



Chap10 Scientific Computing and Data Processing

Python科学计算与数据分析开发基础

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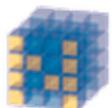
10.1

科学计算生态 系统SciPy

SciPy

特征

- 基于Python的软件生态系统 (ecosystem)
- 开源
- 主要为数学、科学和工程服务



NumPy

Base N-dimensional array
package



SciPy library

Fundamental library for
scientific computing



Matplotlib

Comprehensive 2D Plotting



IPython

Enhanced Interactive Console



Sympy

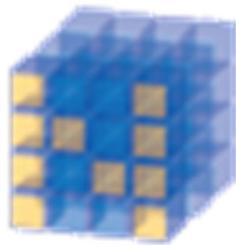
Symbolic mathematics



pandas

Data structures & analysis

NumPy



特征

- 高性能科学计算和数据分析的基础包
- 强大的ndarray对象
- 精巧的函数和ufunc函数
- 适合线性代数和随机数处理等科学计算

S_{ource}

```
>>> import numpy as np  
>>> xArray = np.ones((3, 4))
```

SciPy library



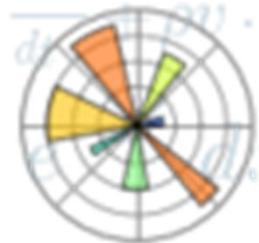
特征

- Python中科学计算程序的核心包
- 有效计算numpy矩阵，让NumPy和SciPy library协同工作
- 致力于科学计算中常见问题的各个工具箱，其不同子模块有不同的应用，如插值、积分、优化和图像处理等

S_{ource}

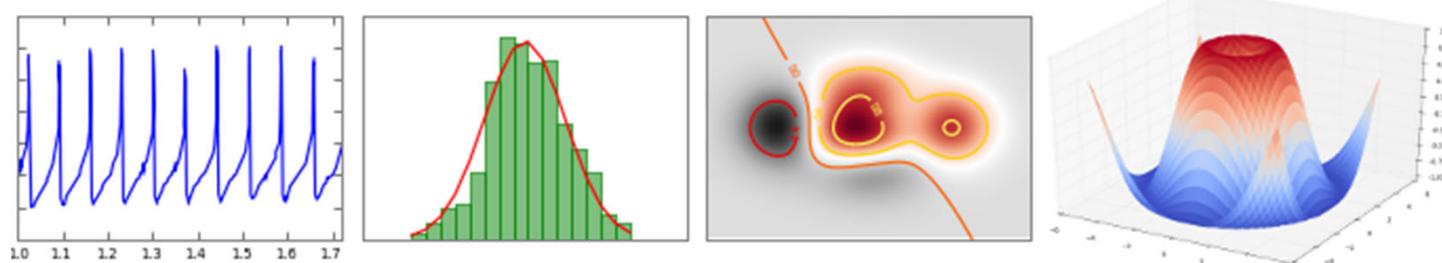
```
>>> import numpy as np
>>> from scipy import linalg
>>> arr = np.array([[1, 2], [3, 4]])
>>> linalg.det(arr)
-2.0
```

Matplotlib



特征

- 基于NumPy
- 二维绘图库，简单快速地生成曲线图、直方图和散点图等形式的图
- 常用的pyplot是一个简单提供类似MATLAB接口的模块



pandas



特征

- 基于 SciPy library和 NumPy
- 高效的Series和DataFrame数据结构
- 强大的可扩展数据操作与分析的Python库
- 高效处理大数据集的切片等功能
- 提供优化库功能读写多种文件格式，如CSV、HDF5

S_{ource}

```
...  
>>> df[2 : 5]  
>>> df.head(4)  
>>> df.tail(3)
```

Home Page

The screenshot shows the SciPy.org website as it would appear in a desktop web browser. The page has a blue header with the SciPy logo and navigation links for "About SciPy", "Getting started", "Documentation", "Install", "Bug reports", "Codes of Conduct", "SciPy conferences", "Topical software", "Citing", "Cookbook", "Blogs", and "NumFOCUS". Below the header, there's a section for "CORE PACKAGES" featuring links to NumPy, SciPy library, Matplotlib, IPython, SymPy, and pandas. The main content area includes sections for "Install", "Getting started", "Documentation", "Report bugs", and "Blogs". It also features icons for NumPy, SciPy library, Matplotlib, IPython, SymPy, and pandas. A "News" section at the bottom lists recent releases: NumPy 1.21.2, SciPy 1.7.1, NumPy 1.21.1, NumPy 1.21.0, and SciPy 1.7.0. Each release link points to "Obtaining NumPy & SciPy libraries".

Python常用的数据结构



其他数据结构?

- **SciPy中的数据结构**



Python原有数据结构的变化

- ndarray (N维数组)
- Series (变长字典)
- DataFrame (数据框)



10.2

NumPy

Python中的数组

- 用list和tuple等数据结构表示数组
 - 一维数组 list = [1,2,3,4]
 - 二维数组 list = [[1,2,3],[4,5,6],[7,8,9]]
- array模块
 - 通过array函数创建数组, array.array("B", range(5))
 - 提供append、insert和read等方法

ndarray

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

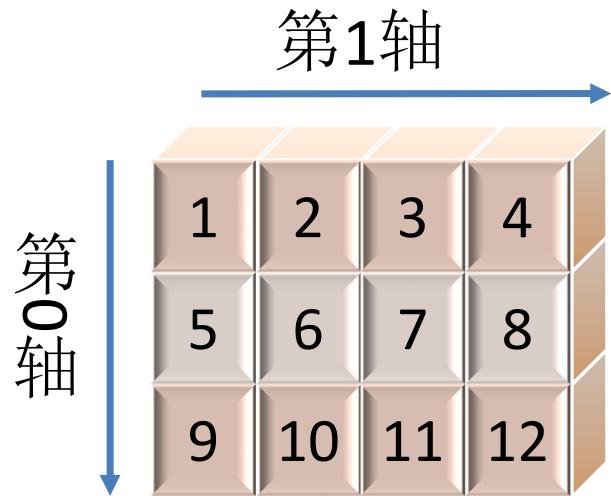
- **ndarray是什么?**

N维数组

- NumPy中基本的数据结构
- 所有元素是同一种类型
- 别名为array
- 利于节省内存和提升计算性能
- 有丰富的函数

10.2.1 ndarray的基本特性

ndarray基本概念



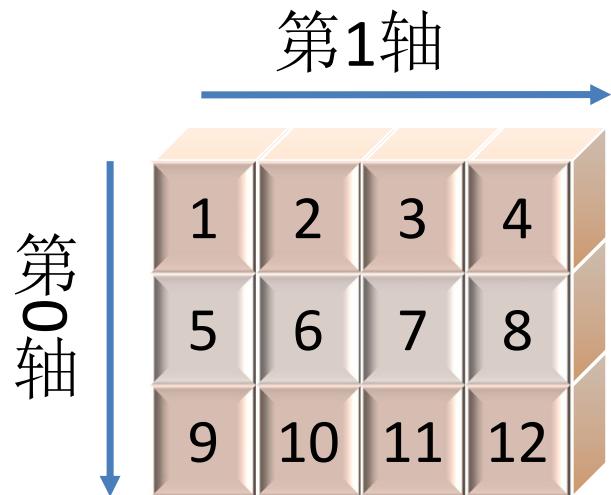
C order vs F order

- **ndarray数组属性**

N维数组

- 形状(dimensions)称为轴(axes), 轴的个数称为秩(rank)
- 沿着第0轴和第1轴操作
 - $\text{axis} = 0$ (按列)
 - $\text{axis} = 1$ (按行)

ndarray基本概念



- **ndarray数组属性**

N维数组

- 基本属性

- ndarray.ndim (秩)
- ndarray.shape (形状)
- ndarray.size (元素总个数)
- ndarray.dtype (元素类型)
- ndarray.itemsize (元素字节大小)

10.2.2 创建 ndarray

ndarray的创建

S_{ource}

```
>>> import numpy as np  
>>> aArray = np.array([1,2,3])  
>>> aArray  
array([1, 2, 3])  
>>> bArray=np.array([(1,2,3),(4,5,6)], dtype ='float32')  
>>> bArray  
array([[1., 2., 3.],  
       [4., 5., 6.]], dtype=float32)  
>>> bArray.ndim, bArray.shape, bArray.dtype  
(2, (2, 3), dtype('float32'))
```

array()函数

ndarray的创建

zeros()
ones()

S_{ource}

```
>>> np.zeros((2, 2))
array([[ 0.,  0.],
       [ 0.,  0.]])
>>> np.ones([2, 3])
array([[ 1.,  1.,  1.],
       [ 1.,  1.,  1.]])
```

ndarray的创建

full()

S_{ource}

```
>>> np.full((2,2), 0)
array([[0, 0],
       [0, 0]])
>>> np.full((2,3), 1, dtype = np.int32)
array([[1, 1, 1],
       [1, 1, 1]], dtype=int32)
>>> np.full((3,3), np.pi)
array([[3.14159265, 3.14159265, 3.14159265],
       [3.14159265, 3.14159265, 3.14159265],
       [3.14159265, 3.14159265, 3.14159265]])
```

ndarray的创建

S_{ource}

```
>>> x = np.array([[1,2,3], [4,5,6]], dtype = np.float32)
>>> np.zeros_like(x)
array([[0., 0., 0.],
       [0., 0., 0.]], dtype=float32)
>>> np.ones_like(x)
array([[1., 1., 1.],
       [1., 1., 1.]], dtype=float32)
>>> np.full_like(x, 5)
array([[5., 5., 5.],
       [5., 5., 5.]], dtype=float32)
```

zeros_like()
ones_like()
full_like()

ndarray的创建

identity()
eye()
diag()

S_{ource}

```
>>> np.identity(3)
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
```



```
>>> np.eye(3)
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
```

S_{ource}

```
>>> np.eye(3, k = 1)
array([[0., 1., 0.],
       [0., 0., 1.],
       [0., 0., 0.]])
```



```
>>> np.eye(4, k = -2)
array([[0., 0., 0., 0.],
       [0., 0., 0., 0.],
       [1., 0., 0., 0.],
       [0., 1., 0., 0.]])
```



```
>>> np.diag(v, k) # v的形式
...
```

ndarray的创建

arange()
linspace()

S_{ource}

```
>>> np.arange(1, 5, 0.5)
array([ 1.,  1.5,  2.,  2.5,  3.,  3.5,  4.,  4.5])
>>> np.linspace(1, 2, 10, endpoint = False)
array([ 1.,  1.1,  1.2,  1.3,  1.4,  1.5,  1.6,  1.7,  1.8,  1.9])
```

ndarray的创建

empty()
random()
normal()
randn()
uniform()
rand()

S_{ource}

```
>>> np.random.random((2, 2))
array([[ 0.79777004,  0.1468679 ],
       [ 0.95838379,  0.86106278]])
>>> np.random.normal(loc=3, scale=3**0.5, size=1000)
>>> np.random.normal(loc=0, scale=1, size=1000)
>>> np.random.randn(1000)
>>> np.random.uniform(low=-5,high=5,size=1000)
>>> # N(3,3), N(0,1), U[-5,5]
```

ndarray的创建

S_{ource}

fromfunction()

```
>>> np.fromfunction(lambda i, j:(i+1)*(j+1), (9,9))
array([[ 1.,  2.,  3.,  4.,  5.,  6.,  7.,  8.,  9.],
       [ 2.,  4.,  6.,  8., 10., 12., 14., 16., 18.],
       [ 3.,  6.,  9., 12., 15., 18., 21., 24., 27.],
       [ 4.,  8., 12., 16., 20., 24., 28., 32., 36.],
       [ 5., 10., 15., 20., 25., 30., 35., 40., 45.],
       [ 6., 12., 18., 24., 30., 36., 42., 48., 54.],
       [ 7., 14., 21., 28., 35., 42., 49., 56., 63.],
       [ 8., 16., 24., 32., 40., 48., 56., 64., 72.],
       [ 9., 18., 27., 36., 45., 54., 63., 72., 81.]])
```

NumPy数组文件存取

```
>>> x = [[1, 2, 3], [4, 5, 6], [7, 8, 9]]
```

```
>>> np.savetxt('arr.txt', x, fmt='%d')
```

```
>>> data = np.loadtxt('arr.txt')
```

