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Chapter 5

Numeric Computing with Numpy

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Chapter Content

- ➢ Introduction to NumPy
- ➢ Why should use Numpy?
- ➢ Numpy Array
- ➢ Numpy Linear Algebra
- ➢ Numpy Matrix Library matlib
- ➢ I/O with Numpy

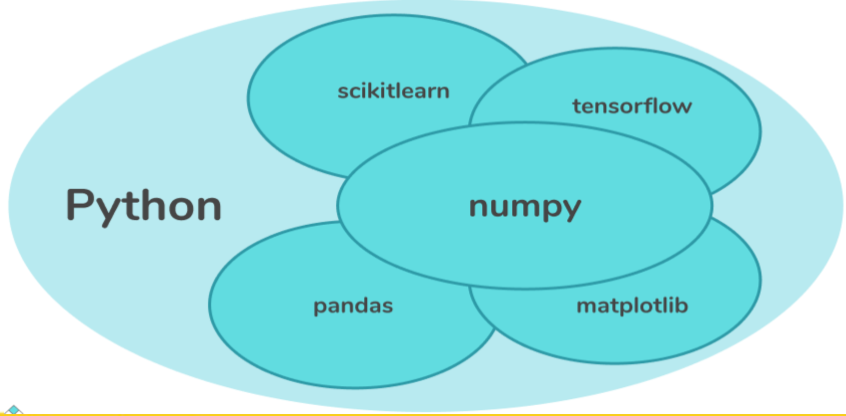
Introduction to NumPy

➔ NumPy is short for *Numerical Python*

➔ Array oriented computing

➔ Efficiently implemented multi-dimensional arrays

➔ Used for *scientific computing*.

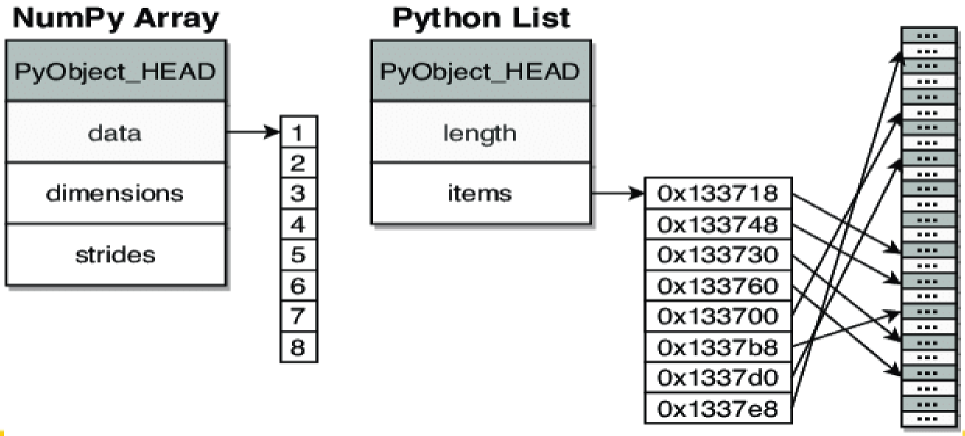


Why should we use Numpy?

➔ Convenient interface for working with ***multi-dimensional array*** data structures efficiently (`ndarray`).

➔ Less memory to store the data.

➔ High computational efficiency



Numpy Getting Started

- ➔ Installing Numpy: `pip install numpy`
- ➔ Import Numpy: `import numpy`
- ➔ Alias of Numpy: `import numpy as np`
- ➔ Check Numpy version: `np.__version__`

Numpy Data Types

→ supports a much greater variety of numerical types than Python does

Boolean	bool_
Integer	int_, intc, intp, int8, int16, int32, int64
Unsigned Integer	uint8, uint16, uint32, uint64
Float	float_, float 16, float32, float 64
Complex	complex_, complex64, complex128

Numpy Array

➔ ndarray (*N-Dimensional array*)

