

CS231n课程笔记翻译: Python Numpy教程



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译者注: 本文智能单元首发, 翻译自斯坦福CS231n课程笔记Python Numpy Tutorial, 由课程教师Andrej Karpathy授权进行翻译。本篇教程由杜客翻译完成, [Flood Sung](#)、[SunisDown](#)、[巩子嘉](#)和一位不愿透露ID的知友对本翻译亦有贡献。

原文如下

这篇教程由[Justin Johnson](#)创作。

我们将使用Python编程语言来完成本课程的所有作业。Python是一门伟大的通用编程语言, 在一些常用库 (numpy, scipy, matplotlib) 的帮助下, 它又会变成一个强大的科学计算环境。

我们期望你们中大多数人对于Python语言和Numpy库比较熟悉, 而对于没有Python经验的同学, 这篇教程可以帮助你们快速了解Python编程环境和如何使用Python作为科学计算工具。

一部分同学对于Matlab有一定经验。对于这部分同学, 我们推荐阅读 [numpy for Matlab users](#)页面。

你们还可以查看本教程的[IPython notebook版](#)。该教程是由[Volodymyr Kuleshov](#)和[Isaac Caswell](#)为课程CS 228创建的。

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Python

Python是一种高级的，动态类型的多范型编程语言。很多时候，大家会说Python看起来简直和伪代码一样，这是因为你能够通过很少行数的代码表达出很有力的思想。举个例子，下面是用Python实现的经典的quicksort算法例子：

```
def quicksort(arr):
    if len(arr) <= 1:
        return arr
    pivot = arr[len(arr) / 2]
    left = [x for x in arr if x < pivot]
    middle = [x for x in arr if x == pivot]
    right = [x for x in arr if x > pivot]
    return quicksort(left) + middle + quicksort(right)

print quicksort([3,6,8,10,1,2,1])
# Prints "[1, 1, 2, 3, 6, 8, 10]"
```

Python版本

Python有两个支持的版本，分别是2.7和3.4。这有点让人迷惑，3.0向语言中引入了很多不向后兼容的变化，2.7下的代码有时候在3.4下是行不通的。在这个课程中，我们使用的是2.7版本。

如何查看版本呢？使用**python --version**命令。

基本数据类型

和大多数编程语言一样，Python拥有一系列的基本数据类型，比如整型、浮点型、布尔型和字符串等。这些类型的使用方式和在其他语言中的使用方式是类似的。

数字：整型和浮点型的使用与其他语言类似。

```
x = 3
print type(x) # Prints "<type 'int'>"
print x       # Prints "3"
print x + 1    # Addition; prints "4"
print x - 1    # Subtraction; prints "2"
print x * 2    # Multiplication; prints "6"
print x ** 2   # Exponentiation; prints "9"
x += 1
print x       # Prints "4"
x *= 2
print x       # Prints "8"
y = 2.5
print type(y) # Prints "<type 'float'>"
print y, y + 1, y * 2, y ** 2 # Prints "2.5 3.5 5.0 6.25"
```

需要注意的是，Python中没有 `x++` 和 `x--` 的操作符。

Python也有内置的长整型和复杂数字类型，具体细节可以查看[文档](#)。

布尔型：Python实现了所有的布尔逻辑，但用的是英语，而不是我们习惯的操作符（比如`&&`和`||`等）。

```
t = True
f = False
print type(t) # Prints "<type 'bool'>"
print t and f # Logical AND; prints "False"
print t or f  # Logical OR; prints "True"
print not t   # Logical NOT; prints "False"
print t != f  # Logical XOR; prints "True"
```

字符串：Python对字符串的支持非常棒。

```
hello = 'hello'    # String literals can use single quotes
world = "world"    # or double quotes; it does not matter.
print hello        # Prints "hello"
print len(hello)   # String length; prints "5"
hw = hello + ' ' + world # String concatenation
print hw           # prints "hello world"
hw12 = '%s %s %d' % (hello, world, 12) # sprintf style string formatting
print hw12         # prints "hello world 12"
```

字符串对象有一系列有用的方法，比如：

```
s = "hello"
print s.capitalize() # Capitalize a string; prints "Hello"
print s.upper()      # Convert a string to uppercase; prints "HELLO"
print s.rjust(7)     # Right-justify a string, padding with spaces; prints "  hello"
print s.center(7)    # Center a string, padding with spaces; prints "  hello  "
print s.replace('l', '(ell)') # Replace all instances of one substring with another;
                               # prints "he(ell)(ell)o"
print '  world '.strip() # Strip leading and trailing whitespace; prints "world"
```