1	2	3
4	5	6
7	8	9

10.2.3 ndarray的操作和运算

ndarray的基本操作-基本索引&花式索引



S_{ource}

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

S_{ource}

```
>>> print(aArray[[0, 2]])  
[[1 2 3] fancy indexing  
 [7 8 9]] 花式索引  
>>> print(aArray[[0, 2], 1])  
[2 8]
```

ndarray的基本操作-切片 (索引)



S_{ource}

```
>>> aArray = np.array([(1, 2, 3), (4, 5, 6)])
array([[1, 2, 3],
       [4, 5, 6]])
>>> print(aArray[0: 2])
[[1 2 3]
 [4 5 6]]
>>> print(aArray[:, 0: 2])
[[1 2]
 [4 5]]
>>> print(aArray[1, 0: 2])
[4 5]
```

S_{ource}

```
>>> print(aArray[::-1])
[[4 5 6]
 [1 2 3]]
>>> print(aArray[:, ::-1])
[[3 2 1]
 [6 5 4]]
```

ndarray的基本操作-切片 (索引)



S_{ource}

```
>>> bArray = np.ones((5, 5))
>>> bArray[1: -1, 1: -1] = 0
>>> print(bArray)
[[1. 1. 1. 1. 1.]
 [1. 0. 0. 0. 1.]
 [1. 0. 0. 0. 1.]
 [1. 0. 0. 0. 1.]
 [1. 1. 1. 1. 1.]]
>>> aArray[[0, 1], :] = aArray[[1, 0], :]
>>> aArray
array([[4, 5, 6],
       [1, 2, 3]])
```

数组切片是创建
副本还是视图?

ndarray的基本操作-布尔索引

S_{ource}

```
>>> aArray = np.arange(1, 101)
>>> bArray = aArray[aArray <= 50]
...
>>> aArray[(aArray % 2 == 0) & (aArray > 50)]
...
>>> aArray[(aArray % 2 == 0)] = -1
...
>>> aArray = np.arange(1, 101)
>>> cArray = np.where(aArray % 2 == 0, -1, aArray)
>>> cArray = np.where(aArray % 2 == 0)
```

np.nonzero()
np.argwhere()

ndarray的基本操作-改变数组形状1

S_{ource}

```
>>> aArray = np.array([(1,2,3),(4,5,6)])
>>> aArray.shape
(2, 3)
>>> bArray = aArray.reshape(3,2)
>>> bArray
array([[1, 2],
       [3, 4],
       [5, 6]])
>>> aArray
array([[1, 2, 3],
       [4, 5, 6]])
```

ndarray的基本操作-改变数组形状1

S_{ource}

```
>>> aArray = np.arange(1, 17)  
>>> aArray  
array([ 1,  2,  3, ..., 14, 15, 16])  
>>> aArray.resize(4, 4)  
>>> aArray  
array([[ 1,  2,  3,  4],  
       [ 5,  6,  7,  8],  
       [ 9, 10, 11, 12],  
      [13, 14, 15, 16]])
```

-1的功能



ndarray的基本操作-改变数组形状2

S_{ource}

```
>>> aArray = np.array([(1,2,3),(4,5,6)])
>>> # 数组展平
>>> x = aArray.ravel()  # view
>>> y = aArray.flatten('F')  # copy
```

ndarray的基本操作-数组组合

S_{ource}

```
>>> bArray = np.array([1,3,7])
>>> cArray = np.array([3,5,8])
>>> np.vstack((bArray, cArray))
array([[1, 3, 7],
       [3, 5, 8]])
>>> np.hstack((bArray, cArray))
array([1, 3, 7, 3, 5, 8])
```

ndarray的基本操作-数组分割

S_{ource}

```
>>> dArray = np.arange(1,17).reshape(4,4)
>>> dArray
array([[ 1,  2,  3,  4],
       [ 5,  6,  7,  8],
       [ 9, 10, 11, 12],
       [13, 14, 15, 16]])
>>> np.hsplit(dArray, 2)
>>> np.vsplit(dArray, 2)
>>> np.split(dArray, 2, axis = 1)
>>> np.split(dArray, 2, axis = 0)
```

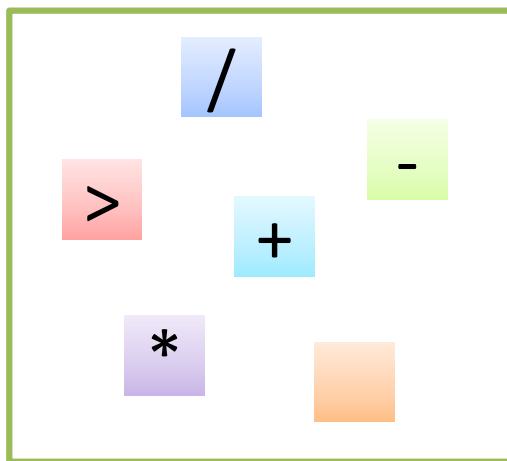
水平方向
垂直方向

ndarray的基本操作-矩阵转置

S_{ource}

```
>>> y = np.array([[7, 3], [6, 4]])
>>> y.T      # y.transpose()
array([[7, 6],
       [3, 4]])
```

ndarray的运算



利用基本运算符

S_{ource}

```
>>> aArray = np.array([(1,2,3),(4,5,6)])
>>> bArray = np.array([(2,2,2),(2,2,2)])
>>> cArray = aArray * bArray
>>> cArray
array([[2, 4, 6],
       [8, 10, 12]])
>>> aArray += bArray
>>> aArray
array([[3, 4, 5],
       [6, 7, 8]])
```

ndarray的运算

S_{ource}

```
>>> x = np.array([[2,3], [3,4]])
>>> y = np.array([[7,3], [6,4]])
>>> np.dot(x, y)
array([[32, 18],
       [45, 25]])
>>> x = np.matrix([[2,3], [3,4]])
>>> y = np.matrix([[7,3], [6,4]])
>>> x * y
matrix([[32, 18],
       [45, 25]])
```

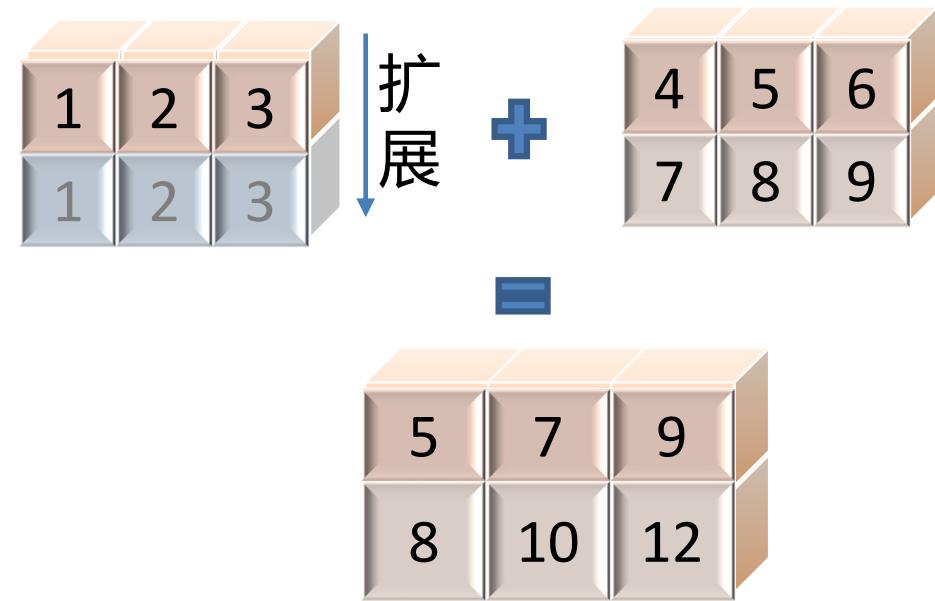
ndarray的运算

广播功能

较小的数组会广播到较大数据的大小，使它们的形状兼容

S_{ource}

```
>>> a = np.array([1,2,3])
>>> b = np.array([[4,5,6],[7,8,9]])
>>> a + b
array([[5, 7, 9],
       [8, 10, 12]])
```



广播

- 若有3名同学各2门课的成绩数组，请计算每门课与该门课均值（mean()方法）的差值。

```
scores = np.array([[98, 76, 87], [76, 88, 91]])
```

处理后输出：

```
array([[ 11., -11.,  0.],
       [-9.,  3.,  6.]])
```

```
scores - scores.mean(axis = 1, keepdims = True)
```

矢量运算&广播例：计算前N项Fibonacci数列

42

$$F_n = \frac{1}{\sqrt{5}} \left(\left(\frac{1+\sqrt{5}}{2} \right)^n - \left(\frac{1-\sqrt{5}}{2} \right)^n \right)$$

Binet's Formula

```
import numpy as np
```

```
def fibonacci(n):
    ratio = (1 + np.sqrt(5)) / 2
    fib = (ratio**n - (-1 / ratio)**n) / np.sqrt(5)
    return fib
```

$N = 20$

```
n = np.arange(1, N + 1)
fib = fibonacci(n)
fib = fib.astype(int)
print(fib)
```

ndarray的运算一简单统计

S_{ource}

```
>>> aArray = np.array([(6,5,4),(3,2,1)])
>>> aArray.sum()
21
>>> np.sum(aArray >= 5)
2
>>> aArray.sum(axis = 0)
array([9, 7, 5])
>>> aArray.sum(axis = 1)
array([ 15, 6])
>>> aArray.min()    # return value
1
>>> aArray.argmin()    # return index
5
```

sum	mean
std	var
min	max
argmin	argmax
cumsum	cumprod

利用基本数组统计方法

ndarray的运算一简单统计

S_{ource}

```
>>> aArray = np.array([(6,5,4),(3,2,1)])  
>>> aArray.mean()  
3.5  
>>> aArray.var()  
2.9166666666666665  
>>> aArray.std()  
1.707825127659933  
>>> np.cumprod(np.arange(1,11))  
array([1, 2, 6, 24, 120, 720, 5040,  
40320, 362880, 3628800], dtype=int32)
```

sum	mean
std	var
min	max
argmin	argmax
cumsum	cumprod

利用基本数组统计方法

ndarray的运算—统计

S_{ource}

```
>>> aArray = np.array([3, 1, 2])
>>> aArray.argsort() # np.argsort(aArray)
array([1, 2, 0], dtype=int64)
>>> aArray[aArray.argsort()]
>>> aArray.argsort()[0]
1
>>> bArray = np.array([(6,4,5),(3,2,8)])
>>> bArray.argsort()
array([[1, 2, 0],
       [1, 0, 2]], dtype=int64)
>>> bArray.argsort(axis = 0)
array([[1, 1, 0],
       [0, 0, 1]], dtype=int64)
```

argsort

利用常用数组统计方法

a.argsort(axis=-1, kind='quicksort')

ndarray的运算—统计

S
ource

```
>>> Z = np.array([1, 3, 7, 3, 2, 2, 3, 2])
>>> count = np.bincount(Z)
>>> count
array([0, 1, 3, 3, 0, 0, 0, 1], dtype=int64)
# 计算Z中出现频次最高的整数
>>> count.argmax()
>>> np.nonzero(count == count.max())
(array([2, 3], dtype=int64),)
```

bincount

利用常用数组统计方法

10.2.4 ufunc函数

ndarray的ufunc函数

- ufunc (universal function, 通用) 是一种能对数组的每一个元素进行操作的函数。NumPy内置的许多ufunc函数都是在C语言级别实现的，计算速度非常快，数据量大时有很大的优势。

Math operations: add, subtract, mod, power, log, ...

Trigonometric functions: sin, cos, tan, tanh, ...

Bit-twiddling functions: bitwise_and, invert, ...

Comparison functions: greater, less, equal, logical_and, ...

Floating functions: isnan, fabs, modf, floor, ...

