# numpy

覃雄派

numpy

# 提纲

- Numpy简介
- Numpy基本概念
- Numpy实例

# numpy

- Numpy简介：What is Numpy?
  - Numpy, SciPy, and Matplotlib provide MATLAB-like functionality in python.
- Numpy Features:
  - Typed multidimensional arrays (matrices)
  - Fast numerical computations (matrix math)
  - High-level math functions

# numpy

- Numpy简介： Why do we need Numpy
- Python does numerical computations slowly
- 1000 x 1000 matrix multiply
  - Python triple loop takes > 10 minutes
  - Numpy takes ~0.03 seconds

# numpy

- Functions of numpy
  - Arrays
  - Shaping and transposition
  - Mathematical Operations
  - Indexing and slicing
  - Broadcasting

# numpy

# numpy

- Numpy基本概念
- Arrays： Structured lists of numbers.
  - Vectors
  - Matrices
  - Images
  - Tensors
  - ConvNets

$$\begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix}$$

# numpy

- Numpy基本概念
- Arrays： Structured lists of numbers.
  - Vectors
  - Matrices
  - Images
  - Tensors
  - ConvNets

$$\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix}$$

# numpy

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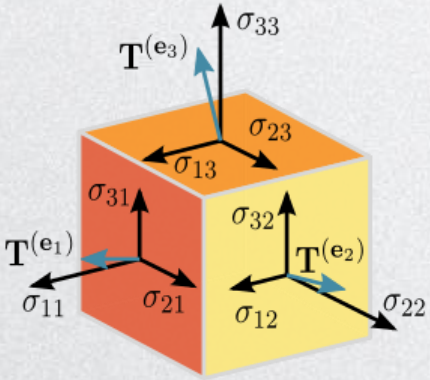


# numpy

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  - Images
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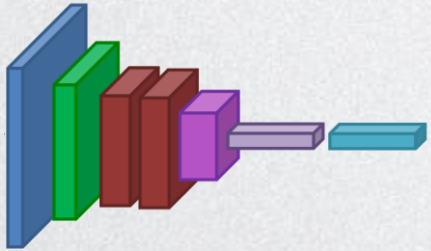


# numpy

# numpy

- Numpy实例
  - 创建1维和2维数组

```
import numpy
import numpy as np

print (np.array([1,2,3,4]) )# 创建1维数组
print (np.array([1,2,3,4], dtype=numpy.float64) )# 创建1维数组，指定数据类型
print (np.array((1.2,2,3,4)) )# 创建1维数组

print (np.array([[1,2],[3,4]]) )# 创建2维数组
```

```
[1 2 3 4]
[1. 2. 3. 4.]
[1.2 2.  3.  4. ]
[[1 2]
 [3 4]]
```

# numpy

- Numpy实例
  - 通过arange和linspace创建数组

```
print (np.arange(15))# 创建1维数组，内容为[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14]
```

```
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14]
```

```
print (np.linspace(1,3,9))# 创建一个1维数组，内容为[1,3]之间的9个均匀间隔的数值[1.  1.25  1.5 1.75  2.  2.25  2.5  2.75  3.]
```

```
[1.   1.25 1.5  1.75 2.   2.25 2.5  2.75 3.  ]
```

# numpy

- Numpy实例
  - 全0、全1、单位矩阵

```
print (np.zeros((3,4)) )# 3行4列的矩阵，元素都是0
print (np.ones((3,4)) ) # 3行4列的矩阵，元素都是1
print (np.eye(3))# 3行3列的单位矩阵

print (np.zeros((2,2,2)) )# 2行2列2层的张量，即3维数组，元素都是0
```

```
[[0. 0. 0. 0.]
 [0. 0. 0. 0.]
 [0. 0. 0. 0.]]
[[1. 1. 1. 1.]
 [1. 1. 1. 1.]
 [1. 1. 1. 1.]]
[[1. 0. 0.]
 [0. 1. 0.]
 [0. 0. 1.]]
[[[0. 0.]
  [0. 0.]]

 [[0. 0.]
  [0. 0.]]]
```