如果想详细查看字符串方法，请看[文档](#)。

容器Containers

译者注：有知友建议container翻译为复合数据类型，供读者参考。

Python有以下几种容器类型：列表（lists）、字典（dictionaries）、集合（sets）和元组（tuples）。

列表Lists

列表就是Python中的数组，但是列表长度可变，且能包含不同类型元素。

```
xs = [3, 1, 2]    # Create a list
print xs, xs[2]   # Prints "[3, 1, 2] 2"
```

```

print xs[-1]      # Negative indices count from the end of the list; prints "2"
xs[2] = 'foo'     # Lists can contain elements of different types
print xs          # Prints "[3, 1, 'foo']"
xs.append('bar')  # Add a new element to the end of the list
print xs          # Prints
x = xs.pop()      # Remove and return the last element of the list
print x, xs       # Prints "bar [3, 1, 'foo']"

```

列表的细节，同样可以查阅[文档](#)。

切片Slicing: 为了一次性地获取列表中的元素，Python提供了一种简洁的语法，这就是切片。

```

nums = range(5)    # range is a built-in function that creates a list of integers
print nums         # Prints "[0, 1, 2, 3, 4]"
print nums[2:4]    # Get a slice from index 2 to 4 (exclusive); prints "[2, 3]"
print nums[2:]     # Get a slice from index 2 to the end; prints "[2, 3, 4]"
print nums[:2]     # Get a slice from the start to index 2 (exclusive); prints "[0, 1]"
print nums[:]      # Get a slice of the whole list; prints "[0, 1, 2, 3, 4]"
print nums[:-1]    # Slice indices can be negative; prints "[0, 1, 2, 3]"
nums[2:4] = [8, 9] # Assign a new sublist to a slice
print nums         # Prints "[0, 1, 8, 8, 4]"

```

在Numpy数组的内容中，我们会再次看到切片语法。

循环Loops: 我们可以这样遍历列表中的每一个元素:

```

animals = ['cat', 'dog', 'monkey']
for animal in animals:
    print animal
# Prints "cat", "dog", "monkey", each on its own line.

```

如果想要在循环体内访问每个元素的指针，可以使用内置的**enumerate**函数

```

animals = ['cat', 'dog', 'monkey']
for idx, animal in enumerate(animals):

```

```
print '#%d: %s' % (idx + 1, animal)
# Prints "#1: cat", "#2: dog", "#3: monkey", each on its own line
```

列表推导List comprehensions: 在编程的时候, 我们常常想要将一种数据类型转换为另一种。下面是一个简单例子, 将列表中的每个元素变成它的平方。

```
nums = [0, 1, 2, 3, 4]
squares = []
for x in nums:
    squares.append(x ** 2)
print squares # Prints [0, 1, 4, 9, 16]
```

使用列表推导, 你就可以让代码简化很多:

```
nums = [0, 1, 2, 3, 4]
squares = [x ** 2 for x in nums]
print squares # Prints [0, 1, 4, 9, 16]
```

列表推导还可以包含条件:

```
nums = [0, 1, 2, 3, 4]
even_squares = [x ** 2 for x in nums if x % 2 == 0]
print even_squares # Prints "[0, 4, 16]"
```

字典Dictionaries

字典用来储存 (键, 值) 对, 这和Java中的Map差不多。你可以这样使用它:

```
d = {'cat': 'cute', 'dog': 'furry'} # Create a new dictionary with some data
print d['cat'] # Get an entry from a dictionary; prints "cute"
print 'cat' in d # Check if a dictionary has a given key; prints "True"
d['fish'] = 'wet' # Set an entry in a dictionary
print d['fish'] # Prints "wet"
# print d['monkey'] # KeyError: 'monkey' not a key of d
print d.get('monkey', 'N/A') # Get an element with a default; prints "N/A"
print d.get('fish', 'N/A') # Get an element with a default; prints "wet"
del d['fish'] # Remove an element from a dictionary
print d.get('fish', 'N/A') # "fish" is no longer a key; prints "N/A"
```

想要知道字典的其他特性, 请查阅[文档](#)。

循环Loops: 在字典中, 用键来迭代更加容易。

```
d = {'person': 2, 'cat': 4, 'spider': 8}
for animal in d:
    legs = d[animal]
    print 'A %s has %d legs' % (animal, legs)
# Prints "A person has 2 legs", "A spider has 8 legs", "A cat has 4 legs"
```

如果你想要访问键和对应的值, 那就使用**iteritems**方法:

```
d = {'person': 2, 'cat': 4, 'spider': 8}
for animal, legs in d.iteritems():
    print 'A %s has %d legs' % (animal, legs)
# Prints "A person has 2 legs", "A spider has 8 legs", "A cat has 4 legs"
```