<https://docs.scipy.org/doc/numpy/reference/ufuncs.html>

ndarray的ufunc函数

File

```
# Filename: prog10-1.py
import time
import math
import numpy as np
x = np.arange(0, 100, 0.01)
t_m1 = time.perf_counter()
for i, t in enumerate(x):
    x[i] = math.pow((math.sin(t)), 2)
t_m2 = time.perf_counter()
y = np.arange(0, 100, 0.01)
t_n1 = time.perf_counter()
y = np.power(np.sin(y), 2)
t_n2 = time.perf_counter()
```

Running time of math: $t_{m2} - t_{m1}$
Running time of numpy: $t_{n2} - t_{n1}$

ndarray的ufunc函数

F_{ile}

```
# Filename: prog10-2.py
import numpy as np
import time
arr1 = np.random.randn(10000000)
arr2 = np.random.randn(10000000)
start = time.perf_counter()
r = 0
for i in range(len(arr1)):
    r += arr1[i] * arr2[i]
print(time.perf_counter() - start, 's')
start = time.perf_counter()
r = np.dot(arr1, arr2)
print(time.perf_counter() - start, 's')
```

4.634805200010305 s
0.0865946999983862 s

将标量函数转换为ufunc函数

- `np.frompyfunc(func, nin, nout)`
`nin`: 参数个数, `int`类型
`nout`: 函数返回对象个数, `int`类型
- Use `frompyfunc` to add broadcasting to the Python function `oct`

```
>>> 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)))
array(['0o12', '0o36', '0o144'], dtype='<U5')
```

思考：构建计算[1,1000]间所有整数的反序数ufunc函数

```
def rev(x):
    return int(str(x)[::-1])
rev_func = np.frompyfunc(rev, 1, 1)
print(rev_func(np.arange(1, 1001)))
```

10.2.5 专门的应用

ndarray的专门应用—线性代数

S
ource

```
>>> import numpy as np
>>> x = np.array([[1,2],
[3,4]])
>>> r1 = np.linalg.det(x)
>>> print(r1)
-2.0
>>> r2 = np.linalg.inv(x)
>>> print(r2)
[[-2.  1. ]
 [ 1.5 -0.5]]
```

dot	矩阵内积
linalg.det	行列式
linalg.inv	逆矩阵
linalg.solve	多元一次方程组求根
linalg.eig	求特征值和特征向量

常用函数示例

求解线性方程组

- 利用NumPy的linalg模块中的solve()函数

例如要求解如下二元一次方程组：

$$-x_0 + 4x_1 = 10$$

$$2x_0 + 3x_1 = 13$$

S
ource

```
>>> a = np.array([[-1,4], [2,3]])
>>> b = np.array([10,13])
>>> x = np.linalg.solve(a, b)
>>> x
array([ 2.,  3.])
```

求解非线性方程组

- 使用scipy.optimize模块中的fsolve()函数来解决。

例如对于如下非线性方程组：

$$2x_0^2 - 3x_1 = 6$$

$$3x_0 + x_1^2 = 25$$

[3. 4.]

F_{ile}

```
from scipy.optimize import fsolve  
  
def f(x):  
    x0, x1 = float(x[0]), float(x[1])  
    return [2*x0**2-3*x1-6, 3*x0+x1**2-25]  
  
x = fsolve(f, [0, 0])  
print(x)
```

10.3

pandas

10.3.1 Series

Series

- 基本特征
 - 由数据和索引组成（有序字典，也称变长字典）

Series()函数

S_{ource}

```
>>> import pandas as pd  
>>> aSer = pd.Series([1, 2.0, 'a'])  
>>> aSer  
0    1  
1    2  
2    a  
dtype: object
```

自定义Series的index

S_{ource}

```
>>> bSer = pd.Series(['apple','peach','lemon'], index = [1,2,3])
>>> bSer
1    apple
2    peach
3    lemon
dtype: object
>>>aSer.index = [1,2,3]
>>> aSer
1    1
2    2
3    a
dtype: object
```

自定义Series的index

S_{ource}

```
>>> bSer.index      # 常进行单独赋值  
Int64Index([1, 2, 3], dtype = 'int64')  
>>> bSer.values  
array(['apple', 'peach', 'lemon'], dtype = object)
```

Series的基本运算

S_{ource}

```
>>> cSer = pd.Series([3, 5, 7], index = ['a', 'b', 'c'])
>>> cSer['b']
5
>>> cSer * 2
a    6
b   10
c   14
dtype: int64
>>> import numpy as np
>>> np.exp(cSer)
a    20.085537
b   148.413159
c  1096.633158
dtype: float64
```

Series的基本运算

切片
基于位置
基于索引

S_{ource}

```
>>> cSer = pd.Series([3, 5, 7], index = ['a', 'b', 'c'])
>>> cSer[1: 2]
b    5
dtype: int64
>>> cSer['a': 'b']
a    3
b    5
dtype: int64
```

Series的数据对齐

S_{ource}

```
>>> data = {'apple':6, 'peach':8, 'lemon':15}  
>>> sindex = ['apple', 'peach', 'orange', 'lemon']  
>>> dSer = pd.Series(data, index = sindex)  
>>> dSer  
apple    6.0  
peach    8.0  
orange    NaN  
lemon    15.0  
dtype: float64
```

S_{ource}

```
>>> pd.isnull(dSer)  
apple    False  
peach    False  
orange    True  
lemon    False  
dtype: bool
```

Series的数据对齐

- **重要功能**
 - 在算术运算中自动对齐不同索引的数据

S
ource

```
>>> eSer = pd.Series({'apple':6, 'peach':8, 'kiwi':20})  
>>> eSer  
apple    6  
peach    8  
kiwi    20  
dtype: int64  
>>> dSer + eSer  
apple    12.0  
kiwi     NaN  
lemon     NaN  
orange     NaN  
peach    16.0  
dtype: float64
```

10.3.2 DataFrame

DataFrame

- 基本特征

- 一个表格型的数据结构（称**数据框**）
- 含有一组有序的列（类似于index）
- 大致可看成共享同一个index的Series集合

	name	pay
0	Mayue	3000
1	Lilin	4500
2	Wuyun	8000

1. 创建和修改DataFrame

DataFrame()函数

S_{ource}

```
>>> data = {'name': ['Mayue', 'Lilin', 'Wuyun'], 'pay': [3000, 4500, 8000]}\n>>> aDF = pd.DataFrame(data)\n>>> aDF\n\n   name    pay\n0 Mayue  3000\n1 Lilin  4500\n2 Wuyun  8000
```

DataFrame的索引和值

S_{ource}

```
>>> data = np.array([('Mayue', 3000), ('Lilin', 4500), ('Wuyun', 8000)])
>>> bDF = pd.DataFrame(data, index = range(1, 4), columns = ['name', 'pay'])
>>> bDF
   name  pay
1 Mayue  3000
2 Lilin  4500
3 Wuyun  8000
>>> bDF.index # 重新赋值即为修改行索引
RangeIndex(start=1, stop=4, step=1)
>>> bDF.columns # 重新赋值即为修改列索引
Index(['name', 'pay'], dtype='object')
>>> bDF.values
array([['Mayue', '3000'],
       ['Lilin', '4500'],
       ['Wuyun', '8000']], dtype=object)
```

设定DataFrame的索引

S_{ource}

```
>>> bDF = pd.DataFrame(data, columns = ['name', 'pay']).set_index('name')
>>> bDF
          pay
name
Mayue    3000
Lilin    4500
Wuyun    8000
>>> bDF = pd.DataFrame(data, index = range(1, 4), columns = ['name', 'pay'])
>>> bDF.set_index('name', inplace = True) # 默认drop参数的值为True， 表示删掉原数据列
>>> bDF
          pay
name
Mayue    3000
Lilin    4500
Wuyun    8000
```

设定DataFrame的索引

S_{ource}

```
>>> bDF = pd.DataFrame(data, index = range(1, 4), columns = ['name', 'pay'])
>>> bDF
   name    pay
1  Mayue  3000
2  Lilin  4500
3  Wuyun  8000
>>> index_new = [1, 3, 2]
>>> bDF = bDF.reindex(index = index_new)
>>> bDF
   name    pay
1  Mayue  3000
3  Wuyun  8000
2  Lilin  4500
>>> columns_new = ['pay', 'name']
>>> bDF = bDF.reindex(columns = columns_new)
>>> bDF
    pay    name
1  3000  Mayue
3  8000  Wuyun
2  4500  Lilin
```

修改DataFrame-添加列

```
>>> aDF
```

	name	pay
0	Mayue	3000
1	Lilin	4500
2	Wuyun	8000

S_{ource}

```
>>> aDF['tax'] = [0.05, 0.05, 0.1]
```

```
>>> aDF
```

	name	pay	tax
0	Mayue	3000	0.05
1	Lilin	4500	0.05
2	Wuyun	8000	0.1

修改DataFrame-添加行

```
>>> aDF
```

```
      name    pay    tax
0    Mayue  3000  0.05
1     Lilin  4500  0.05
2    Wuyun  8000  0.1
```

S_{ource}

```
>>> aDF.loc[5] = {'name': 'Liuxi', 'pay': 5000, 'tax': 0.05}
>>> aDF
      name    pay    tax
0    Mayue  3000  0.05
1     Lilin  4500  0.05
2    Wuyun  8000  0.1
5     Liuxi  5000  0.05
```

修改DataFrame-添加行

```
>>> aDF
```

```
      name    pay    tax  
0   Mayue  3000  0.05  
1     Lilin  4500  0.05  
2    Wuyun  8000  0.1  
5    Liuxi  5000  0.05
```

```
>>> tempDF
```

```
      name    pay    tax  
7   Yeqing  7000  0.1  
9  Qianjie  9500  0.1
```

Source

```
>>> aDF.append(tempDF)
```

```
      name    pay    tax  
0   Mayue  3000  0.05  
1     Lilin  4500  0.05  
2    Wuyun  8000  0.1  
5    Liuxi  5000  0.05  
7   Yeqing  7000  0.1  
9  Qianjie  9500  0.1
```

修改DataFrame-添加行

```
>>> aDF
```

```
          name    pay    tax  
0      Mayue  3000  0.05  
1        Lilin  4500  0.05  
2       Wuyun  8000  0.1  
5       Liuxi  5000  0.05
```

```
>>> tempDF
```

```
          name    pay    tax  
7     Yeqing  7000  0.1  
9   Qianjie  9500  0.1
```

S
ource

```
>>> pieces = [aDF, tempDF]
```

```
>>> pd.concat(pieces)
```

	name	pay	tax
0	Mayue	3000	0.05
1	Lilin	4500	0.05
2	Wuyun	8000	0.1
5	Liuxi	5000	0.05
7	Yeqing	7000	0.1
9	Qianjie	9500	0.1

删除

```
>>> aDF
```

```
      name    pay    tax
0    Mayue  3000  0.05
1     Lilin  4500  0.05
2    Wuyun  8000  0.1
5    Liuxi  5000  0.05
```

S_{ource}

```
>>> aDF.drop(5)
```

```
      name    pay    tax
0    Mayue  3000  0.05
1     Lilin  4500  0.05
2    Wuyun  8000  0.1
```

```
>>> aDF.drop('tax', axis = 1)
```

```
      name    pay
0    Mayue  3000
1     Lilin  4500
2    Wuyun  8000
5    Liuxi  5000
```

inplace = True

修改DataFrame

```
>>> aDF
```

```
      name    pay    tax  
0   Mayue  3000  0.05  
1     Lilin  4500  0.05  
2    Wuyun  8000  0.1  
5    Liuxi  5000  0.05
```