0-D Array

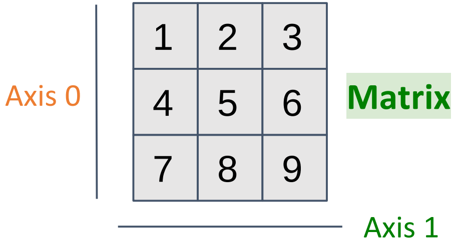

```
np.array(1)
```

1-D Array

Vector

```
np.array([1, 2, 3])
```

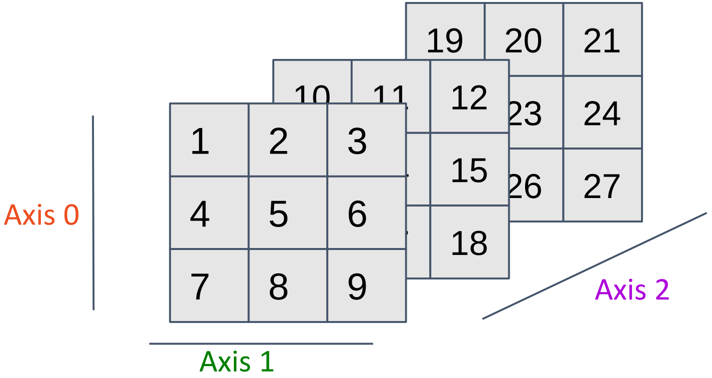
2-D Array



Matrix

```
np.array([[1, 2, 3],
          [4, 5, 6],
          [7, 8, 9]])
```

3-D Array




```
np.array([[[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, 27]]])
```

Numpy Array

- ✓ Numpy Array Creation
- ✓ Numpy Array Indexing
- ✓ Numpy Array Slicing
- ✓ Numpy Arithmetic Operations
- ✓ Numpy Arithmetic Functions
- ✓ Numpy Array Manipulation Functions
- ✓ Numpy Broadcasting
- ✓ Numpy Statistical Operations

Numpy Array Creation

➔ Using the function array()

```python
import numpy as np
arr = np.array([1, 2, 3, 4, 5])
```

➔ Converting from lists, tuples.

```python
list1 = [1, 2, 3, 4, 5]
arr = np.array(list1)
```

```python
tuple1 = (1, 2, 3, 4, 5)
arr = np.array(tuple1)
```

➔ Using special Numpy functions: empty(shape, dtype) , ones(shape, dtype), zeros(shape,dtype), arange(start,stop,step,dtype), random.random(size), full(shape, fill_value,dtype), eyes(nrow,[ncol],dtype).

```python
Ex: arr = np.empty(2, dtype=int)
        arr = np.zeros(2,
dtype=int)
```

Numpy Array Attributes

ndarray.shape

return the size of array

(3,3)

