Numpy

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Programming for Scientists

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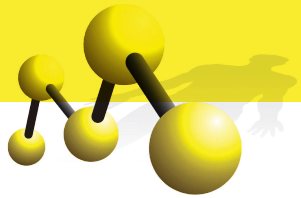
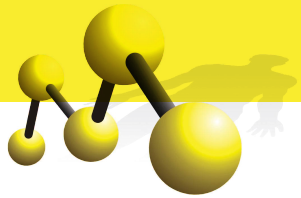
Historical



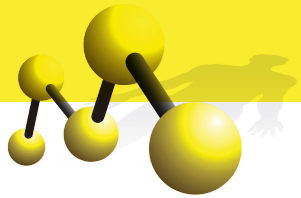
- Numeric (1995)
- Numarray (for large arrays)
- scipy.core (briefly, around 2005)
- numpy (2005)

Currently



- numpy 1.6
- de facto standard
- very stable

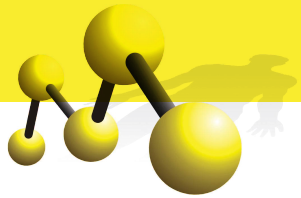
Basic Type



numpy.array or numpy.ndarray.

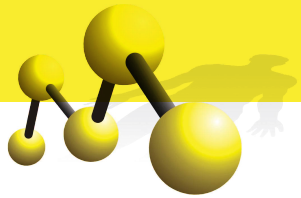
Multi-dimensional array of numbers.

numpy example



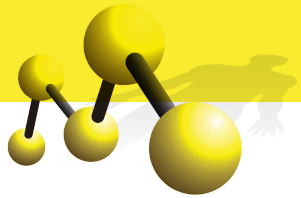
```
import numpy as np
A = np.array([
      [0,1,2],
      [2,3,4],
      [4,5,6],
      [6,7,8]])
print A[0,0]
print A[0,1]
print A[1,0]
```

Some Array Properties



```
import numpy as np
A = np.array([
      [0,1,2],
      [2,3,4],
      [4,5,6],
      [6,7,8]])
print A.shape
print A.size
```

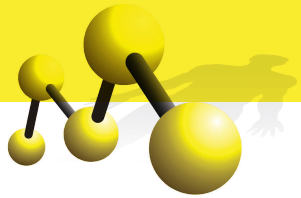
Some Array Functions



```
...
print A.max()
print A.min()
```

- max(): maximum
- min(): minimum
- ptp(): spread (max - min)
- sum(): sum
- std(): standard deviation
- ...

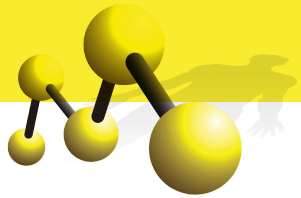
Other Functions



- np.exp
- np.sin
- ...

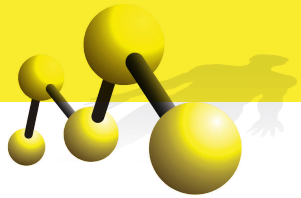
All of these work element-wise!

Arithmetic Operations



```
import numpy as np
A = np.array([0,1,2,3])
B = np.array([1,1,2,2])

print A + B
print A * B
print A / B
```

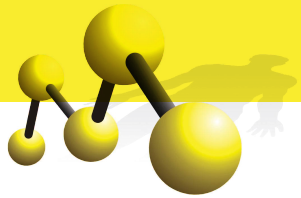
Broadcasting



Mixing arrays of different dimensions

```
import numpy as np
A = np.array([
      [0,0,1],
      [1,1,2],
      [1,2,2],
      [3,2,2]
      ])
B = np.array([2,1,2])

print A + B
print A * B
```

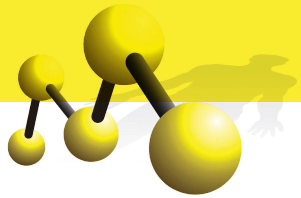
Broadcasting



Special case: scalar.

```
import numpy as np
A = np.arange(100)
print A + 2
A += 2
```

Data Types



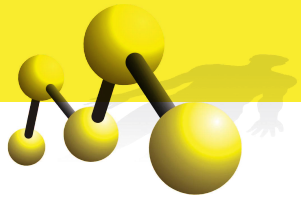
numpy.ndarray is a homogeneous array of numbers.

Types

- Boolean
- int8, int16, ...
- uint8, uint16,...
- float32, float64,...
- ...

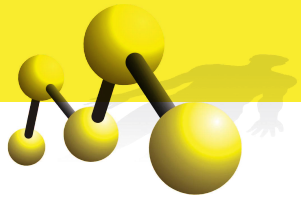
Some types are only available in some platforms (e.g., float96).