S
ource

```
>>> aDF['tax'] = 0.03
```

```
>>> aDF
```

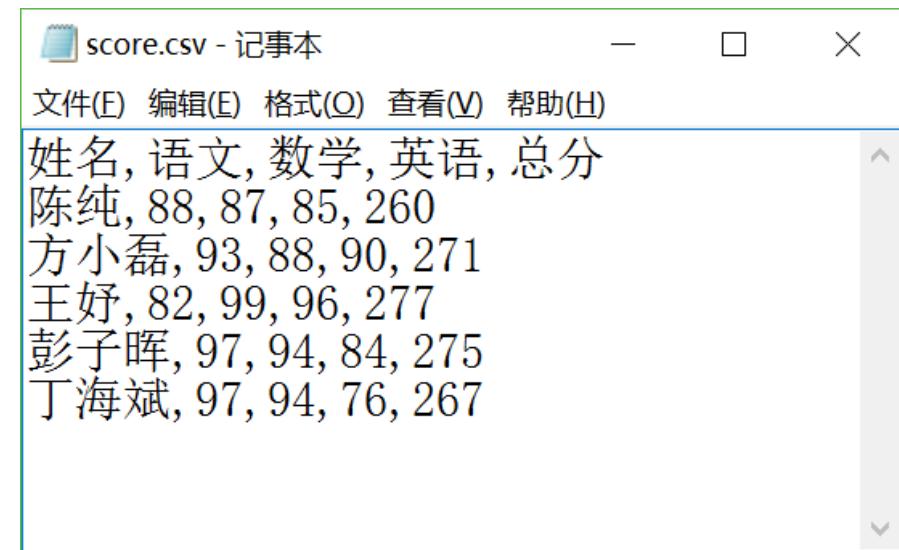
```
      name    pay    tax  
0   Mayue  3000  0.03  
1     Lilin  4500  0.03  
2    Wuyun  8000  0.03  
5    Liuxi  5000  0.03
```

```
>>> aDF.loc[5] = ['Liuxi', 9800, 0.05]
```

```
      name    pay    tax  
0   Mayue  3000  0.03  
1     Lilin  4500  0.03  
2    Wuyun  8000  0.03  
5    Liuxi  9800  0.05
```

2.DataFrame数据文件存取

	A	B	C	D	E
1	姓名	语文	数学	英语	总分
2	陈纯	88	87	85	260
3	方小磊	93	88	90	271
4	王好	82	99	96	277
5	彭子晖	97	94	84	275
6	丁海斌	97	94	76	267



score.csv - 记事本

文件(E) 编辑(E) 格式(O) 查看(V) 帮助(H)

姓名, 语文, 数学, 英语, 总分
陈纯, 88, 87, 85, 260
方小磊, 93, 88, 90, 271
王好, 82, 99, 96, 277
彭子晖, 97, 94, 84, 275
丁海斌, 97, 94, 76, 267

score.csv

DataFrame数据存取-读csv文件

S_{ource}

```
>>> import pandas as pd  
>>> data = pd.read_csv('score.csv', encoding = 'gb2312')  
>>> data
```

	姓名	语文	数学	英语	总分
0	陈纯	88	87	85	260
1	方小磊	93	88	90	271
2	王好	82	99	96	277
3	彭子晖	97	94	84	275
4	丁海斌	97	94	76	267

如何将姓名作为index?

DataFrame数据存取-写csv文件

File

```
# Filename: to_csv.py
import pandas as pd
df = pd.DataFrame(data)
df.to_csv('score_copy.csv')
```

DataFrame数据存取-读写excel文件

F_{ile}

```
# Filename: excel_rw.py
import pandas as pd
df = pd.read_excel('score.xlsx')
df.to_excel('score.xlsx', sheet_name = 'score')
```

DataFrame数据存取-读写excel文件

A	B	C	D	E	F	
1	name	Math	Physics	English	Python	PE
2	stu1		73	92	82	95
3	stu2	92	95	88	96	85
4	stu3	90	92	93	95	90
5	stu4	83	93	86	85	60
6	stu5	87		70	93	75
7	stu6	95	87	90	98	80

S
ource

```
>>> import pandas as pd  
>>> df = pd.read_excel('score.xlsx', index_col = 'name')  
>>> df
```

		Math	Physics	English	Python	PE
	name					
stu1		Nan	73.0	92	82	95
stu2		92.0	95.0	88	96	85
stu3		90.0	92.0	93	95	90
stu4		83.0	93.0	86	85	60
stu5		87.0	Nan	70	93	75
stu6		95.0	87.0	90	98	80

判断重复行 `df.duplicated()`

删除重复行 `df.drop_duplicates([某列索引])`

数据清洗——处理缺失值

A	B	C	D	E	F	
1	name	Math	Physics	English	Python	PE
2	stu1		73	92	82	95
3	stu2	92	95	88	96	85
4	stu3	90	92	93	95	90
5	stu4	83	93	86	85	60
6	stu5	87		70	93	75
7	stu6	95	87	90	98	80

S_{ource}

```
>>> df.dropna() # 返回不包含NaN的行, df不变  
          Math Physics English Python PE  
name  
stu2 92.0   95.0    88    96  85  
stu3 90.0   92.0    93    95  90  
stu4 83.0   93.0    86    85  60  
stu6 95.0   87.0    90    98  80
```

数据预处理——处理缺失值

A	B	C	D	E	F	
1	name	Math	Physics	English	Python	PE
2	stu1		73	92	82	95
3	stu2	92	95	88	96	85
4	stu3	90	92	93	95	90
5	stu4	83	93	86	85	60
6	stu5	87		70	93	75
7	stu6	95	87	90	98	80

thresh参数

S_{ource}

>>> df.dropna(how = 'all') # 返回不全为NaN的行,
df不变

	Math	Physics	English	Python	PE
name					
stu1	NaN	73.0	92	82	95
stu2	92.0	95.0	88	96	85
stu3	90.0	92.0	93	95	90
stu4	83.0	93.0	86	85	60
stu5	87.0	NaN	70	93	75
stu6	95.0	87.0	90	98	80

数据预处理——处理缺失值

	A	B	C	D	E	F
1	name	Math	Physics	English	Python	PE
2	stu1		73	92	82	95
3	stu2	92	95	88	96	85
4	stu3	90	92	93	95	90
5	stu4	83	93	86	85	60
6	stu5	87		70	93	75
7	stu6	95	87	90	98	80

S_{ource}

```
>>> df.fillna(0)      # 用0填充NaN
```

	Math	Physics	English	Python	PE
name					
stu1	0.0	73.0	92	82	95
stu2	92.0	95.0	88	96	85
stu3	90.0	92.0	93	95	90
stu4	83.0	93.0	86	85	60
stu5	87.0	0.0	70	93	75
stu6	95.0	87.0	90	98	80

数据预处理——处理缺失值

	A	B	C	D	E	F
1	name	Math	Physics	English	Python	PE
2	stu1		73	92	82	95
3	stu2	92	95	88	96	85
4	stu3	90	92	93	95	90
5	stu4	83	93	86	85	60
6	stu5	87		70	93	75
7	stu6	95	87	90	98	80

S_{ource}

```
>>> df.fillna(df.mean()) # 用该列数据的平均值填充  
NaN
```

	Math	Physics	English	Python	PE
name					
stu1	89.4	73.0	92	82	95
stu2	92.0	95.0	88	96	85
stu3	90.0	92.0	93	95	90
stu4	83.0	93.0	86	85	60
stu5	87.0	88.0	70	93	75
stu6	95.0	87.0	90	98	80

数据预处理——处理缺失值

	A	B	C	D	E	F
1	name	Math	Physics	English	Python	PE
2	stu1		73	92	82	95
3	stu2	92	95	88	96	85
4	stu3	90	92	93	95	90
5	stu4	83	93	86	85	60
6	stu5	87		70	93	75
7	stu6	95	87	90	98	80

S_{ource}

```
>>> df.fillna(method = 'bfill') # 指定缺失值的填充方向  
          Math Physics English Python PE
```

name

```
stu1 92.0    73.0    92     82  95  
stu2 92.0    95.0    88     96  85  
stu3 90.0    92.0    93     95  90  
stu4 83.0    93.0    86     85  60  
stu5 87.0    87.0    70     93  75  
stu6 95.0    87.0    90     98  80
```

3.数据预处理——处理缺失值

	A	B	C	D	E	F
1	name	Math	Physics	English	Python	PE
2	stu1		73	92	82	95
3	stu2	92	95	88	96	85
4	stu3	90	92	93	95	90
5	stu4	83	93	86	85	60
6	stu5	87		70	93	75
7	stu6	95	87	90	98	80

S_{ource}

```
>>>df.fillna(method = 'bfill', inplace = True)
```

```
>>> df
```

	Math	Physics	English	Python	PE
name					
stu1	92.0	73.0	92	82	95
stu2	92.0	95.0	88	96	85
stu3	90.0	92.0	93	95	90
stu4	83.0	93.0	86	85	60
stu5	87.0	87.0	70	93	75
stu6	95.0	87.0	90	98	80

3.数据预处理——数值规约之抽样

S_{ource}

```
>>> from sklearn import datasets  
>>> iris = datasets.load_iris()  
>>> iris_df = pd.DataFrame(iris.data, columns = ['sepal length',  
'sepal width', 'petal length', 'petal width'])  
>>> iris_df['label'] = iris.target  
>>> iris_df.sample(n = 20) # 不放回随机抽样20条记录  
>>> iris_df.sample(frac = 0.3) # 不放回随机抽样30%的记录
```

4.数据选择

	code		name	lasttrade
0	MMM		3M	195.80
1	AXP	American Express		76.80
2	AAPL		Apple	153.06
3	BA		Boeing	180.76
4	CAT	Caterpillar		102.43
5	CVX		Chevron	106.52
6	CSCO		Cisco	31.21
7	KO		Coca-Cola	43.90
8	DIS	Disney		107.52
9	DD	E I du Pont de Nemours and Co		77.82
10	XOM		Exxon Mobil	81.93
11	GE	General Electric		28.05
12	GS	Goldman Sachs		215.39
13	HD		Home Depot	156.30
14	IBM		IBM	151.98
15	INTC		Intel	35.40
16	JNJ	Johnson & Johnson		127.00
17	JPM		JPMorgan Chase	84.78
18	MCD		McDonald's	148.15
19	MRK		Merck	63.78
20	MSFT		Microsoft	67.69
21	NKE		Nike	51.77
22	PFE		Pfizer	32.46
23	PG	Procter & Gamble		86.24
24	TRV	Travelers Companies Inc		120.79
25	UTX		United Technologies	121.16
26	UNH		UnitedHealth	172.59
27	VZ		Verizon	45.42
28	V		Visa	92.48
29	WMT		Wal-Mart	78.77

选择方式

- 选择行
- 选择列
- 选择区域
- 筛选 (条件选择)

	close	high	low	open	volume
2016-05-23	63.590000	64.099998	63.560001	63.860001	3074100
2016-05-24	64.870003	65.099998	63.790001	63.790001	3946100
2016-05-25	65.309998	65.760002	65.010002	65.040001	5755900
2016-05-26	65.230003	65.370003	64.949997	65.290001	3593500
2016-05-27	65.519997	65.699997	65.330002	65.389999	3925700
2016-05-31	65.760002	65.919998	65.400002	65.699997	5256000
2016-06-01	65.910004	65.959999	65.180000	65.760002	3816000
2016-06-02	66.410004	66.410004	65.599998	65.860001	3052200
2016-06-03	65.489998	65.820000	64.769997	65.529999	4336100
2016-06-06	65.940002	66.199997	65.500000	65.550003	3915200
2016-06-07	65.889999	66.599998	65.879997	66.150002	3779500
2016-06-08	66.260002	66.580002	65.940002	65.940002	2601100
2016-06-09	65.709999	65.779999	64.900002	65.720001	3883800
2016-06-10	64.970001	65.480003	64.709999	65.260002	3939100
2016-06-13	63.669998	64.889999	63.630001	64.800003	5883400
2016-06-14	61.070000	63.660000	60.380001	63.590000	12323200
2016-06-15	61.419998	62.160000	60.860001	61.470001	5979900

DataFrame数据选择-选择行

- 选择行

- 花式索引
- 切片 (基于索引/位置)
- 专门的方法

S_{ource}

```
>>> df
      姓名 语文 数学 英语 总分
a 陈纯 88 87 85 260
b 方小磊 93 88 90 271
c 王妤 82 99 96 277
d 彭子晖 97 94 84 275
e 丁海斌 97 94 76 267
```

```
>>> df[['a', 'b', 'c']]
>>> df['a':'c']
>>> df[0: 3]
>>> df.head(3)
```

DataFrame数据选择-选择列

- 选择列
– 列名

```
>>> df
```

	姓名	语文	数学	英语	总分
a	陈纯	88	87	85	260
b	方小磊	93	88	90	271
c	王妤	82	99	96	277
d	彭子晖	97	94	84	275
e	丁海斌	97	94	76	267



```
>>> df['姓名']
```

```
>>> df.姓名
```