ndarray.ndim

return number of array dimension

2

ndarray.dtype

return data type of elements in the array

int64

1	2	3
4	5	6
7	8	9

ndarray.size

return number of elements in the array

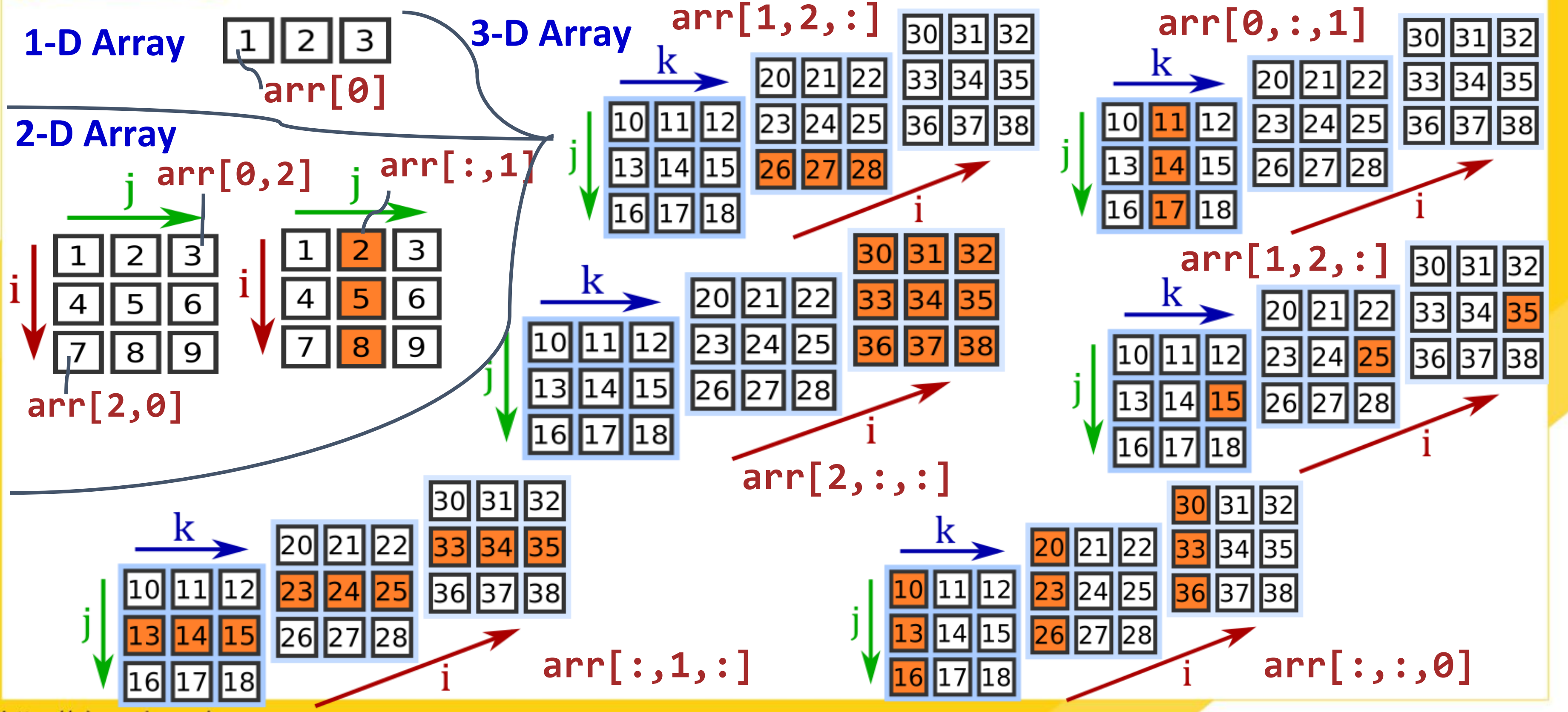
9

ndarray.itemsize

return the size (in bytes) of elements in the array

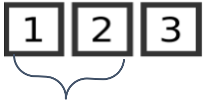
8

Numpy Array Indexing



Numpy Array Slicing

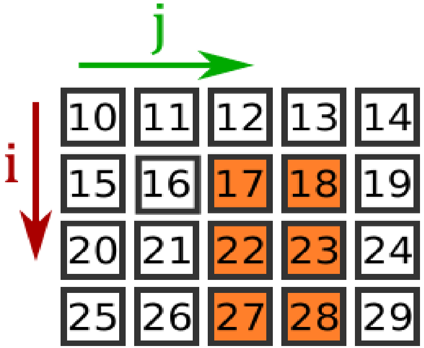
1-D Array



arr[:1]

[*start*:*end*]

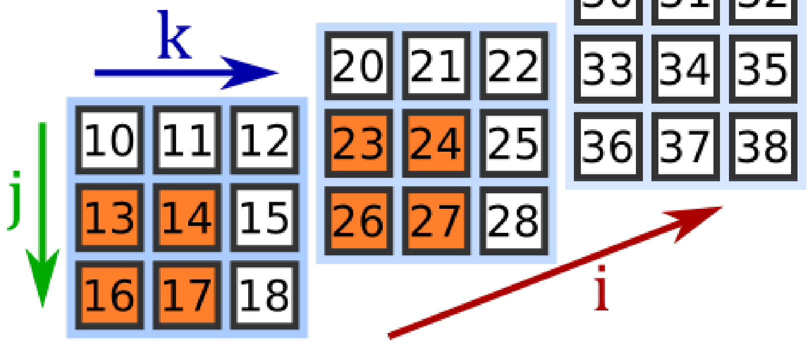
2-D Array



arr[1:,2:4]

3-D Array

arr[:2,1:,:2]



Numpy Arithmetic Operations

```python
import numpy as np
a = np.arange(9, dtype = np.float_).reshape(3,3)
b = np.array([10,10,10])
```

```
[[ 0, 1, 2]
[ 3, 4, 5 ]
[ 6, 7, 8 ]]
```

```
[10, 10, 10]
```

np.add (a,b)

```
[[ 10, 11, 12 ]
[ 13, 14, 15 ]
[ 16, 17 18 ]]
```

np.subtract (a,b)

```
[[ 10, 11, 12]
[ 13, 14, 15]
[ 16, 17, 18]]
```

np.multiply (a,b)

```
[[-10, -9, -8]
[-7, -6, -5]
[-4, -3, -2]]
```

np.divide (a,b)

```
[[ 0, 0.1, 0.2]
[ 0.3, 0.4, 0.5]
[ 0.6, 0.7, 0.8]]
```

Numpy Arithmetic Functions

```
import numpy as np
a = np.array([7,3,4,5,1])
b = np.array([3,4,5,6,7])
```