字典推导Dictionary comprehensions: 和列表推导类似, 但是允许你方便地构建字典。

```
nums = [0, 1, 2, 3, 4]
even_num_to_square = {x: x ** 2 for x in nums if x % 2 == 0}
print even_num_to_square # Prints "{0: 0, 2: 4, 4: 16}"
```

集合Sets

集合是独立不同个体的无序集合。示例如下:

```
animals = {'cat', 'dog'}
print 'cat' in animals # Check if an element is in a set; prints "True"
print 'fish' in animals # prints "False"
animals.add('fish') # Add an element to a set
print 'fish' in animals # Prints "True"
print len(animals) # Number of elements in a set; prints "3"
animals.add('cat') # Adding an element that is already in the set does nothing
print len(animals) # Prints "3"
animals.remove('cat') # Remove an element from a set
print len(animals) # Prints "2"
```

和前面一样, 要知道更详细的, 查看[文档](#)。

循环Loops: 在集合中循环的语法和在列表中一样，但是集合是无序的，所以你在访问集合的元素的时候，不能做关于顺序的假设。

```
animals = {'cat', 'dog', 'fish'}
for idx, animal in enumerate(animals):
    print '#%d: %s' % (idx + 1, animal)
# Prints "#1: fish", "#2: dog", "#3: cat"
```

集合推导Set comprehensions: 和字典推导一样，可以很方便地构建集合：

```
from math import sqrt
nums = {int(sqrt(x)) for x in range(30)}
print nums # Prints "set([0, 1, 2, 3, 4, 5])"
```

元组Tuples

元组是一个值的有序列表（不可改变）。从很多方面来说，元组和列表都很相似。和列表最重要的不同在于，元组可以在字典中用作键，还可以作为集合的元素，而列表不行。例子如下：

```
d = {(x, x + 1): x for x in range(10)} # Create a dictionary with tuple keys
print d
t = (5, 6) # Create a tuple
print type(t) # Prints "<type 'tuple'>"
print d[t] # Prints "5"
print d[(1, 2)] # Prints "1"
```

文档有更多元组的信息。

函数Functions

Python函数使用def来定义函数：

```
def sign(x):
    if x > 0:
```



```

        return 'positive'
    elif x < 0:
        return 'negative'
    else:
        return 'zero'

for x in [-1, 0, 1]:
    print sign(x)
# Prints "negative", "zero", "positive"

```

我们常常使用可选参数来定义函数:

```

def hello(name, loud=False):
    if loud:
        print 'HELLO, %s' % name.upper()
    else:
        print 'Hello, %s!' % name

hello('Bob') # Prints "Hello, Bob"
hello('Fred', loud=True) # Prints "HELLO, FRED!"

```

函数还有很多内容, 可以查看[文档](#)。

类Classes

Python对于类的定义是简单直接的:

```

class Greeter(object):

    # Constructor
    def __init__(self, name):
        self.name = name # Create an instance variable

    # Instance method
    def greet(self, loud=False):
        if loud:
            print 'HELLO, %s!' % self.name.upper()
        else:
            print 'Hello, %s' % self.name

```

```
g = Greeter('Fred') # Construct an instance of the Greeter class
g.greet()           # Call an instance method; prints "Hello, Fred"
g.greet(loud=True)  # Call an instance method; prints "HELLO, FRED!"
```

更多类的信息请查阅[文档](#)。

Numpy

Numpy是Python中用于科学计算的核心库。它提供了高性能的多维数组对象，以及相关工具。

数组Arrays

一个numpy数组是一个由不同数值组成的网格。网格中的数据都是同一种数据类型，可以通过非负整型数的元组来访问。维度的数量被称为数组的阶，数组的大小是一个由整型数构成的元组，可以描述数组不同维度上的大小。

我们可以从列表创建数组，然后利用方括号访问其中的元素：

```
import numpy as np

a = np.array([1, 2, 3]) # Create a rank 1 array
print type(a)          # Prints "<type 'numpy.ndarray'>"
print a.shape           # Prints "(3,)"
print a[0], a[1], a[2]  # Prints "1 2 3"
a[0] = 5                # Change an element of the array
print a                 # Prints "[5, 2, 3]"

b = np.array([[1,2,3],[4,5,6]]) # Create a rank 2 array
print b                  # 显示一下矩阵b
print b.shape            # Prints "(2, 3)"
print b[0, 0], b[0, 1], b[1, 0] # Prints "1 2 4"
```