不支持

`df['姓名', '语文']`

`df['语文': '英语']`

支持

`df[['姓名', '语文']]`

DataFrame数据选择-选择区域

```
>>> df
```

	姓名	语文	数学	英语	总分
a	陈纯	88	87	85	260
b	方小磊	93	88	90	271
c	王好	82	99	96	277
d	彭子晖	97	94	84	275
e	丁海斌	97	94	76	267

• 选择区域

- 标签 (loc)
- 位置 (iloc)

S_{ource}

```
>>> df.loc['b': 'd', '语文': '英语']  
>>> df.iloc[1: 4, 1: 4]
```

DataFrame数据选择-选择区域

```
>>> df
```

	姓名	语文	数学	英语	总分
a	陈纯	88	87	85	260
b	方小磊	93	88	90	271
c	王好	82	99	96	277
d	彭子晖	97	94	84	275
e	丁海斌	97	94	76	267

- 选择区域-行或列

- 标签 (loc)
- 位置 (iloc)



单独列索
引用[]

```
>>> df.loc['a': 'c',]  
>>> df.loc[:, ['语文', '数学']]  
>>> df.iloc[:, [1, 2, 3]]
```

常用基于索引处理数据方式

S
ource

```
>>> temp_index = df2.index
>>> temp_index
Index(['b', 'd', 'e'], dtype='object')
>>> df.loc[temp_index]
   姓名 语文 数学 英语 总分
b 方小磊 93 88 90 271
d 彭子晖 97 94 84 275
e 丁海斌 97 94 76 267
```

DataFrame数据选择-选择区域-重新索引

```
>>> df
```

	姓名	语文	数学	英语	总分
a	陈纯	88	87	85	260
b	方小磊	93	88	90	271
c	王妤	82	99	96	277
d	彭子晖	97	94	84	275
e	丁海斌	97	94	76	267

S
ource

```
>>> df.iloc[:, [0, 2, 1, 3, 4]]
```

	姓名	数学	语文	英语	总分
a	陈纯	87	88	85	260
b	方小磊	88	93	90	271
c	王妤	99	82	96	277
d	彭子晖	94	97	84	275
e	丁海斌	94	97	76	267

```
>>> df.reindex(columns = ['姓名',  
'数学', '语文', '英语', '总分']) #不要总分
```

```
>>> df.reindex(columns = ['姓名',  
'数学', '语文', '英语', '总分'])
```

DataFrame数据选择-条件筛选

```
>>> df
      姓名 语文 数学 英语 总分
a 陈纯 88 87 85 260
b 方小磊 93 88 90 271
c 王好 82 99 96 277
d 彭子晖 97 94 84 275
e 丁海斌 97 94 76 267
```

找出索引值在'b'~'d'
之间（包括'b'和'd'）
并且数学成绩大于等于
90的学生记录

S_{ource}

```
>>> df[(df.index >= 'b') & (df.index <= 'd') & (df.数学 >= 90)]
```

DataFrame数据选择-条件筛选

S_{ource}

```
>>> A = iris_df[iris_df.label == 0].sample(frac = 0.3)
>>> B = iris_df[iris_df.label == 1].sample(frac = 0.2)
>>> C = A.append(B)
>>> C
```

	sepal length	sepal width	petal length	petal width	label
48	5.3	3.7	1.5	0.2	0
32	5.2	4.1	1.5	0.1	0
...					
62	6.0	2.2	4.0	1.0	1
59	5.2	2.7	3.9	1.4	1
91	6.1	3.0	4.6	1.4	1

```
>>> C.shape  
(25, 5)
```

分层抽样

DataFrame数据选择-筛选

```
>>> df
   姓名 语文 数学 英语 总分
a 陈纯 88 87 85 260
b 方小磊 93 88 90 271
c 王妤 82 99 96 277
d 彭子晖 97 94 84 275
e 丁海斌 97 94 76 267
```

1. 查找陈纯和彭子晖的成绩记录；
2. 查找所有陈姓同学的成绩记录

S
ource

```
>>> df[df.姓名.isin(['陈纯', '彭子晖'])]
>>> df[df['姓名'].str.contains('^陈')]
```

10.3.3 Series和DataFrame 数据统计与分析

S_{ource}

```
import pandas as pd  
>>> dir(pd.Series)  
[..., 'head', ..., 'index', ..., 'stack', 'std', ..., 'where', ...]  
>>> dir(pd.DataFrame)  
[..., 'head', ..., 'index', ..., 'stack', 'std', ..., 'to_csv', ...]
```

数据统计与分析-简单统计

```
>>> df  
      姓名 语文 数学 英语 总分  
a 陈纯 88 87 85 260  
b 方小磊 93 88 90 271  
c 王妤 82 99 96 277  
d 彭子晖 97 94 84 275  
e 丁海斌 97 94 76 267
```

S
ource

```
>>> df.mean()
```

语文 91.4

数学 92.4

英语 86.2

总分 270.0

dtype: float64

```
>>> df.数学.mean()
```

92.4

数据统计与分析-排序

S
ource

```
>>> df.sort_values(by = '总分')
```

	姓名	语文	数学	英语	总分
a	陈纯	88	87	85	260
e	丁海斌	97	94	76	267
b	方小磊	93	88	90	271
d	彭子晖	97	94	84	275
c	王妤	82	99	96	277

```
>>> df.sort_values(by = '总分')[3].姓名
```

a	陈纯
e	丁海斌
b	方小磊

Name: 姓名, dtype: object

数据统计与分析-简单统计

统计数学成绩大于等于90的学生每门课程（包括总分）的平均值

统计总分大于等于270的学生人数



```
>>> df[(df.数学 >= 90)].mean()  
语文    92.000000  
数学    95.666667  
英语    85.333333  
总分    273.000000  
dtype: float64  
>>> len(df[(df.总分 >= 270)])  
3
```

数据统计与分析-describe和info

S
ource

```
>>> df.describe()
```

	语文	数学	英语	总分
count	5.000000	5.000000	5.000000	5.000000
mean	91.400000	92.400000	86.200000	270.000000
std	6.426508	4.929503	7.42967	6.78233
min	82.000000	87.000000	76.000000	260.000000
25%	88.000000	88.000000	84.000000	267.000000
50%	93.000000	94.000000	85.000000	271.000000
75%	97.000000	94.000000	90.000000	275.000000
max	97.000000	99.000000	96.000000	277.000000

```
>>> df.info()
```

...

数据统计与分析- value_counts

S_{ource}

```
>>> df.数学.value_counts()  
94    2  
88    1  
99    1  
87    1  
Name: 数学, dtype: int64
```

数据统计与分析-分组

按总分是否
大于等于
270为界将
等级分为A
和B两级

.groups属性

S_{ource}

```
>>> mark = ['A' if item >= 270 else 'B' for item in df.总分]  
>>> df.姓名.groupby(mark).count()  
等级  
A 3  
B 2  
Name: 姓名, dtype: int64
```

```
# 或将等级列添加到数据中  
>>> df['等级'] = mark  
>>> df.groupby('等级').姓名.count()
```

数据统计与分析-分组

S_{ource}

```
>>> df.groupby('等级').mean()
          语文    数学    英语    总分
等级
A   90.666667  93.666667  90.0  274.333333
B   92.500000  90.500000  80.5  263.500000
>>> df.groupby('等级')[['语文', '英语']].mean()
          语文    英语
等级
A   90.666667  90.0
B   92.500000  80.5
```

数据统计与分析-分组

S_{ource}

```
>>> df.groupby('等级')[['语文', '英语']].agg(['mean', 'max'])  
          语文    英语  
          mean max  mean max
```

等级	语文	英语	mean	max	mean	max
A	90.666667	97	90.0	96		
B	92.500000	97	80.5	85		

```
>>> df.groupby('等级').agg({'语文': ['mean', 'max'], '英语': ['min']})  
          语文    英语  
          mean max  min
```

等级	语文	英语	mean	max	min
A	90.666667	97	90.0	96	84
B	92.500000	97	92.5	97	76

多函数聚合agg([m1, m2])方法

数据统计与分析-分组

S_{ource}

```
>>> def ranging(x):
        return x.max() - x.min()
>>> df.groupby('等级')[['语文', '英语']].agg(['mean', 'max', ranging])
          语文      英语
          mean max ranging  mean max ranging
等级
A  90.666667  97      15  90.0  96      12
B  92.500000  97      9  80.5  85      9
```

数据统计与分析-groupby&apply

apply方法可对 DataFrame对象进行操作，既可作用于行或列，也可作用于Series的每一个元素上



```
>>> df.groupby('等级').apply(len)
>>> df.loc[:, ['a', 'c']].apply(np.float32)

   a   c
0  3.0  1.0
1  1.0  3.0
2  8.0  1.0
3  2.0  2.0
```

数据统计与分析-透视

- 从不同层面查看表格数据的汇总信息
- pandas中常用pivot_table()函数来对数据进行透视实现分组的功能

S
ource

```
>>> pd.pivot_table(df, index = '等级')  
          总分    数学    英语    语文  
等级
```

```
A  274.333333  93.666667  90.0  90.666667  
B  263.500000  90.500000  80.5  92.500000
```

```
>>> pd.pivot_table(df, values=['语文', '英语'], index = '等级',  
aggfunc = [np.mean, max])
```

```
          mean      max  
          英语    语文    英语    语文  
等级
```

```
A  90.0  90.666667  96  97  
B  80.5  92.500000  85  97
```

数据统计与分析-透视



```
>>> data = pd.DataFrame({'A': ['one', 'two', 'one', 'two', 'one', 'two', 'one', 'one'], 'B': ['red',  
'blue', 'white', 'red', 'red', 'blue', 'white', 'blue'], 'C': [54, 66, 78, 35, 98, 102, 105, 97]})  
>>> data  
      A    B    C  
0  one  red   54  
1  two blue   66  
2  one white  78  
...  
>>> pd.pivot_table(data, values = 'C', index = 'A', columns = 'B', fill_value = 0)  
>>> pd.pivot_table(data, values = 'C', index = 'A', columns = 'B', fill_value = 0, margins = True)
```

columns参数用于设置列层次的属性

数据统计与分析-合并

- 纵向连接（合并）：df1.append(df2)和pd.concat(df1, df2)
- 横向连接（合并）：pd.merge()

pd.merge(df_left, df_right, how='inner', on=None, left_on=None, right_on=None)

数据统计与分析-合并

```
>>> stus # 学生信息表  
    学号 姓名 性别 年龄  
0 1001 王萌 女 18  
1 1002 马小军 男 17  
2 1003 张弛 男 19  
3 1004 刘星 男 19  
4 1005 张恒 女 18  
>>> scores # 学生成绩表  
    学号 科目 成绩  
0 1001 数学 98  
1 1002 数学 87  
2 1003 英语 85  
3 1005 数学 92  
4 1005 体育 85
```

```
>>> pd.merge(stus, scores)  
    学号 姓名 性别 年龄 科目 成绩  
0 1001 王萌 女 18 数学 98  
1 1002 马小军 男 17 数学 87  
2 1003 张弛 男 19 英语 85  
3 1005 张恒 女 18 数学 92  
4 1005 张恒 女 18 体育 85
```