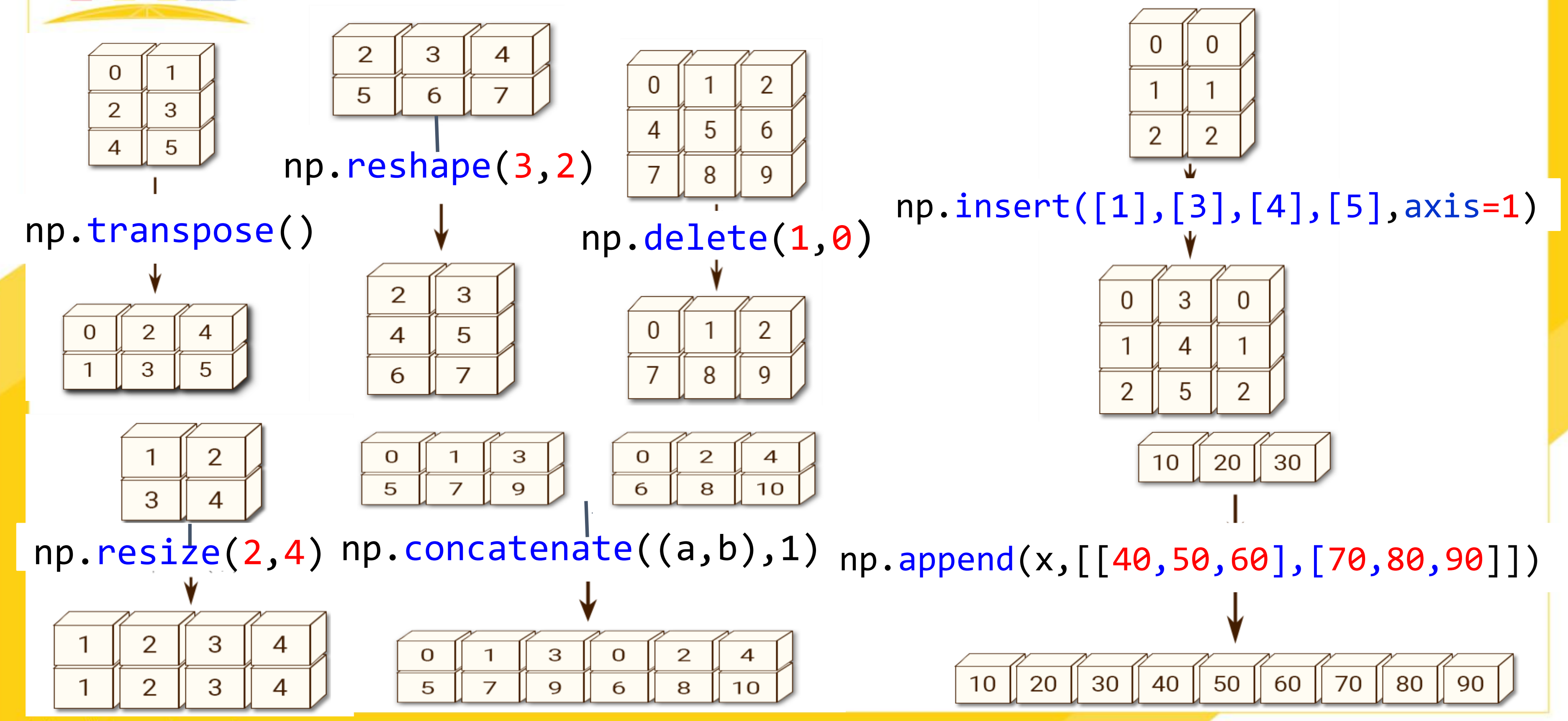
```
np.remainder (a,b)
```
⇨ [1, 3, 4, 5, 1]

```
np.mod (a,b)
```
⇨ [1, 3, 4, 5, 1]

```
np.power (a,b)
```
⇨ [343, 81,1024,15625, 1]

```
np.reciprocal (a)
```
⇨ [0, 0, 0, 0, 1]