Numpy还提供了很多其他创建数组的方法：

```
import numpy as np

a = np.zeros((2,2)) # Create an array of all zeros
print a             # Prints "[[ 0.  0.]
```

```

#          [ 0.  0.]]"
```

```

b = np.ones((1,2))  # Create an array of all ones
print b             # Prints "[[ 1.  1.]]"
```

```

c = np.full((2,2), 7) # Create a constant array
print c             # Prints "[[ 7.  7.]
                    #          [ 7.  7.]]"
```

```

d = np.eye(2)        # Create a 2x2 identity matrix
print d              # Prints "[[ 1.  0.]
                    #          [ 0.  1.]]"
```

```

e = np.random.random((2,2)) # Create an array filled with random values
print e                # Might print "[[ 0.91940167  0.08143941]
                    #          [ 0.68744134  0.87236687]]"
```

其他数组相关方法，请查看[文档](#)。

访问数组

Numpy提供了多种访问数组的方法。

切片：和Python列表类似，numpy数组可以使用切片语法。因为数组可以是多维的，所以你必须为每个维度指定好切片。

```

import numpy as np

# Create the following rank 2 array with shape (3, 4)
# [[ 1  2  3  4]
#  [ 5  6  7  8]
#  [ 9 10 11 12]]
a = np.array([[1,2,3,4], [5,6,7,8], [9,10,11,12]])

# Use slicing to pull out the subarray consisting of the first 2 rows
# and columns 1 and 2; b is the following array of shape (2, 2):
# [[2 3]
#  [6 7]]
b = a[:2, 1:3]

# A slice of an array is a view into the same data, so modifying it
# will modify the original array.
print a[0, 1]  # Prints "2"
```

```
b[0, 0] = 77    # b[0, 0] is the same piece of data as a[0, 1]
print a[0, 1]   # Prints "77"
```

你可以同时使用整型和切片语法来访问数组。但是，这样做会产生一个比原数组低阶的新数组。需要注意的是，这里和MATLAB中的情况是不同的：

```
import numpy as np

# Create the following rank 2 array with shape (3, 4)
# [[ 1  2  3  4]
#  [ 5  6  7  8]
#  [ 9 10 11 12]]
a = np.array([[1,2,3,4], [5,6,7,8], [9,10,11,12]])

# Two ways of accessing the data in the middle row of the array.
# Mixing integer indexing with slices yields an array of lower rank,
# while using only slices yields an array of the same rank as the
# original array:
row_r1 = a[1, :]    # Rank 1 view of the second row of a
row_r2 = a[1:2, :]  # Rank 2 view of the second row of a
print row_r1, row_r1.shape # Prints "[5 6 7 8] (4,)"
print row_r2, row_r2.shape # Prints "[[5 6 7 8]] (1, 4)"

# We can make the same distinction when accessing columns of an array:
col_r1 = a[:, 1]
col_r2 = a[:, 1:2]
print col_r1, col_r1.shape # Prints "[ 2  6 10] (3,)"
print col_r2, col_r2.shape # Prints "[[ 2]
                             #          [ 6]
                             #          [10]] (3, 1)"]
```

整型数组访问：当我们使用切片语法访问数组时，得到的总是原数组的一个子集。整型数组访问允许我们利用其它数组的数据构建一个新的数组：

```
import numpy as np

a = np.array([[1,2], [3, 4], [5, 6]])

# An example of integer array indexing.
# The returned array will have shape (3,) and
print a[[0, 1, 2], [0, 1, 0]] # Prints "[1 4 5]"

# The above example of integer array indexing is equivalent to this:
```

```
print np.array([a[0, 0], a[1, 1], a[2, 0]]) # Prints "[1 4 5]"

# When using integer array indexing, you can reuse the same
# element from the source array:
print a[[0, 0], [1, 1]] # Prints "[2 2]"

# Equivalent to the previous integer array indexing example
print np.array([a[0, 1], a[0, 1]]) # Prints "[2 2]"
```

整型数组访问语法还有个有用的技巧，可以用来选择或者更改矩阵中每行中的一个元素：

```
import numpy as np

# Create a new array from which we will select elements
a = np.array([[1,2,3], [4,5,6], [7,8,9], [10, 11, 12]])

print a # prints "array([[ 1,  2,  3],
#                        [ 4,  5,  6],
#                        [ 7,  8,  9],
#                        [10, 11, 12]])"

# Create an array of indices
b = np.array([0, 2, 0, 1])

# Select one element from each row of a using the indices in b
print a[np.arange(4), b] # Prints "[ 1  6  7 11]"

# Mutate one element from each row of a using the indices in b
a[np.arange(4), b] += 10

print a # prints "array([[11,  2,  3],
#                        [ 4,  5, 16],
#                        [17,  8,  9],
#                        [10, 21, 12]])"
```