数据统计与分析-corr

S_{ource}

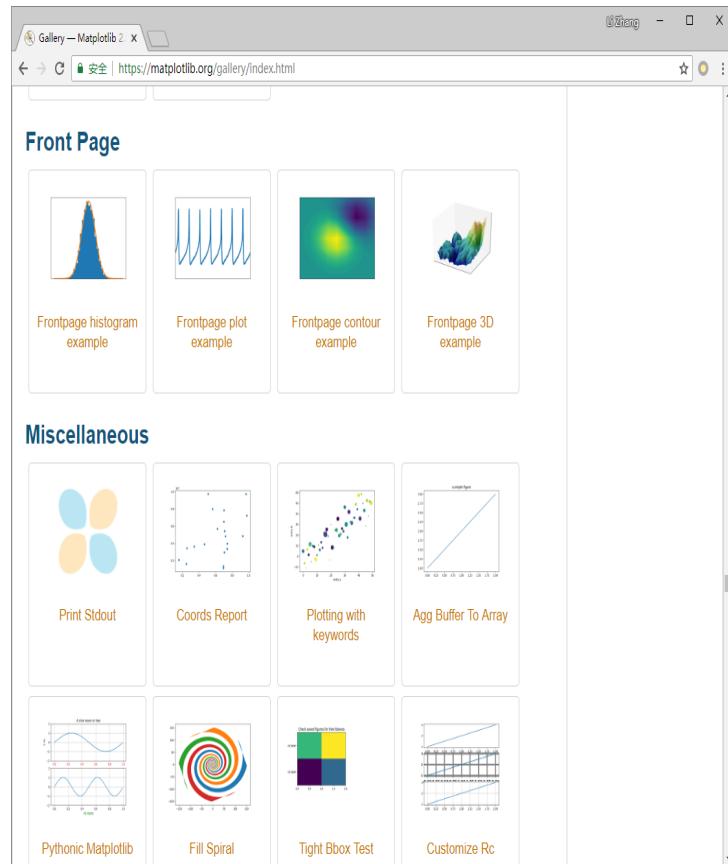
```
>>> df.corr()
```

	语文	数学	英语	总分
语文	1.000000	-0.258843	-0.792723	-0.108978
数学	-0.258843	1.000000	0.236180	0.740275
英语	-0.792723	0.236180	1.000000	0.515971
总分	-0.108978	0.740275	0.515971	1.000000

10.4

Matplotlib及相关可视化包

Matplotlib绘图



- Matplotlib绘图

最著名Python绘图库，主要用于二维绘图

- 画图质量高
- 方便快捷的绘图模块

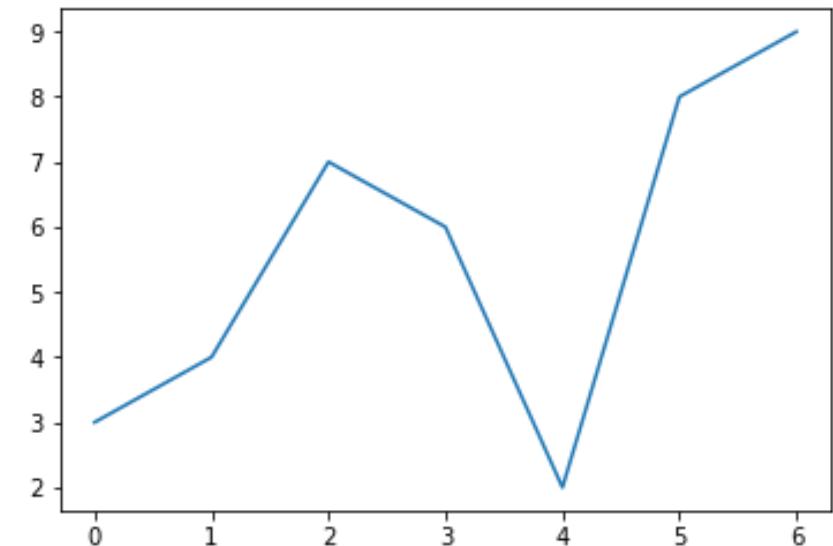
- 绘图API——pyplot模块

10.4.1 Matplotlib绘图基本方法

折线图

S
ource

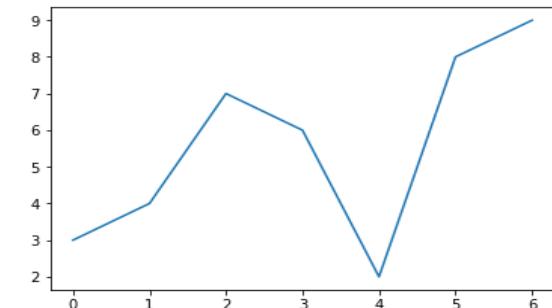
```
>>> import matplotlib.pyplot as plt  
>>> plt.plot([3, 4, 7, 6, 2, 8, 9])  
>>> plt.show() # 阻塞/交互模式
```



```
plt.plot(range(7), [3, 4, 7, 6, 2, 8, 9])
```

一些概念

- 画板 (Figure) : 默认生成一个编号为1的画板，一个画板中可包含多个坐标系
- 坐标系 (Axes) : 用于绘图，包括各种绘图元素 (Artist)
- 手动创建一个画板并使用默认坐标系绘图
`plt.figure()`
- 手动创建画板和坐标系，并设置它们的属性
`plt.figure(figsize=(6, 6), dpi=150)`
`plt.axes((0.1, 0.1, 0.8, 0.8)) # left, bottom, width, height`



一些概念

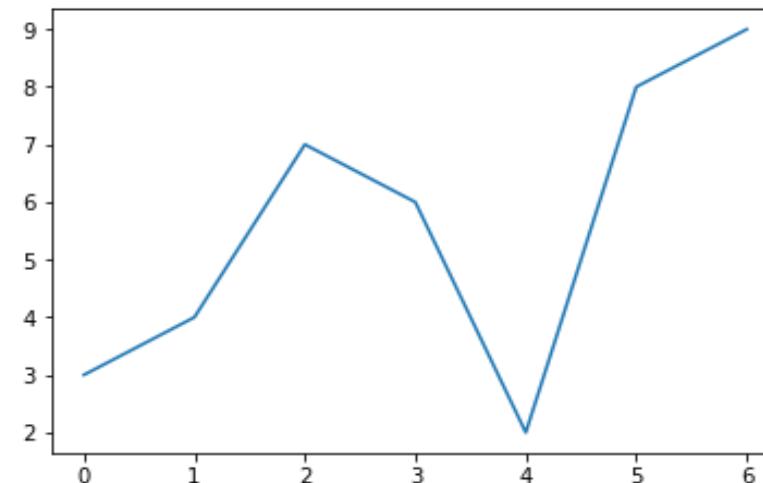
- 使用多个画板绘制多张图（使用默认坐标系）

```
plt.figure(1) # 可再次使用该语句调用此画板继续在其上绘图
```

```
plt.plot([3, 4, 7, 6, 2, 8, 9])
```

```
plt.figure(2)
```

```
plt.plot([3, 4, 8, 6, 2, 8, 5])
```

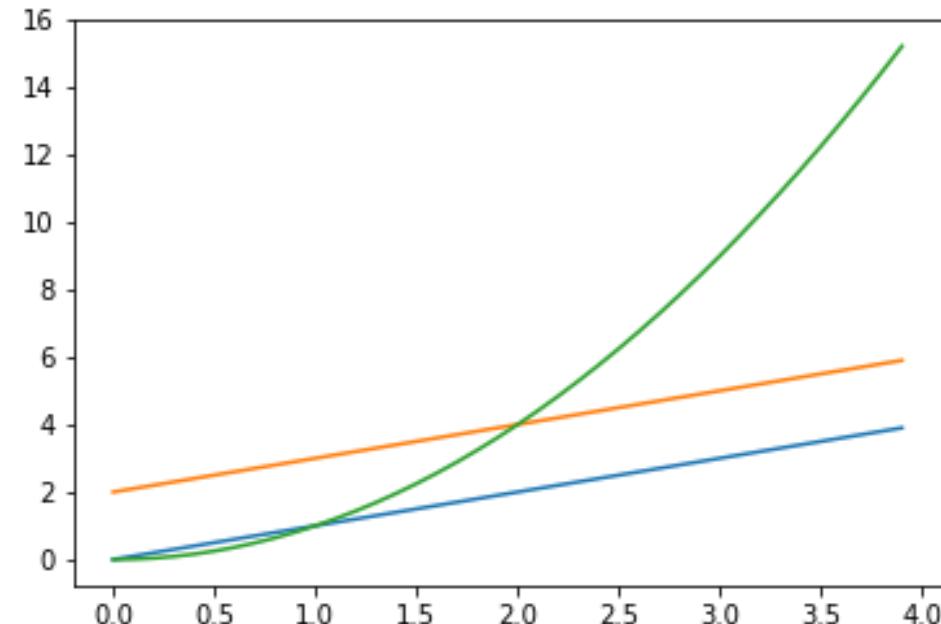


折线图-绘制多组数据

- NumPy数组也可以作为 Matplotlib的参数
- 多组成对数据绘图

S_{ource}

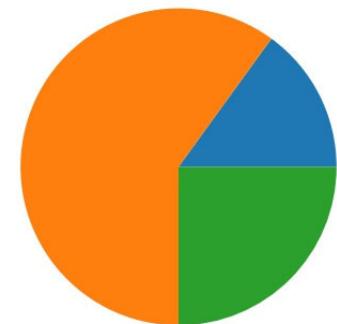
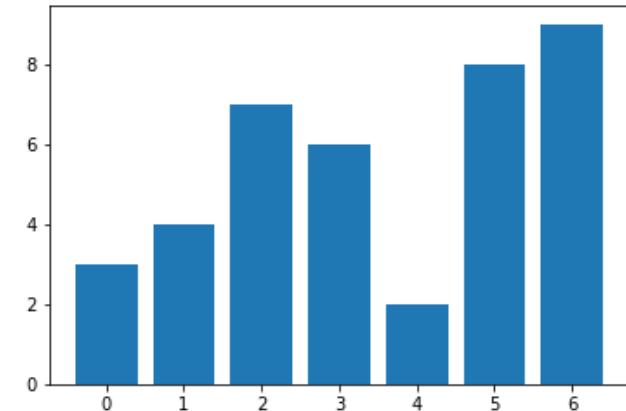
```
>>> import numpy as np  
>>> import matplotlib.pyplot as plt  
>>> t=np.arange(0.,4.,0.1)  
>>> plt.plot(t, t, t, t+2, t, t**2)
```



绘制其他类型的图

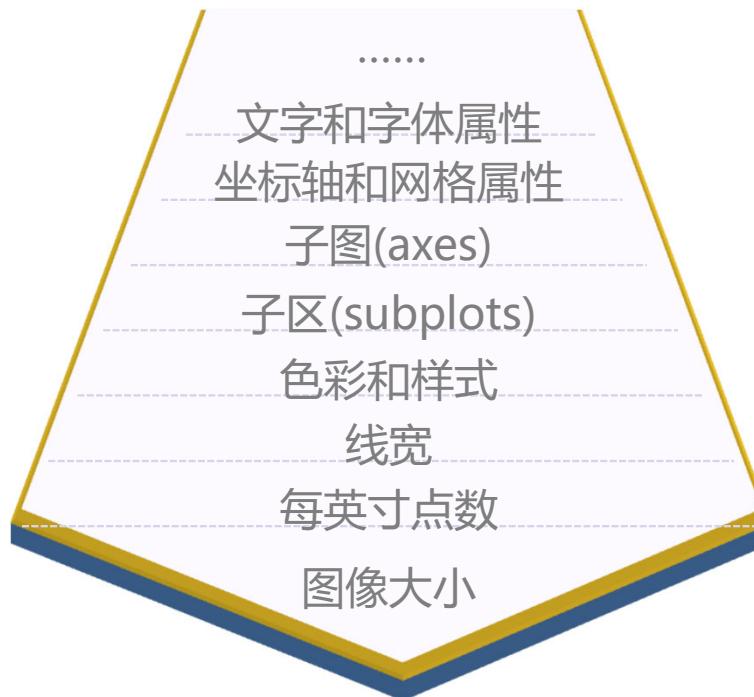
Source

```
>>> import matplotlib.pyplot as plt  
>>> plt.bar(range(7), [3, 4, 7, 6, 2, 8, 9])  
>>> plt.pie(range(7), [3, 4, 7, 6, 2, 8, 9])
```