Object Construction



```
import numpy as np
A = np.array([0,1,1],np.float32)
A = np.array([0,1,1],float)
A = np.array([0,1,1],bool)
```

Reduction



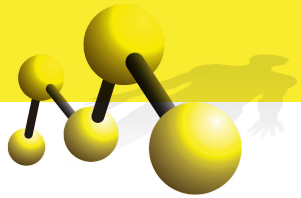
```
A = np.array([
      [0,0,1],
      [1,2,3],
      [2,4,2],
      [1,0,1]])
print A.max(0)
print A.max(1)
print A.max()
```

prints

[2,4,3]
[1,3,4,1]
4

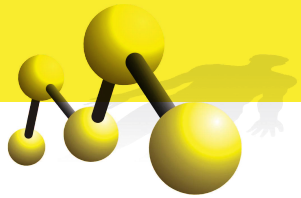
The same is true for many other functions.

Slicing



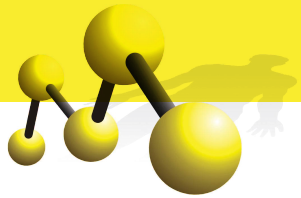
```
import numpy as np
A = np.array([
      [0,1,2],
      [2,3,4],
      [4,5,6],
      [6,7,8]])
print A[0]
print A[0].shape
print A[1]
print A[:,2]
```

Slices Share Memory!



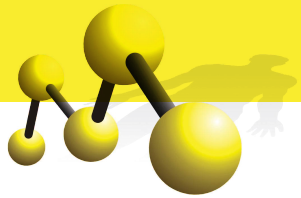
```
import numpy as np
A = np.array([
      [0,1,2],
      [2,3,4],
      [4,5,6],
      [6,7,8]])
B = A[0]
B[0] = -1
print A[0,0]
```

Pass is By Reference



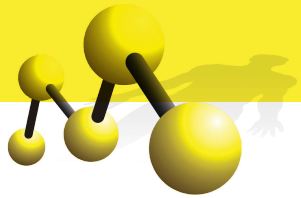
```
def double(A):
    A *= 2

A = np.arange(20)
double(A)
```

Pass is By Reference



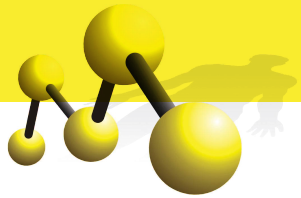
```
def double(A):
    A *= 2

A = np.arange(20)
double(A)

A = np.arange(20)
B = A.copy()
```

Logical Arrays



```
A = np.array([-1,0,1,2,-2,3,4,-2])
print (A > 0)
```

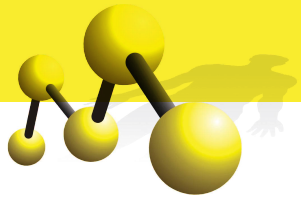
Logical Arrays II



```
A = np.array([-1,0,1,2,-2,3,4,-2])
print ( (A > 0) & (A < 3) ).mean()
```

What does this do?

Logical Indexing

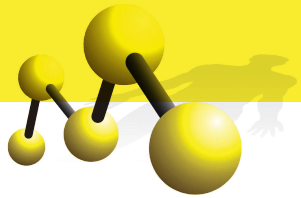


```
A[A < 0] = 0
```

or

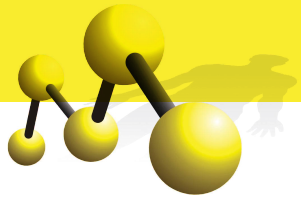
```
A *= (A > 0)
```

Logical Indexing



```
print 'Mean of positives', A[A > 0].mean()
```

Some Helper Functions



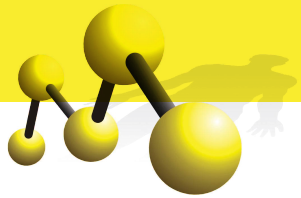
Constructing Arrays

```
A = np.zeros((10,10), dtype=np.int8)
B = np.ones(10)
C = np.arange(100).reshape((10,10))
...
```

Multiple Dimensions

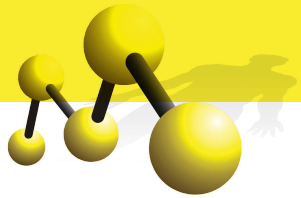
```
img = np.zeros((1024,1024,3),dype=np.uint8)
```

Documentation



http://docs.scipy.org/doc/

Matplotlib



Matplotlib is a plotting library for Python.

```
import pylab
import numpy as np
X = np.linspace(-4,+4,1000)
pylab.plot(X,np.exp(-X**2))
pylab.xlabel(r'$x$')
pylab.ylabel(r'$\exp(-x^{2})$')
pylab.savefig('gaussian.pdf')
```

http://matplotlib.sf.net/

Matplotlib Example