布尔型数组访问：布尔型数组访问可以让你选择数组中任意元素。通常，这种访问方式用于选取数组中满足某些条件的元素，举例如下：

```
import numpy as np

a = np.array([[1,2], [3, 4], [5, 6]])

bool_idx = (a > 2) # Find the elements of a that are bigger than 2;
```

```

# this returns a numpy array of Booleans of the same
# shape as a, where each slot of bool_idx tells
# whether that element of a is > 2.

print bool_idx      # Prints "[[False False]
                    #      [ True  True]
                    #      [ True  True]]"

# We use boolean array indexing to construct a rank 1 array
# consisting of the elements of a corresponding to the True values
# of bool_idx
print a[bool_idx]   # Prints "[3 4 5 6]"

# We can do all of the above in a single concise statement:
print a[a > 2]      # Prints "[3 4 5 6]"

```

为了教程的简介，有很多数组访问的细节我们没有详细说明，可以查看[文档](#)。

数据类型

每个Numpy数组都是数据类型相同的元素组成的网格。Numpy提供了很多的数据类型用于创建数组。当你创建数组的时候，Numpy会尝试猜测数组的数据类型，你也可以通过参数直接指定数据类型，例子如下：

```

import numpy as np

x = np.array([1, 2]) # Let numpy choose the datatype
print x.dtype       # Prints "int64"

x = np.array([1.0, 2.0]) # Let numpy choose the datatype
print x.dtype         # Prints "float64"

x = np.array([1, 2], dtype=np.int64) # Force a particular datatype
print x.dtype         # Prints "int64"

```

更多细节查看[文档](#)。

数组计算

基本数学计算函数会对数组中元素逐个进行计算，既可以利用操作符重载，也可以使用函数方式：

```
import numpy as np

x = np.array([[1,2],[3,4]], dtype=np.float64)
y = np.array([[5,6],[7,8]], dtype=np.float64)

# Elementwise sum; both produce the array
# [[ 6.0  8.0]
#  [10.0 12.0]]
print x + y
print np.add(x, y)

# Elementwise difference; both produce the array
# [[-4.0 -4.0]
#  [-4.0 -4.0]]
print x - y
print np.subtract(x, y)

# Elementwise product; both produce the array
# [[ 5.0 12.0]
#  [21.0 32.0]]
print x * y
print np.multiply(x, y)

# Elementwise division; both produce the array
# [[ 0.2          0.33333333]
#  [ 0.42857143  0.5         ]]
print x / y
print np.divide(x, y)

# Elementwise square root; produces the array
# [[ 1.          1.41421356]
#  [ 1.73205081  2.         ]]
print np.sqrt(x)
```

和MATLAB不同，*是元素逐个相乘，而不是矩阵乘法。在Numpy中使用dot来进行矩阵乘法：

```
import numpy as np

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

```

v = np.array([9,10])
w = np.array([11, 12])

# Inner product of vectors; both produce 219
print v.dot(w)
print np.dot(v, w)

# Matrix / vector product; both produce the rank 1 array [29 67]
print x.dot(v)
print np.dot(x, v)

# Matrix / matrix product; both produce the rank 2 array
# [[19 22]
#  [43 50]]
print x.dot(y)
print np.dot(x, y)

```

Numpy提供了很多计算数组的函数，其中最常用的一个是**sum**：

```

import numpy as np

x = np.array([[1,2],[3,4]])

print np.sum(x) # Compute sum of all elements; prints "10"
print np.sum(x, axis=0) # Compute sum of each column; prints "[4 6]"
print np.sum(x, axis=1) # Compute sum of each row; prints "[3 7]"

```

想要了解更多函数，可以查看[文档](#)。

除了计算，我们还常常改变数组或者操作其中的元素。其中将矩阵转置是常用的一个，在Numpy中，使用**T**来转置矩阵：

```

import numpy as np

x = np.array([[1,2], [3,4]])
print x      # Prints "[[1 2]
              #          [3 4]]"
print x.T    # Prints "[[1 3]
              #          [2 4]]"

# Note that taking the transpose of a rank 1 array does nothing:
v = np.array([1,2,3])

```



```
print v      # Prints "[1 2 3]"
print v.T    # Prints "[1 2 3]"
```

Numpy还提供了更多操作数组的方法, 请查看[文档](#)。

广播Broadcasting

广播是一种强有力的机制, 它让Numpy可以让不同大小的矩阵在一起进行数学计算。我们常常会有一个小的矩阵和一个大的矩阵, 然后我们会需要用小的矩阵对大的矩阵做一些计算。

举个例子, 如果我们想要把一个向量加到矩阵的每一行, 我们可以这样做:

```
import numpy as np

# We will add the vector v to each row of the matrix x,
# storing the result in the matrix y
x = np.array([[1,2,3], [4,5,6], [7,8,9], [10, 11, 12]])
v = np.array([1, 0, 1])
y = np.empty_like(x)    # Create an empty matrix with the same shape as x

# Add the vector v to each row of the matrix x with an explicit loop
for i in range(4):
    y[i, :] = x[i, :] + v

# Now y is the following
# [[ 2  2  4]
#  [ 5  5  7]
#  [ 8  8 10]
#  [11 11 13]]
print y
```

这样是行得通的, 但是当x矩阵非常大, 利用循环来计算就会变得很慢很慢。我们可以换一种思路:

```
import numpy as np

# We will add the vector v to each row of the matrix x,
# storing the result in the matrix y
x = np.array([[1,2,3], [4,5,6], [7,8,9], [10, 11, 12]])
v = np.array([1, 0, 1])
vv = np.tile(v, (4, 1))    # Stack 4 copies of v on top of each other
print vv                    # Prints "[[1 0 1]"
```

```

#           [1 0 1]
#           [1 0 1]
#           [1 0 1]]"

y = x + vv # Add x and vv elementwise
print y # Prints "[[ 2  2  4
#       [ 5  5  7]
#       [ 8  8 10]
#       [11 11 13]]"
```

Numpy广播机制可以让我们不用创建vv，就能直接运算，看看下面例子：

```

import numpy as np

# We will add the vector v to each row of the matrix x,
# storing the result in the matrix y
x = np.array([[1,2,3], [4,5,6], [7,8,9], [10, 11, 12]])
v = np.array([1, 0, 1])
y = x + v # Add v to each row of x using broadcasting
print y # Prints "[[ 2  2  4]
#       [ 5  5  7]
#       [ 8  8 10]
#       [11 11 13]]"
```

对两个数组使用广播机制要遵守下列规则：

如果数组的秩不同，使用1来将秩较小的数组进行扩展，直到两个数组的尺寸的长度都一样。

如果两个数组在某个维度上的长度是一样的，或者其中一个数组在该维度上长度为1，那么我们就说这两个数组在该维度上是**相容的**。

如果两个数组在所有维度上都是相容的，他们就能使用广播。

如果两个输入数组的尺寸不同，那么注意其中较大的那个尺寸。因为广播之后，两个数组的尺寸将和那个较大的尺寸一样。

在任何一个维度上，如果一个数组的长度为1，另一个数组长度大于1，那么在该维度上，就好像是对第一个数组进行了复制。

如果上述解释看不明白，可以读一读[文档](#)和这个[解释](#)。**译者注：**强烈推荐阅读文档中的例子。

支持广播机制的函数是全局函数。哪些是全局函数可以在[文档](#)中查找。

下面是一些广播机制的使用：

```

import numpy as np
```

```
# Compute outer product of vectors
v = np.array([1,2,3]) # v has shape (3,)
w = np.array([4,5])    # w has shape (2,)
# To compute an outer product, we first reshape v to be a column
# vector of shape (3, 1); we can then broadcast it against w to yield
# an output of shape (3, 2), which is the outer product of v and w:
# [[ 4  5]
#  [ 8 10]
#  [12 15]]
print np.reshape(v, (3, 1)) * w

# Add a vector to each row of a matrix
x = np.array([[1,2,3], [4,5,6]])
# x has shape (2, 3) and v has shape (3,) so they broadcast to (2, 3),
# giving the following matrix:
# [[2 4 6]
#  [5 7 9]]
print x + v

# Add a vector to each column of a matrix
# x has shape (2, 3) and w has shape (2,).
# If we transpose x then it has shape (3, 2) and can be broadcast
# against w to yield a result of shape (3, 2); transposing this result
# yields the final result of shape (2, 3) which is the matrix x with
# the vector w added to each column. Gives the following matrix:
# [[ 5  6  7]
#  [ 9 10 11]]
print (x.T + w).T

# Another solution is to reshape w to be a row vector of shape (2, 1);
# we can then broadcast it directly against x to produce the same
# output.
print x + np.reshape(w, (2, 1))

# Multiply a matrix by a constant:
# x has shape (2, 3). Numpy treats scalars as arrays of shape ();
# these can be broadcast together to shape (2, 3), producing the
# following array:
# [[ 2  4  6]
#  [ 8 10 12]]
print x * 2
```

广播机制能够让你的代码更简洁更迅速，能够用的时候请尽量使用！

Numpy文档

这篇教程涉及了你需要的numpy中的一些重要内容，但是numpy远不止如此。可以查阅[numpy文献](#)来学习更多。

SciPy

Numpy提供了高性能的多维数组，以及计算和操作数组的基本工具。[SciPy](#)基于Numpy，提供了大量的计算和操作数组的函数，这些函数对于不同类型的科学和工程计算非常有用。

熟悉SciPy的最好方法就是阅读[文档](#)。我们会强调对于本课程有用的部分。

图像操作

SciPy提供了一些操作图像的基本函数。比如，它提供了将图像从硬盘读入到数组的函数，也提供了将数组中数据写入的硬盘成为图像的函数。下面是一个简单的例子：