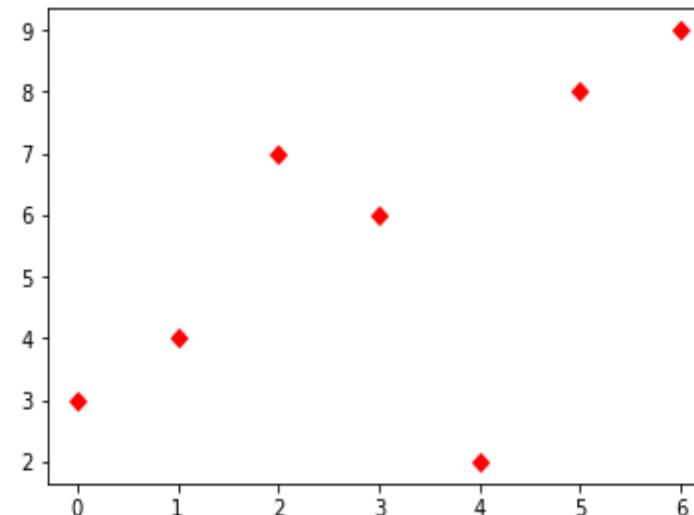
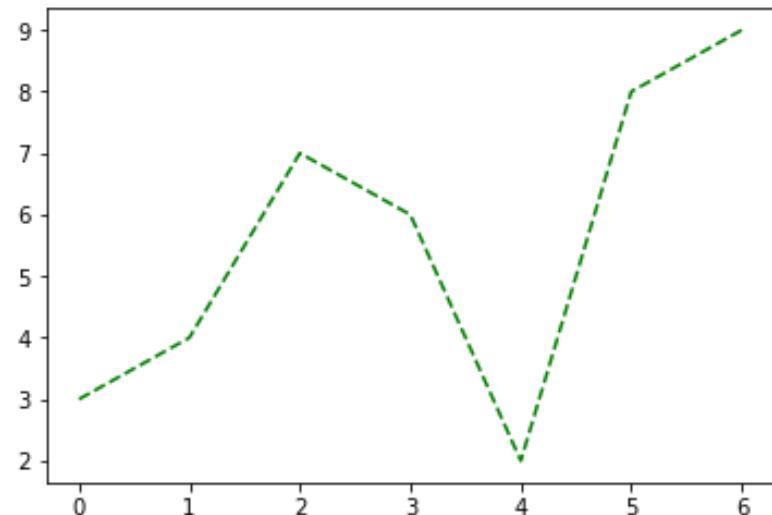
10.4.2 Matplotlib图形属性控制

Matplotlib属性



Matplotlib可以控制的默认属性

色彩和样式



```
plt.plot(range(7), [3, 4, 7, 6, 2, 8, 9], 'g--')  
plt.plot(range(7), [3, 4, 7, 6, 2, 8, 9], 'rD')
```

色彩和样式

符号	颜色
b	blue
g	green
r	red
c	cyan
m	magenta
Y	yellow
k	black
w	white

线型	描述
'-'	solid
'--'	dashed
'-. '	dash_dot
::'	dotted
'None'	draw nothing
--'	draw nothing
--"	draw nothing

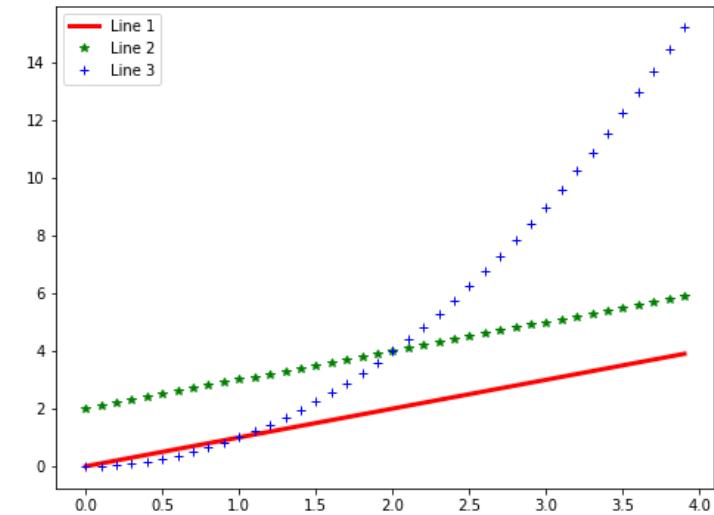
标记	描述
"o"	circle
"v"	triangle_down
"s"	square
"p"	pentagon
"*"	star
"h"	hexagon1
"+"	plus
"D"	diamond
...	...

多种属性

F_{ile}

Filename: prog10-2.py

```
import matplotlib.pyplot as plt
import numpy as np
plt.figure(figsize=(8,6),dpi=100)
t=np.arange(0.,4.,0.1)
plt.plot(t,t,color='red',linestyle='-',linewidth=3,label='Line 1')
plt.plot(t,t+2,color='green',linestyle=' ',marker='*',linewidth=3,label='Line 2')
plt.plot(t,t**2,color='blue',linestyle=' ',marker='+',linewidth=3,label='Line 3')
plt.legend(loc='upper left')
```



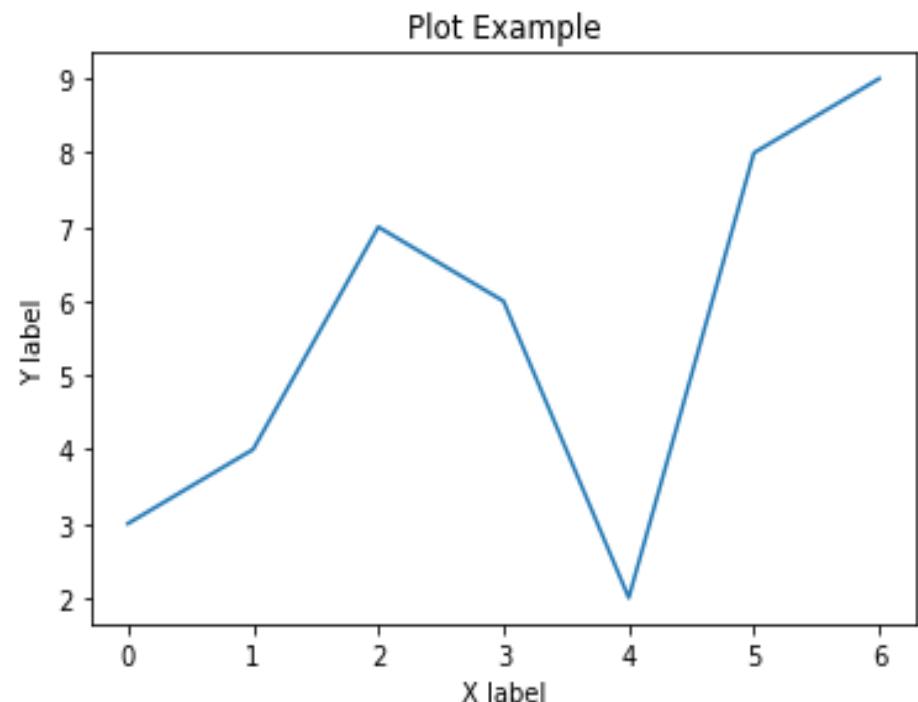
文字

加标题：图、横轴和纵轴

F_{ile}

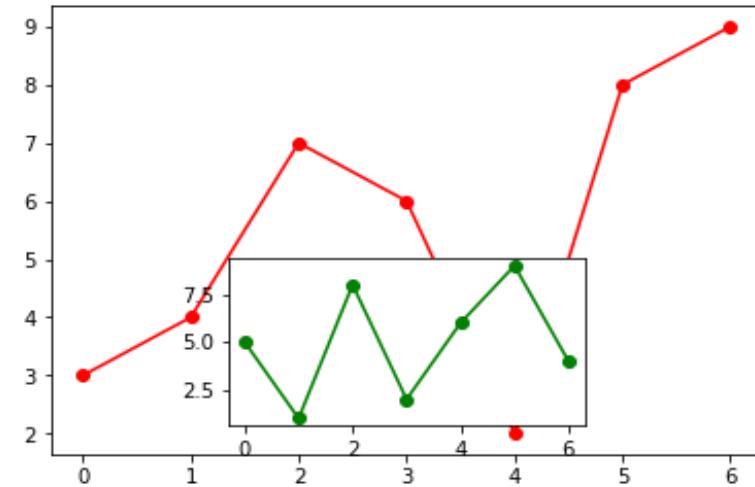
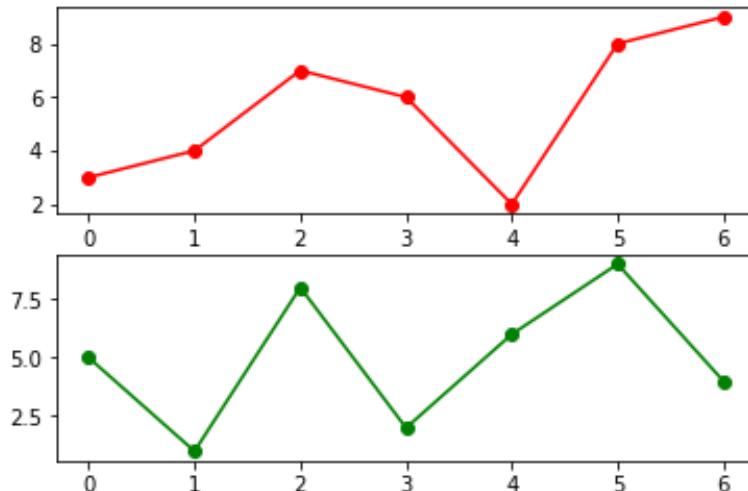
Filename: prog10-3.py

```
import matplotlib.pyplot as plt  
plt.title('Plot Example')  
plt.xlabel('X label')  
plt.ylabel('Y label')  
plt.plot(range(7), [3, 4, 7, 6, 2, 8, 9])
```

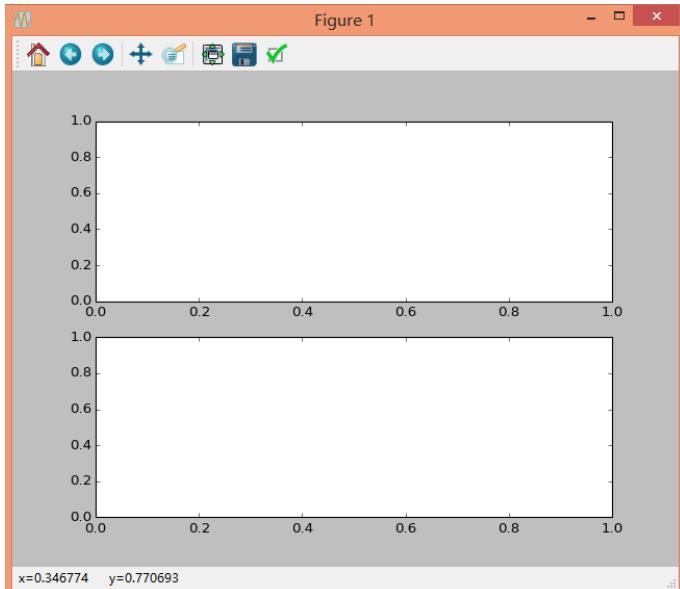


绘制子图

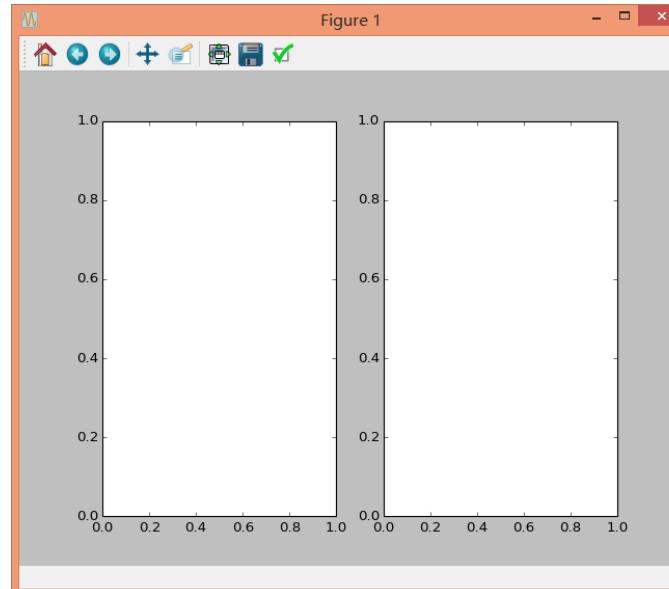
- 在Matplotlib中绘图在当前图形（figure）和当前坐标系（axes）中进行，默认在一个编号为1的figure中绘图，可以在一个图的多个区域分别绘图
- 使用subplot()函数和axes()函数