Numpy Array Manipulation Functions



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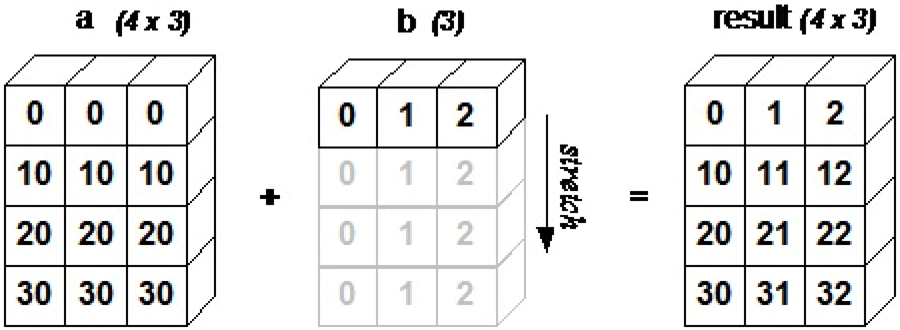
Numpy Broadcasting

➔ ***Broadcasting*** refers to how **numpy** treats arrays with different dimension during arithmetic operations which lead to certain constraints, the smaller array is broadcast across the larger array so that they have compatible shapes.

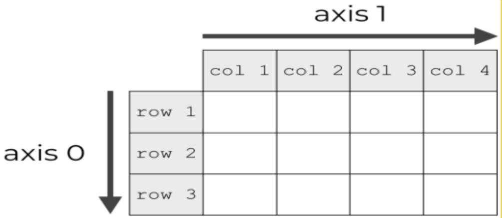


Numpy Broadcasting

➔ **Broadcasting Rules:**

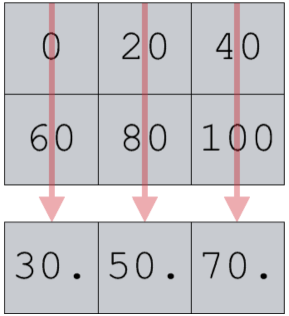
- If the arrays don’t have the same rank then prepend the shape of the lower rank array with 1s until both shapes have the same length.
- The two arrays are compatible in a dimension if they have the same size in the dimension or if one of the arrays has size 1 in that dimension.
- The arrays can be broadcast together iff they are compatible with all dimensions.
- After broadcasting, each array behaves as if it had shape equal to the element-wise maximum of shapes of the two input arrays.
- In any dimension where one array had size 1 and the other array had size greater than 1, the first array behaves as if it were copied along

Numpy Statistical Operations

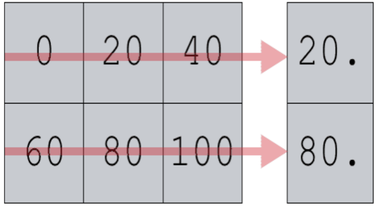


→ np.median(*array*,*[axis]*,...)

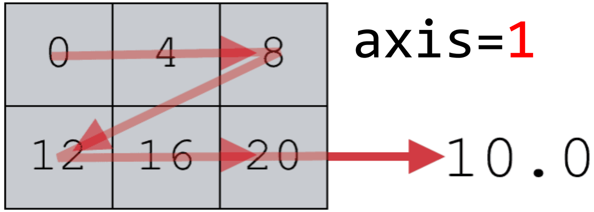
axis=0



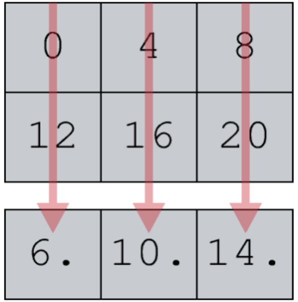
axis=1



→ np.mean(*array*, *[axis]*,...)