# numpy

- Numpy实例
  - random矩阵

```
# random random
a = np.random.random((10,3))
print(a)
```

```
[[0.99294316 0.64164652 0.74508153]
 [0.14256115 0.28379451 0.71494861]
 [0.47819953 0.57213991 0.85432021]
 [0.68229682 0.30149229 0.75411727]
 [0.18049368 0.77827893 0.53392431]
 [0.53981262 0.38707349 0.2009222 ]
 [0.79698328 0.51150558 0.41391815]
 [0.62769333 0.88913342 0.84572052]
 [0.36855129 0.24882605 0.1437408 ]
 [0.98474505 0.22020911 0.35715525]]
```

# numpy

- concatenate

```
a = np.array( [[11,2],[5,33]])
b = np.array( [[34,5],[77,92]])
print(a)
print(b)

c = np.concatenate([a,b])
print(c)

d = np.concatenate([a,b], axis=1)
print(d)
```

```
[[11  2]
 [ 5 33]]
[[34  5]
 [77 92]]
[[11  2]
 [ 5 33]
 [34  5]
 [77 92]]
[[11  2 34  5]
 [ 5 33 77 92]]
```

按行拼接

按列拼接

# numpy

- Numpy实例
  - zeros_like, ones_like矩阵

```
a = np.random.random((5,3))
b = np.zeros_like(a)
print(b)
c =  np.ones_like(a)
print(c)
```

```
[[0.  0.  0.]
 [0.  0.  0.]
 [0.  0.  0.]
 [0.  0.  0.]
 [0.  0.  0.]]
[[1.  1.  1.]
 [1.  1.  1.]
 [1.  1.  1.]
 [1.  1.  1.]
 [1.  1.  1.]]
```

# numpy

- Numpy实例
  - astype矩阵

```
# astype
a = np.random.random((5,3))
a = a+3
print(a)
a = a.astype( np.uint32)
print(a)
```

```
[[3.78855597 3.52076375 3.54510472]
 [3.46129928 3.5575374  3.70342108]
 [3.38203519 3.45268724 3.03687321]
 [3.00055904 3.41857347 3.37152952]
 [3.63758365 3.33651026 3.27828937]]
[[3 3 3]
 [3 3 3]
 [3 3 3]
 [3 3 3]
 [3 3 3]]
```

# numpy

- Numpy实例
  - 显示数组的属性

```
ar = np.zeros((2,2,2)) # 2行2列2层的张量，即3维数组，元素都是0
print (ar.ndim)   # 数组的维数，3
print (ar.shape) # 数组每一维的大小，(2, 2, 2)
print (ar.size)   # 数组的元素个数，8
print (ar.dtype)  # 元素类型float64
print (ar.itemsize ) # 每个元素所占的字节数，8
```

```
3
(2, 2, 2)
8
float64
8
```

- Arrays can have any number of dimensions, including zero (a scalar).
- Arrays are typed
  - np.uint8, np.int64, np.float32, np.float64
- Arrays are dense
  - Each element of the array exists and has the same type.

# numpy

- Numpy实例
  - Accessing the array

```
ar = (np.array( [[2,3,4],[5,6,7]] ) )# 2行3列数组，也就是一个矩阵
print (ar) # 输出整个数组
print (ar[1,2])# 输出一个元素，7
print (ar[1,:])# 输出一行，下标为1的行，即[5 6 7]
print (ar[:,1])# 输出一列，下标为1的列，即[3 6]
print (ar[0:2,0:2])# 输出一个行列子集，行下标为0、1，列下标为0、1
ar[1,:] = [8,9,10]# 改变一行
print (ar)
```

注意代码后的注释

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

# numpy

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| -10 | -9 | -8 | -7 | -6 | -5 | -4 | -3 | -2 | -1 |