```
from scipy.misc import imread, imsave, imresize

# Read an JPEG image into a numpy array
img = imread('assets/cat.jpg')
print img.dtype, img.shape # Prints "uint8 (400, 248, 3)"

# We can tint the image by scaling each of the color channels
# by a different scalar constant. The image has shape (400, 248, 3);
# we multiply it by the array [1, 0.95, 0.9] of shape (3,);
# numpy broadcasting means that this leaves the red channel unchanged,
# and multiplies the green and blue channels by 0.95 and 0.9
# respectively.
img_tinted = img * [1, 0.95, 0.9]

# Resize the tinted image to be 300 by 300 pixels.
img_tinted = imresize(img_tinted, (300, 300))

# Write the tinted image back to disk
imsave('assets/cat_tinted.jpg', img_tinted)
```

译者注：如果运行这段代码出现类似**ImportError: cannot import name imread**的报错，那么请利用pip进行Pillow的下载，可以解决问题。命令：pip install Pillow。



左边是原始图片，右边是变色和变形的图片。

MATLAB文件

函数`scipy.io.loadmat`和`scipy.io.savemat`能够让你读和写MATLAB文件。具体请查看[文档](#)。

点之间的距离

SciPy定义了一些有用的函数，可以计算集合中点之间的距离。

函数`scipy.spatial.distance.pdist`能够计算集合中所有两点之间的距离：

```

import numpy as np
from scipy.spatial.distance import pdist, squareform

# Create the following array where each row is a point in 2D space:
# [[0 1]
#  [1 0]
#  [2 0]]
x = np.array([[0, 1], [1, 0], [2, 0]])
print x

# Compute the Euclidean distance between all rows of x.
# d[i, j] is the Euclidean distance between x[i, :] and x[j, :],
# and d is the following array:
# [[ 0.          1.41421356  2.23606798]
#  [ 1.41421356  0.          1.          ]
#  [ 2.23606798  1.          0.          ]]
d = squareform(pdist(x, 'euclidean'))
print d

```

具体细节请阅读[文档](#)。

函数`scipy.spatial.distance.cdist`可以计算不同集合中点的距离，具体请查看[文档](#)。

Matplotlib

Matplotlib是一个作图库。这里简要介绍`matplotlib.pyplot`模块，功能和MATLAB的作图功能类似。

绘图

matplotlib库中最重要的函数是**Plot**。该函数允许你做出2D图形，如下：

```

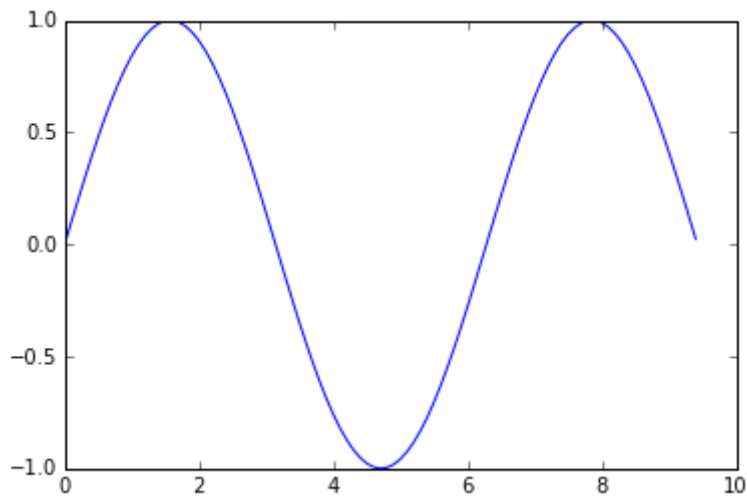
import numpy as np
import matplotlib.pyplot as plt