axis=1

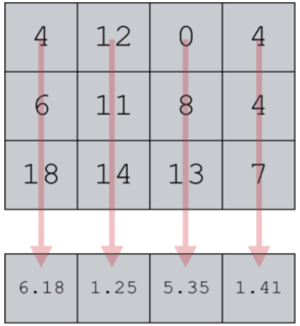


axis=0

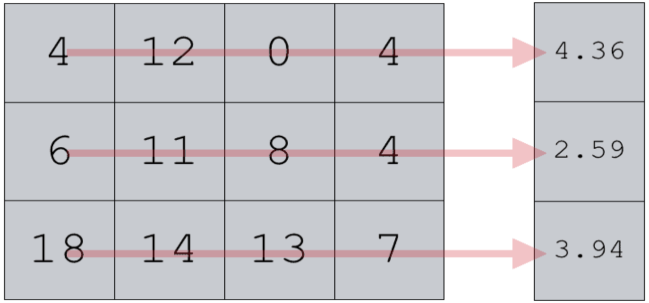
Numpy Statistical Operations

➔ `np.std(array,[axis],...)` # standard deviation

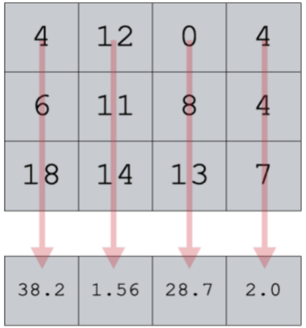
axis=0



axis=1

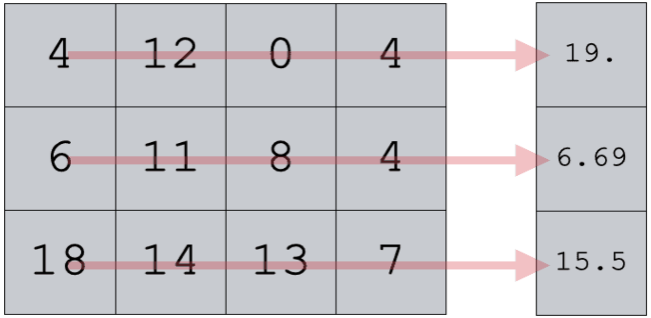


➔ `np.var(array, [axis],...)` # variance



axis=0

axis=1



Numpy Linear Algebra

- ➔ `Linalg` : the package in NumPy for Linear Algebra
- ➔ `dot()`: product of two arrays

  `vdot()`: Complex-conjugating dot product

  Example : a = [[1, 0], [0, 1]]

  >>> b = [[4, 1], [2, 2]]

  >>> np.dot(a, b)

  array([[4, 1], [2, 2]])

Numpy Linear Algebra

➔ `inner()`: product of two arrays

- numpy.inner(*a*, *b*, */*)
  - **a, b: array_like**

    If *a* and *b* are non-scalar, 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])

Numpy Linear Algebra

➔ outer(): compute the outer product of two vectors

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

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

Numpy Linear Algebra

➔ matmul(): Matrix product of two arrays

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

Parameters: x1, x2: array_like

Input arrays, scalars not allowed.

Out: ndarray, optional

If provide allocation, 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.

Numpy Linear Algebra

Another linear algebra functions

➔ det()

➔ inv()

➔ trace()

➔ rank()

Numpy Matrix Library matlib

➔ has functions that return **matrices** instead of ndarray objects.

```
import numpy as np
import numpy.matlib
# with the specified shape and type without initializing entries
mat_e =np.matlib.empty((3, 2), dtype = int)
# filled with 0
mat_zeros = np.matlib.zeros(5, 3)
# filled with 1
mat_ones = np.matlib.ones(4, 3)
# diagonal elements filled with 1, others with 0
mat_ones = np.matlib.eye(3,5)
# create square matrix with 0, diagonal filled with 1, others with 0
mat_zeros = np.matlib.identity(5)
# filled with random data
mat_e =np.matlib.empty(3, 2))
```

I/O with Numpy

➔ What are the I/O functions of NumPy?

The I/O functions provided by NumPy are:

- `load()` and `save()` functions handle numPy binary files (with `npyextension`)
- `loadtxt()` and `savetxt()` functions handle normal text files

I/O with Numpy

➔ numpy.save(): The input array is stored in a disk file with the numpy.save() file and with an npy extension.

Ex:

```
#The input array is stored in a disk file with
the numpy.save() file and with an npy extension.
import numpy as np
a = np.array([1,2,3,4,5])
np.save('outfile',a)
# use load() function to reconstruct
import numpy as np
b = np.load('outfile.npy')
print b
```

```
#The output as:
array([1, 2, 3, 4, 5])
```

I/O with Numpy

➔ `numpy.savetxt()` and `numpy.loadtxt()` functions help in storage and retrieval of the array data in simple text file format.

Ex:

```
import numpy as np
a = np.array([1,2,3,4,5])
np.savetxt('out.txt',a)
b = np.loadtxt('out.txt')
print b
```

The output produced appears as: [1. 2. 3. 4. 5.]