- Python Slicing
  - Syntax: start:stop:step

```
#python list slicing
a = list(range(10))
print(a)
print(a[:3]) # indices 0, 1, 2
print(a[-3:]) # indices 7, 8, 9
print(a[3:8:2]) # indices 3, 5, 7
        #从3开始，步长为2，包头不包尾
print(a[4:1:-1]) # indices 4, 3, 2 (this
        #从4开始逆序，步长为1，包头不包
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
[0, 1, 2]
[7, 8, 9]
[3, 5, 7]
[4, 3, 2]
```

a = list(range(10))
a[:3]  # indices 0, 1, 2
a[-3:]  # indices 7, 8, 9

a[3:8:2] # indices 3, 5, 7
 #从3开始，步长为2，包头不包尾，即不包括下标8

a[4:1:-1] # indices 4, 3, 2 (this one is tricky)
 #从4开始逆序，步长为1，包头不包尾，即不包括下标1

# numpy

- Numpy实例
  - Accessing the array：index
    - `x[0,0]  # top-left element`
    - `x[0,-1]  # first row, last column`
    - `x[0,:]  # first row (many entries)`
    - `x[:,0]  # first column (many entries)`
  - Notes:
    - Zero-indexing
    - Multi-dimensional indices are comma-separated (i.e., a tuple)

# numpy

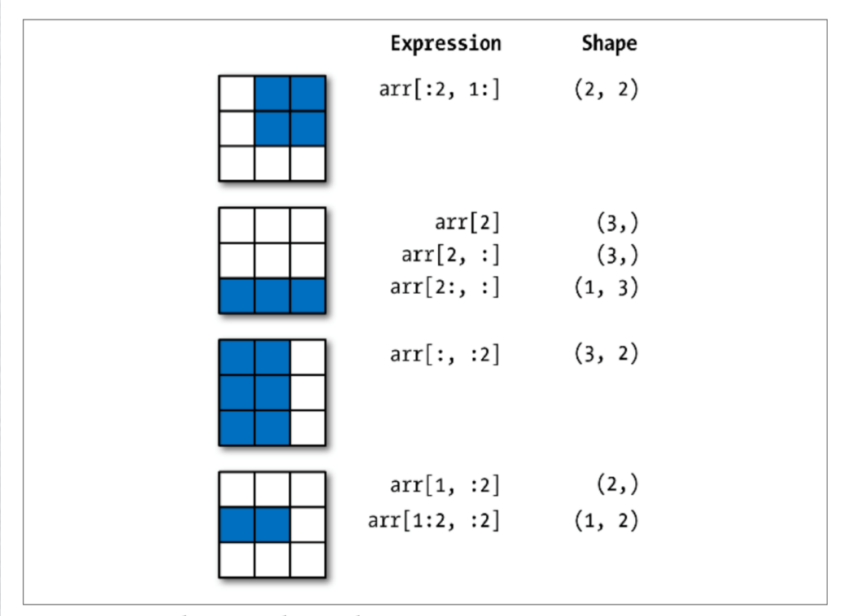
- Indexing, slices and arrays
  - `I[1:-1,1:-1]   # select all but one-pixel border`
  - `I = I[:,:,::-1]        # swap channel order`
  - `I[I<10] = 0            # set dark pixels to black`
  - `I[[1,3], :]            # select 2nd and 4th row`

Slices are views. Writing to a slice overwrites the original array.
Can also index by a list or Boolean array.

Swap channel order请参考
https://stackoverflow.com/questions/54951686/swapping-data-from-one-channel-to-another-using-numpy
此处不展开，不做要求

# numpy

- 数据切片总结
  - 切片方式有2种
  - 1.与Python的列表类型类似，可以通过索引进行切片



# numpy

- 数据切片总结
  - 切片方式有2种
  - 2.布尔型索引，即通过布尔型数组对数据进行切片

```
names = np.array(['Bob','Joe','Bob','Alice'])
data = np.random.randn(4,5)
print(names=='Bob') # names=='Bob'会返回一个布尔型的数组
print(data[names == 'Bob']) # 通过布尔型的数组进行切片
print(names!='Bob') # names!='Bob'会返回一个布尔型的数组
print(data[names != 'Bob']) # 通过布尔型的数组进行切片
print((names=='Bob')|(names=='Alice')) # 可以考虑多个条件
print(data[(names=='Bob')|(names=='Alice')]) # 通过布尔型的数组进行切片

data[data<0] = 0 # 通过布尔型切片选出所有的负数，统一置为0
print(data)
```

```
[ True False  True False]
[[ 1.63691799 -0.53269813  0.01980702  0.13260588 -2.36245474]
 [-0.01958163  0.10687501  0.16590426 -3.24077582 -0.49340068]]
[False  True False  True]
[[-1.53338532 -0.77079493  2.16274676  0.89637885  0.32211041]
 [-0.48750183  2.67493798  1.50098849 -0.06362239  1.15835726]]
[ True False  True  True]
[[ 1.63691799 -0.53269813  0.01980702  0.13260588 -2.36245474]
 [-0.01958163  0.10687501  0.16590426 -3.24077582 -0.49340068]
 [-0.48750183  2.67493798  1.50098849 -0.06362239  1.15835726]]
[[1.63691799 0.         0.01980702 0.13260588 0.        ]
 [0.         0.         2.16274676 0.89637885 0.32211041]
 [0.         0.10687501 0.16590426 0.         0.        ]
 [0.         2.67493798 1.50098849 0.         1.15835726]]
```