# Compute the x and y coordinates for points on a sine curve
x = np.arange(0, 3 * np.pi, 0.1)
y = np.sin(x)

# Plot the points using matplotlib
plt.plot(x, y)
plt.show() # You must call plt.show() to make graphics appear.

```

运行上面代码会产生下面的作图:

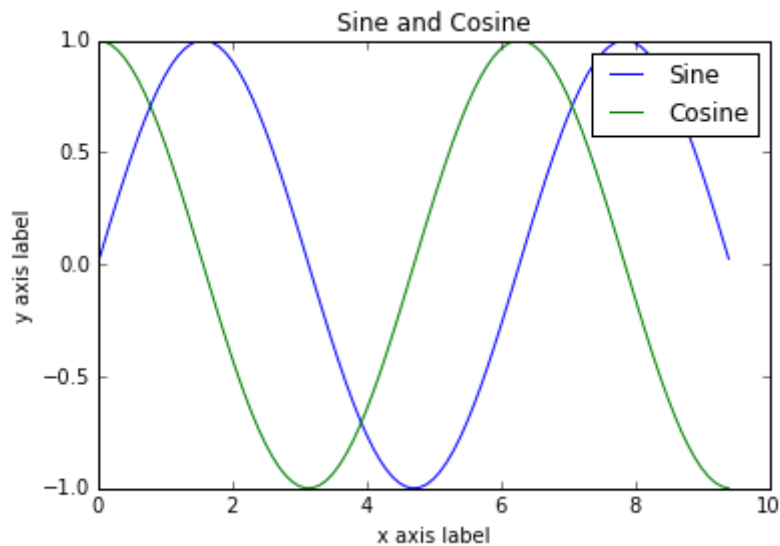


只需要少量工作, 就可以一次画不同的线, 加上标签, 坐标轴标志等。

```
import numpy as np
import matplotlib.pyplot as plt

# Compute the x and y coordinates for points on sine and cosine curves
x = np.arange(0, 3 * np.pi, 0.1)
y_sin = np.sin(x)
y_cos = np.cos(x)

# Plot the points using matplotlib
plt.plot(x, y_sin)
plt.plot(x, y_cos)
plt.xlabel('x axis label')
plt.ylabel('y axis label')
plt.title('Sine and Cosine')
plt.legend(['Sine', 'Cosine'])
plt.show()
```



可以在[文档](#)中阅读更多关于plot的内容。

绘制多个图像

可以使用**subplot**函数来在一幅图中画不同的东西:

```
import numpy as np
import matplotlib.pyplot as plt

# Compute the x and y coordinates for points on sine and cosine curves
x = np.arange(0, 3 * np.pi, 0.1)
y_sin = np.sin(x)
y_cos = np.cos(x)

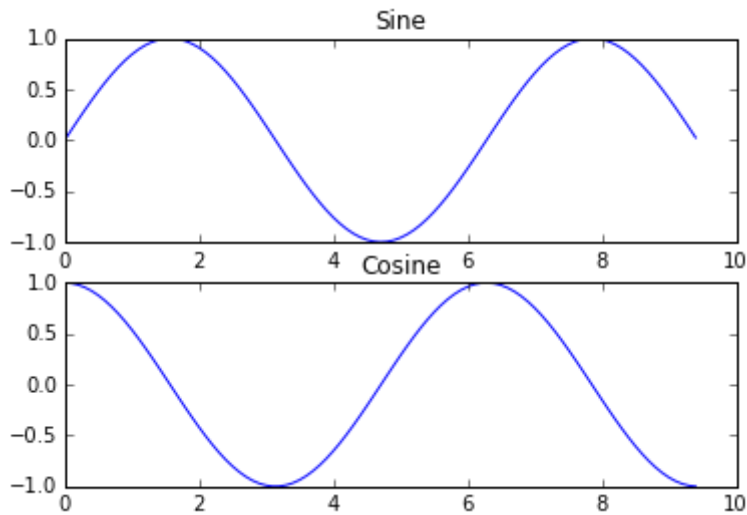
# Set up a subplot grid that has height 2 and width 1,
# and set the first such subplot as active.
plt.subplot(2, 1, 1)

# Make the first plot
plt.plot(x, y_sin)
plt.title('Sine')

# Set the second subplot as active, and make the second plot.
plt.subplot(2, 1, 2)
plt.plot(x, y_cos)
plt.title('Cosine')
```



```
# Show the figure.  
plt.show()
```



关于**subplot**的更多细节，可以阅读[文档](#)。

图像

你可以使用**imshow**函数来显示图像，如下所示：

```
import numpy as np  
from scipy.misc import imread, imresize  
import matplotlib.pyplot as plt  
  
img = imread('assets/cat.jpg')  
img_tinted = img * [1, 0.95, 0.9]  
  
# Show the original image  
plt.subplot(1, 2, 1)  
plt.imshow(img)  
  
# Show the tinted image  
plt.subplot(1, 2, 2)  
  
# A slight gotcha with imshow is that it might give strange results
```

```
# if presented with data that is not uint8. To work around this, we  
# explicitly cast the image to uint8 before displaying it.  
plt.imshow(np.uint8(img_tinted))  
plt.show()
```

