signatures, for a total of 888 typemaps supported "out of the box". Each of these typemaps, in turn, might require several unit tests in order to verify expected behavior for both proper and improper inputs. Currently, this results in more than 1,000 individual unit tests executed when `make test` is run in the `numpy/tools/swig` subdirectory.

To facilitate this many similar unit tests, some high-level programming techniques are employed, including C and SWIG macros, as well as Python inheritance. The purpose of this document is to describe the testing infrastructure employed to verify that the `numpy.i` typemaps are working as expected.

Testing organization

There are three independent testing frameworks supported, for one-, two-, and three-dimensional arrays respectively. For one-dimensional arrays, there are two C++ files, a header and a source, named:

```
Vector.h
Vector.cxx
```

that contain prototypes and code for a variety of functions that have one-dimensional arrays as function arguments. The file:

```
Vector.i
```

is a SWIG interface file that defines a python module `Vector` that wraps the functions in `Vector.h` while utilizing the typemaps in `numpy.i` to correctly handle the C arrays.

The `Makefile` calls `swig` to generate `Vector.py` and `Vector_wrap.cxx`, and also executes the `setup.py` script that compiles `Vector_wrap.cxx` and links together the extension module `_Vector.so` or `_Vector.dylib`, depending on the platform. This extension module and the proxy file `Vector.py` are both placed in a subdirectory under the `build` directory.

The actual testing takes place with a Python script named:

```
testVector.py
```

that uses the standard Python library module `unittest`, which performs several tests of each function defined in `Vector.h` for each data type supported.

Two-dimensional arrays are tested in exactly the same manner. The above description applies, but with `Matrix` substituted for `Vector`. For three-dimensional tests, substitute `Tensor` for `Vector`. For four-dimensional tests, substitute `SuperTensor` for `Vector`. For flat in-place array tests, substitute `Flat` for `Vector`. For the descriptions that follow, we will reference the `Vector` tests, but the same information applies to `Matrix`, `Tensor` and `SuperTensor` tests.

The command `make test` will ensure that all of the test software is built and then run all three test scripts.

Testing header files

`Vector.h` is a C++ header file that defines a C macro called `TEST_FUNC_PROTOS` that takes two arguments: `TYPE`, which is a data type name such as `unsigned int`; and `SNAME`, which is a short name for the same data type with no spaces, e.g. `uint`. This macro defines several function prototypes that have the prefix `SNAME` and have at least one argument that is an array of type `TYPE`. Those functions that have return arguments return a `TYPE` value.

`TEST_FUNC_PROTOS` is then implemented for all of the data types supported by `numpy.i`:

- `signed char`
- `unsigned char`
- `short`
- `unsigned short`
- `int`
- `unsigned int`
- `long`
- `unsigned long`
- `long long`
- `unsigned long long`
- `float`
- `double`

Testing source files

`Vector.cxx` is a C++ source file that implements compilable code for each of the function prototypes specified in `Vector.h`. It defines a C macro `TEST_FUNCS` that has the same arguments and works in the same way as `TEST_FUNC_PROTOS` does in `Vector.h`. `TEST_FUNCS` is implemented for each of the 12 data types as above.

Testing SWIG interface files

`Vector.i` is a SWIG interface file that defines python module `Vector`. It follows the conventions for using `numpy.i` as described in this chapter. It defines a SWIG macro `%apply_numpy_typemaps` that has a single argument `TYPE`. It uses the SWIG directive `%apply` to apply the provided typemaps to the argument signatures found in `Vector.h`. This macro is then implemented for all of the data types supported by `numpy.i`. It then does a `%include "Vector.h"` to wrap all of the function prototypes in `Vector.h` using the typemaps in `numpy.i`.

Testing Python scripts

After `make` is used to build the testing extension modules, `testVector.py` can be run to execute the tests. As with other scripts that use `unittest` to facilitate unit testing, `testVector.py` defines a class that inherits from `unittest.TestCase`:

```
class VectorTestCase(unittest.TestCase):
```

However, this class is not run directly. Rather, it serves as a base class to several other python classes, each one specific to a particular data type. The `VectorTestCase` class stores two strings for typing information:

self.typeStr
: A string that matches one of the `SNAME` prefixes used in `Vector.h` and `Vector.cxx`. For example, `"double"`.

self.typeCode
: A short (typically single-character) string that represents a data type in numpy and corresponds to `self.typeStr`. For example, if `self.typeStr` is `"double"`, then `self.typeCode` should be `"d"`.

Each test defined by the `VectorTestCase` class extracts the python function it is trying to test by accessing the `Vector` module's dictionary:

```
length = Vector.__dict__[self.typeStr + "Length"]
```

In the case of double precision tests, this will return the python function `Vector.doubleLength`.

We then define a new test case class for each supported data type with a short definition such as:

```
class doubleTestCase(VectorTestCase):
    def __init__(self, methodName="runTest"):
        VectorTestCase.__init__(self, methodName)
        self.typeStr  = "double"
        self.typeCode = "d"
```

Each of these 12 classes is collected into a `unittest.TestSuite`, which is then executed. Errors and failures are summed together and returned as the exit argument. Any non-zero result indicates that at least one test did not pass.

CHAPTER

FOUR

ACKNOWLEDGEMENTS

Large parts of this manual originate from Travis E. Oliphant's book Guide to NumPy (which generously entered Public Domain in August 2008). The reference documentation for many of the functions are written by numerous contributors and developers of NumPy.

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