# numpy

- 课堂思考与练习
  - 请计算下列数组data中姓氏为Smith的同学的成绩的平均值和标准差

```
data = np.array([['Bob', 'Smith', '12', '2019-02-01'],
                 ['Joe', 'Smith', '13', '2018-03-07'],
                 ['Roy', 'Ratner', '12', '2019-02-05'],
                 ['Rita', 'Smith', '14', '2017-02-16'],
                 ['Alice', 'Holmes', '11', '2020-02-29'],
                 ['Wool', 'Smith', '15', '2016-02-14']])
```

# numpy

- Numpy实例
  - 矩阵的一些基本运算a= $\begin{bmatrix}1 & 1\\ 1 & 1\end{bmatrix}, b = \begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$

- Arithmetic operations are element-wise
- Logical operator return a bool array
- In place operations modify the array

```
a = np.ones((2,2))
b = np.eye(2)

print (a > 2)# 判断各个元素是否大于2
print (a+b)# 对应元素相加
print (a-b)# 对应元素相减
print (a*b)# 对应元素相乘
print (b/a) # 对应元素相除
print ((a*2)*(b*2))# a的各个元素先乘以2，b的各个元素先乘以2，两个矩阵的各个元素再相乘
```

```
[[False False]
 [False False]]
[[2. 1.]
 [1. 2.]]
[[0. 1.]
 [1. 0.]]
[[1. 0.]
 [0. 1.]]
[[1. 0.]
 [0. 1.]]
[[4. 0.]
 [0. 4.]]
```

```
#也可以把矩阵和一个标量进行运算
print (a+  3.3)# 对应元素相加
print (a-  3.3)# 对应元素相减
print (a*  3.3)# 对应元素相乘
print (b/  3.3) # 对应元素相除
```

```
[[4.3 4.3]
 [4.3 4.3]]
[[-2.3 -2.3]
 [-2.3 -2.3]]
[[3.3 3.3]
 [3.3 3.3]]
[[0.3030303 0.       ]
 [0.        0.3030303]]
```

# numpy

- Numpy实例
  - 矩阵的一些基本运算
  - 通过向量化（vectorization）的方式避免了for循环，效率高

```
In [7]: import numpy as np

In [8]: my_arr = np.arange(1000000)

In [9]: my_list = list(range(1000000))
```

Now let's multiply each sequence by 2:

```
In [10]: %time for _ in range(10): my_arr2 = my_arr * 2
CPU times: user 20 ms, sys: 50 ms, total: 70 ms
Wall time: 72.4 ms

In [11]: %time for _ in range(10): my_list2 = [x * 2 for x in my_list]
CPU times: user 760 ms, sys: 290 ms, total: 1.05 s
Wall time: 1.05 s
```

面向数组的编程，对数组元素执行批量操作——编程思路的转变

Array vs. List

70ms vs 1.05s

# numpy

- Numpy实例
  - 矩阵的一些基本运算a= $\begin{bmatrix}1 & 1\\1 & 1\end{bmatrix}, b = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$

```
#Logical operator
b = np.eye(2)
print( b>=1)
```

```
[[ True False]
 [False  True]]
```

- Arithmetic operations are element-wise
- Logical operator return a bool array
- In place operations modify the array

# numpy

- Numpy实例
  - 矩阵的一些基本运算a= $\begin{bmatrix} 4 & 15 \\ 20 & 75 \end{bmatrix}, b = \begin{bmatrix} 2 & 5 \\ 5 & 15 \end{bmatrix}$

```
#In place operations modify the array
a = np.array( [[4,15],
               [20,75]] )
b = np.array( [[2,5],
               [5,15]] )
print(a)
print(b)
a = a/b
print(a)
```

```
[[ 4 15]
 [20 75]]
[[ 2  5]
 [ 5 15]]
[[2. 3.]
 [4. 5.]]
```

a/=b出错，改成a = a/b

- Arithmetic operations are element-wise
- Logical operator return a bool array
- In place operations modify the array

# numpy

- Math, universal functions
  - Also called ufuncs is Element-wise
- Examples:
  - np.exp
  - np.sqrt
  - np.sin
  - np.cos
  - np.isnan

```
#In place operations modify the array
a = np.array( [[4,15],[20,75]] )
print( np.sqrt(a))
```

```
[[2.         3.87298335]
 [4.47213595 8.66025404]]
```

# numpy

- Numpy实例
  - Sum/min/max

```
import numpy as np

a = (np.array( [[2,3,4],[5,6,7]] ) )# 2行3列数组，也就是一个矩阵
print(a.sum()) # sum all entries
print(a.sum(axis=0)) # 沿着行方向，计算每一列的和，即[ 7  9 11]
print(a.sum(axis=1)) # sum over columns
print(a.sum(axis=1, keepdims=True))  #keepdims=True

print(a.min ())
print(a.max ())
```

```
27
[ 7  9 11]
[ 9 18]
[[ 9]
 [18]]
2
7
```

- Use the axis parameter to control which axis NumPy operates on
- Typically, the axis specified will disappear, keepdims keeps all dimensions

# numpy

- Numpy实例
  - 矩阵拼接

```
a = np.ones((2,2))# 2行2列矩阵，元素都是1
b = np.eye(2)# 2行2列单位矩阵

print (np.vstack((a,b)))# 纵向合并两个矩阵,形成4行2列的数组
print (np.hstack((a,b)))# 横向合并两个矩阵，形成2行4列的数组
```

```
[[1.  1.]
 [1.  1.]
 [1.  0.]
 [0.  1.]]
[[1.  1.  1.  0.]
 [1.  1.  0.  1.]]
```

# numpy

- Numpy实例
  - Reshape变形

```
ar = np.arange(15)# 生成1维数组，
print(ar.shape)# 输出(15L,)

print (ar.reshape(3,5))# 1维变成2维
print(ar.reshape(3,5).shape)# 输出(3L,5L)
print (ar.reshape(5,3))# 改变各维大小
print(ar.reshape(5,3).shape)# 输出(5L,3L)

print(ar.flatten())# 2维变成1维
print(ar.flatten().shape)# 输出(15L,)
```

```
(15,)
[[ 0  1  2  3  4]
 [ 5  6  7  8  9]
 [10 11 12 13 14]]
(3, 5)
[[ 0  1  2]
 [ 3  4  5]
 [ 6  7  8]
 [ 9 10 11]
 [12 13 14]]
(5, 3)
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14]
(15,)
```

# numpy

- Numpy实例
  - Reshape变形
  - 另一个实例

```
#reshape more
a = np.array([1,2,3,4,5,6])
a = a.reshape(3,2)
print(a)
a = a.reshape(2,-1)
print(a)
a = a.ravel()#多维数组转换为一维数组
print(a)

# Total number of elements cannot change.
# Use -1 to infer axis shape
# Row-major by default (MATLAB is column-major)
```

```
[[1 2]
 [3 4]
 [5 6]]
[[1 2 3]
 [4 5 6]]
[1 2 3 4 5 6]
```

# numpy

- Numpy实例
  - 浅拷贝和深拷贝

```
ar = np.ones((2,2))
br = ar
print(br is ar)

cr = ar.copy()# 深拷贝
print(cr is ar)
```

```
True
False
```

# numpy

- Return values
  - Numpy functions return either **views** or **copies**
    - Views share data with the original array, like references in Java/C++
      - Altering entries of a view, changes the same entries in the original
    - The numpy documentation says which functions return views or copies
      - np.copy, np.view make explicit copies and views

# numpy

- Return values
  - Numpy functions return either **views** or **copies**.
  - 与Python列表的重要区别：数据切片是原数据的一个视图view，而非拷贝copy，对于切片上的任何操作都会反映在原数据上
    - 在实际的编程实践中，非常容易在这一点上出错
    - 如果希望数据切片是原数据上的一份拷贝，应显式地调用copy()函数

```
import numpy as np
arr = np.arange(10)
print(arr)
arr_slice = arr[5:8] # 选取一个切片，注意该切片为原数据的视图
arr_slice[0] = 1234
print(arr) # 原数据索引为5的值发生了改变
arr_slice1 = arr[1:3].copy() # 拷贝出一个切片
arr_slice1[0] = 1234
print(arr) # 原数据索引为1的值没有发生了改变
```

```
[0 1 2 3 4 5 6 7 8 9]
[   0    1    2    3    4 1234    6    7    8    9]
[   0    1    2    3    4 1234    6    7    8    9]
```

# numpy

- Numpy实例
  - 矩阵转置和矩阵乘法

```
ar = np.array([[1,0],[2,3]])
print (ar.transpose())# 矩阵的转置

ar = np.array([[1,2],[3,4]])
br = np.array([[5,6],[7,8]])

print(np.dot(ar,br)  )# 矩阵乘法
```

```
[[1 2]
 [0 3]]
[[19 22]
 [43 50]]
```

# numpy

- Numpy实例
  - 特征值、特征向量、SVD分解

```
import numpy.linalg as nplg
ar = np.array([[-1,1,0],[-4,3,0],[1,0,2]])
x, y = numpy.linalg.eig(ar)# 特征值和特征向量
print ("x",x)
print ("y",y)
print (numpy.linalg.eig(ar))# 特征值和特征向量
print(np.dot(ar, y[:,0]))# 验算0号特征值和特征向量
print( x[0] *y[:,0])
print(np.dot(ar, y[:,1]))# 验算1号特征值和特征向量
print( x[1] *y[:,1])
print(np.dot(ar, y[:,2]))# 验算2号特征值和特征向量
print( x[2] *y[:,2])

ar = np.array([[1,0],[2,3]])
u,s,vT = np.linalg.svd(ar) # SVD分解
print ("u",u)
print("s",s)
print("vT",vT)

Sigma=np.array( [ [s[0],0], [0,s[1]] ])
temp1 = np.dot(u, Sigma)
temp2 = np.dot(temp1, vT)
print(temp2)
```

```
x [2.  1.  1.]
y [[ 0.          0.40824829  0.40824829]
 [ 0.          0.81649658  0.81649658]
 [ 1.         -0.40824829 -0.40824829]]
(array([2., 1., 1.]), array([[ 0.        ,  0.40824829,  0.40824829],
       [ 0.        ,  0.81649658,  0.81649658],
       [ 1.        , -0.40824829, -0.40824829]]))
[0. 0. 2.]
[0. 0. 2.]
[ 0.40824829  0.81649658 -0.40824829]
[ 0.40824829  0.81649658 -0.40824829]
[ 0.40824829  0.81649658 -0.40824829]
[ 0.40824829  0.81649658 -0.40824829]
```

```
u [[-0.16018224 -0.98708746]
 [-0.98708746  0.16018224]]
s [3.65028154 0.82185442]
vT [[-0.58471028 -0.81124219]
 [-0.81124219  0.58471028]]
[[ 1.0000000e+00 -4.4408921e-16]
 [ 2.0000000e+00  3.0000000e+00]]
```

# numpy

- Numpy实例
  - Broadcasting
    - When operating on multiple arrays, broadcasting rules are used
    - Each dimension must match, from right-to-left
    - Dimensions of size 1 will broadcast (as if the value was repeated)
    - Otherwise, the dimension must have the same shape
    - Extra dimensions of size 1 are added to the left as needed

```
#broadcasting
a = np.random.random((5,3))
print(a)
a = a+1
print(a)
```

```
[[0.50864461 0.82415144 0.51872029]
 [0.36315603 0.88448091 0.72948211]
 [0.76725595 0.97937764 0.62829754]
 [0.18044825 0.85757133 0.03235834]
 [0.58714485 0.17216633 0.41380195]]
[[1.50864461 1.82415144 1.51872029]
 [1.36315603 1.88448091 1.72948211]
 [1.76725595 1.97937764 1.62829754]
 [1.18044825 1.85757133 1.03235834]
 [1.58714485 1.17216633 1.41380195]]
```

5*3的矩阵，每个元素，加上实数1

# numpy

- Numpy实例
- 写入文件

```
import numpy as np
data = np.random.random((4,3))
print(data)
np.save('bin_data', data)# 存入二进制文件bin_data.npy
loaded_data = np.load('bin_data.npy')
print(data)
```

```
[[0.53469027 0.27232821 0.86685555]
 [0.31708048 0.089706   0.01579114]
 [0.56721678 0.82554299 0.10713553]
 [0.53647069 0.83037797 0.04685006]]
[[0.53469027 0.27232821 0.86685555]
 [0.31708048 0.089706   0.01579114]
 [0.56721678 0.82554299 0.10713553]
 [0.53647069 0.83037797 0.04685006]]
```

# numpy

- Numpy实例
- 写入文件

```
import numpy as np
a  = np.array([[3.3, -0.3], [-0.3, 5.5]])
print(a)

np.savez('data1.npz', kw=a)
data = np.load('data1.npz')
a = data['kw']
print(a)
# NPZ files can hold multiple arrays #上述实例的kw是一个名字
# np.savez_compressed similar.
```

```
[[ 3.3 -0.3]
 [-0.3  5.5]]
[[ 3.3 -0.3]
 [-0.3  5.5]]
```

# numpy

- Numpy实例
- 写入文件

```
import numpy as np
ar = np.random.rand(5,5)
print(ar)
np.savetxt('txt_data.txt', ar, fmt='%0.8f')# 存入文本文件
br=np.loadtxt('txt_data.txt', dtype=np.float32)
print(br)
```

```
[[0.03598973 0.40317196 0.06378865 0.58898706 0.75733172]
 [0.84137219 0.38056775 0.76486695 0.90368303 0.49065687]
 [0.08756266 0.83337941 0.13406773 0.07288254 0.19418188]
 [0.19500955 0.81605742 0.66445988 0.51764073 0.94448538]
 [0.54816263 0.85934666 0.23400618 0.53817725 0.14403302]]
[[0.03598973 0.40317196 0.06378865 0.58898705 0.7573317 ]
 [0.8413722  0.38056776 0.76486695 0.903683   0.49065688]
 [0.08756266 0.8333794  0.13406773 0.07288254 0.19418187]
 [0.19500954 0.81605744 0.6644599  0.5176407  0.94448537]
 [0.54816264 0.8593467  0.23400618 0.53817725 0.14403301]]
```

# numpy

- Numpy实例
- 写入文件

```
import numpy as np
data = np.genfromtxt('cdv_data.csv', delimiter=',', names=True)
print(data)
```

```
[(1., 123., 1., 1.) (2., 124., 2., 2.) (3., 125., 3., 3.)]
```

# numpy

# numpy

- Load image

```
#load images
from PIL import Image
import numpy as np

im = np.array(Image.open('./boy.png'))

print(type(im))
print(im.dtype)
print(im.shape)
```

```
<class 'numpy.ndarray'>
uint8
(543, 520, 3)
```

# numpy

- show image

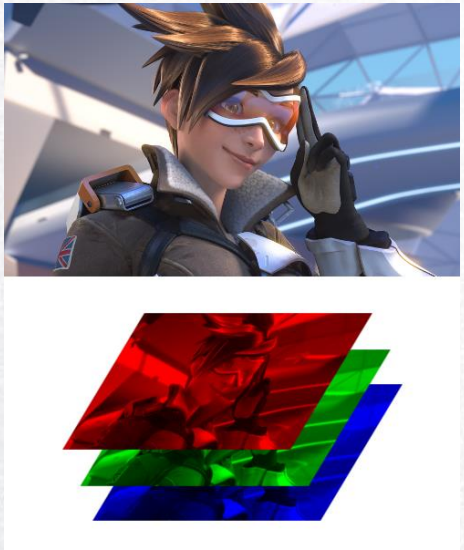
```
import numpy as np
import matplotlib.pylab as plt
def plot_image(im, h=8, **kwargs):
    """
    Helper function to plot an image.
    """
    y = im.shape[0]
    x = im.shape[1]
    w = (y/x) * h
    plt.figure(figsize=(w,h))
    plt.imshow(im, interpolation="none", **kwargs)
    plt.axis('off')

plot_image(im)
```

更多资料请见https://note.nkmk.me/en/python-numpy-image-processing/
http://www.degeneratestate.org/posts/2016/Oct/23/image-processing-with-numpy/

# numpy

- Image arrays
- Images are 3D arrays: width, height, and channels
- Common image formats:
  - height x width x RGB (band-interleaved)
  - height x width (band-sequential)
- Gotchas:
  - Channels may also be BGR (OpenCV does this)
  - May be [width x height], not [height x width]



# numpy

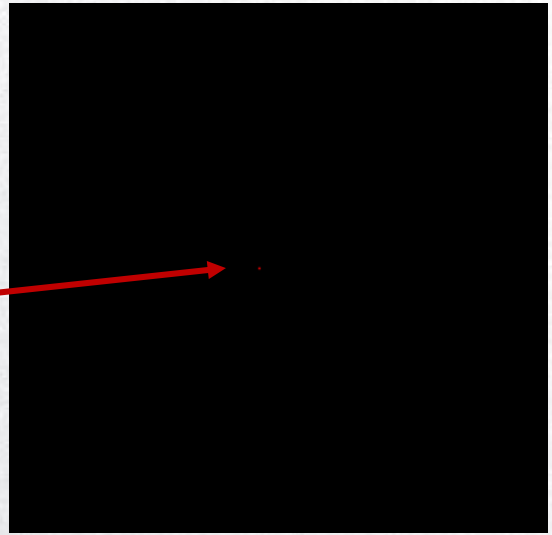
- Make image

```
#make image
from PIL import Image
import numpy as np

w, h = 512, 512
data = np.zeros((h, w, 3), dtype=np.uint8)
data[256, 256] = [255, 0, 0]
data[255, 256] = [255, 0, 0]
data[256, 255] = [255, 0, 0]
data[255, 255] = [255, 0, 0]
img = Image.fromarray(data, 'RGB')
img.save('my.png')
#img.show()

im = np.array(Image.open('./my.png'))
plot_image(im)
```

红点



# numpy

- Math, upcasting
- Just as in Python and Java, the result of a math operator is cast to the more general or precise datatype
  - uint64 + uint16 → uint64
  - float32 / int32 → float32
- Warning: upcasting does not prevent overflow/underflow. You must manually cast first.

  - Use case: images often stored as uint8
  - You should convert to float32 or float64 before doing math

# numpy

此内容可选

- Broadcasting
  - Suppose we want to add a color value to an image
  - a.shape is 100, 200, 3
  - b.shape is 3
  - a + b will pad b with two extra dimensions so it has an effective shape of 1 x 1 x 3.
  - So, the addition will broadcast over the first and second dimensions.

# numpy

此内容可选

- Broadcasting failures
  - If a.shape is 100, 200, 3 but b.shape is 4 then a + b will fail.
  - The trailing dimensions must have the same shape (or be 1)

# numpy

# numpy

- 总结：Tips to avoid bugs
  - Know what your datatypes are
  - Check whether you have a view or a copy
  - Use matplotlib for sanity checks
  - Use pdb(Python调试器) or print to check each step of your computation
  - Know np.dot vs np.mult

**Python 调试器之pdb**

使用PDB的方式有两种:

1. 单步执行代码,通过命令 python -m pdb xxx.py 启动脚本，进入单步执行模式

pdb命令行:

1）进入命令行Debug模式，python -m pdb xxx.py

可以使用集成开发环境
(1) Spyder
(2) VS code (python plugin)
(3) PyCharm

# numpy

- 参考资料

部分内容来自
https://www.cs.cornell.edu/courses/cs4670/2018sp/lec08-numpy.pptx