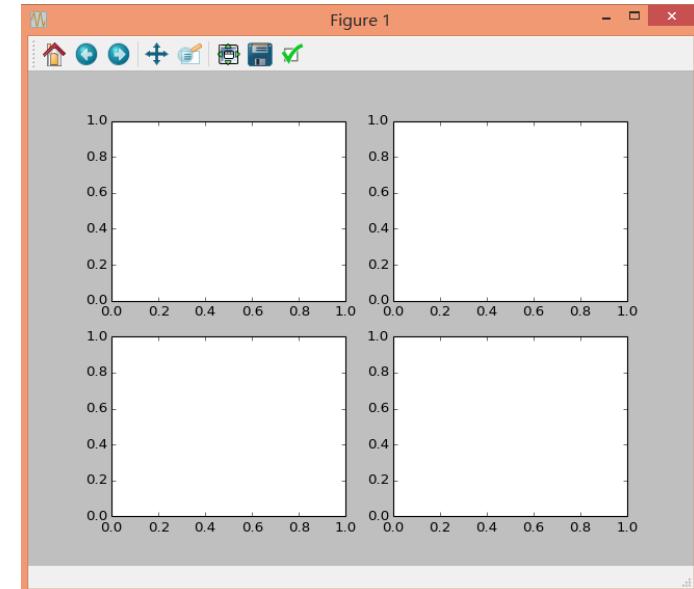
多子图-subplots



```
plt.subplot(211)  
plt.subplot(212)
```



```
plt.subplot(121)  
plt.subplot(122)
```



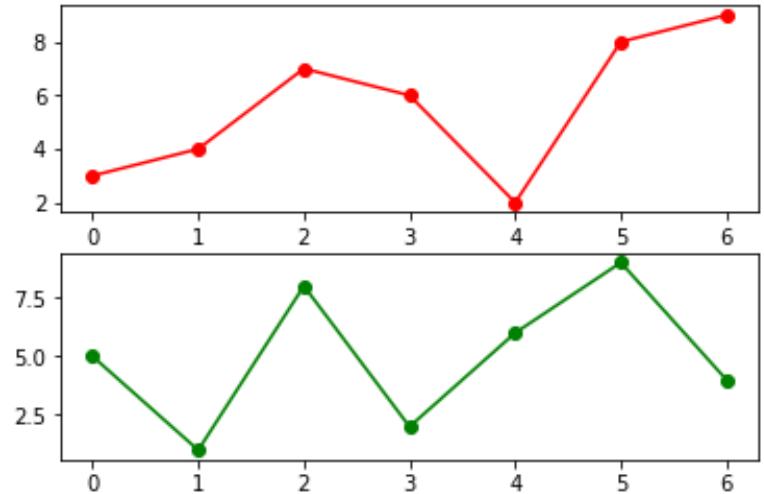
```
plt.subplot(221)  
plt.subplot(222)  
plt.subplot(223)  
plt.subplot(224)
```

多子图-subplots



pyplot样式

```
# Filename: Prog10-4.py
import matplotlib.pyplot as plt
plt.figure(1)      # 默认创建，缺省
plt.subplot(211)    # 第一个子图
plt.plot(range(7), [3, 4, 7, 6, 2, 8, 9], color = 'r', marker = 'o')
plt.subplot(212)    # 第二个子图
plt.plot(range(7), [5, 1, 8, 2, 6, 9, 4], color = 'green', marker = 'o')
```



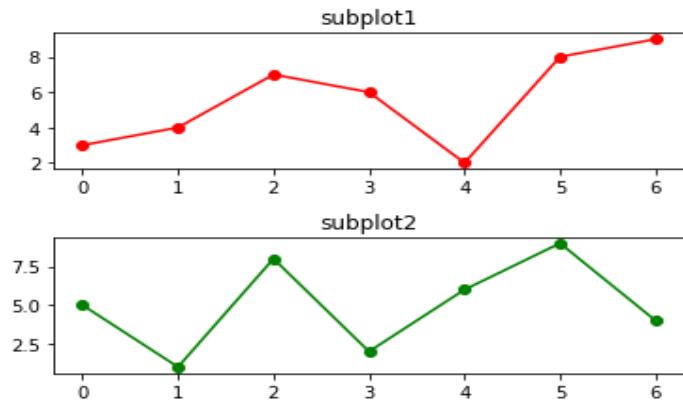
多子图-subplots

F_{ile}

Filename: Prog10-5.py

```
import matplotlib.pyplot as plt
fig, (ax0, ax1) = plt.subplots(2, 1)
ax0.plot(range(7), [3, 4, 7, 6, 2, 8, 9], color = 'r', marker = 'o')
ax0.set_title('subplot1')
plt.subplots_adjust(hspace = 0.5)
ax1.plot(range(7), [5, 1, 8, 2, 6, 9, 4], color = 'green', marker = 'o')
ax1.set_title('subplot2')
```

OO样式



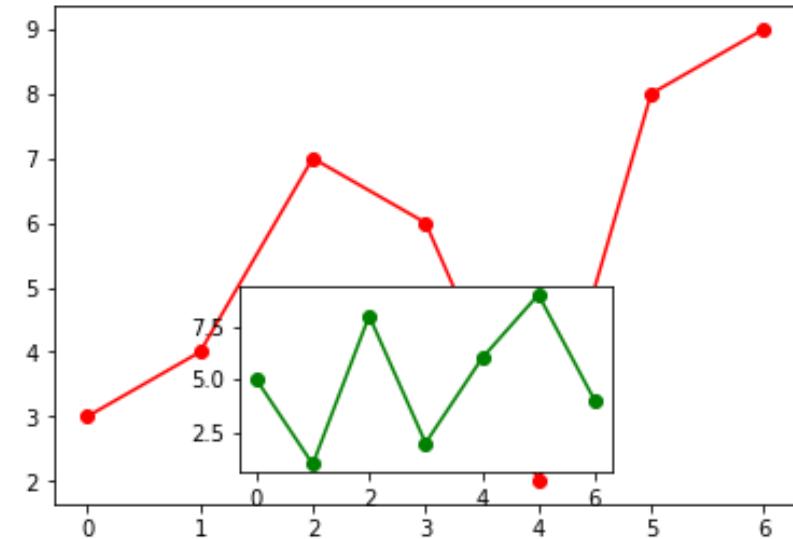
子图-axes

`axes([left,bottom,width,height])`
参数范围为(0,1)

F ile

Filename: Prog10-6.py

```
import matplotlib.pyplot as plt
plt.axes([.1, .1, 0.8, 0.8])
plt.plot(range(7), [3, 4, 7, 6, 2, 8, 9], color = 'r', marker = 'o')
plt.axes([.3, .15, 0.4, 0.3])
plt.plot(range(7), [5, 1, 8, 2, 6, 9, 4], color = 'green', marker = 'o')
```



10.4.3 常见类型图

直方图

plt.hist(x, [bins], [range])

`plt.hist(X, bins=5) # 默认值为10`

`scores = np.array([86, 77, 50, 98, 95, 65, 80, 40, 61, 82])`

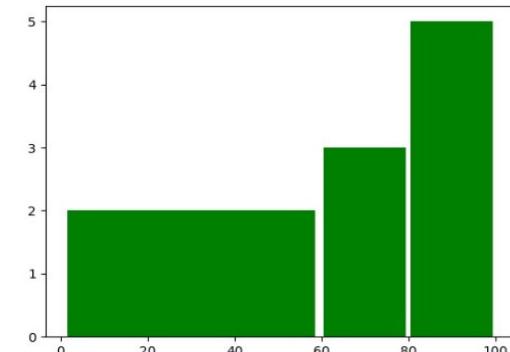
`bins = [0, 60, 80, 100]`

`plt.hist(scores, bins=bins, rwidth=0.95, color='g')`

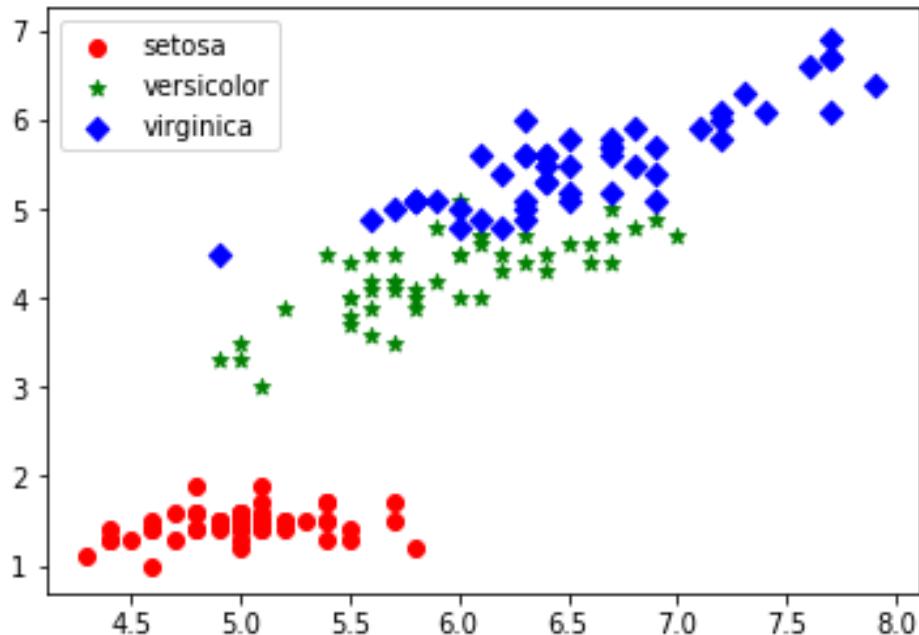
理解：

`>>> plt.hist([1, 4, 5, 2, 6])`

`>>> plt.hist([1, 4, 5, 2, 6], bins=5, range=(1, 4))`



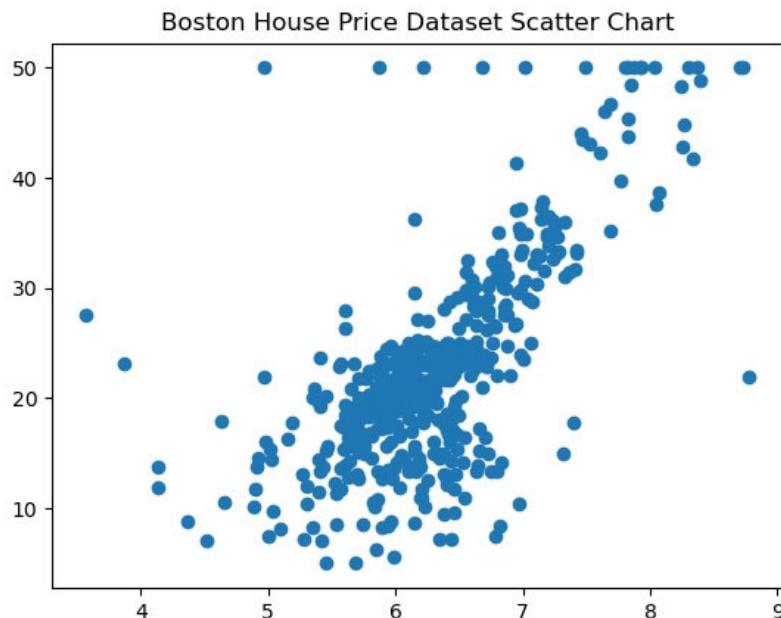
散点图



```
from sklearn import datasets  
import matplotlib.pyplot as plt  
  
iris = datasets.load_iris()  
print(iris.data, iris.target)  
  
X = [item[0] for item in iris.data] # 获取萼片长度  
Y = [item[2] for item in iris.data] # 获取花瓣长度  
plt.scatter(X[:50],Y[:50],color='red',marker='o',label='setosa')  
plt.scatter(X[50:100],Y[50:100],color='green',marker='*',label='versicolor')  
plt.scatter(X[-50:],Y[-50:],color='blue',marker='D',label='virginica')  
plt.legend(loc='best')  
plt.show()
```

数据探索阶段

散点图



```
from sklearn import datasets  
import matplotlib.pyplot as plt  
  
boston = datasets.load_boston()  
X = boston.data  
y = boston.target  
plt.scatter(X[:, 5], y)  
plt.title('Boston House Price Dataset Scatter Chart')  
plt.show()
```

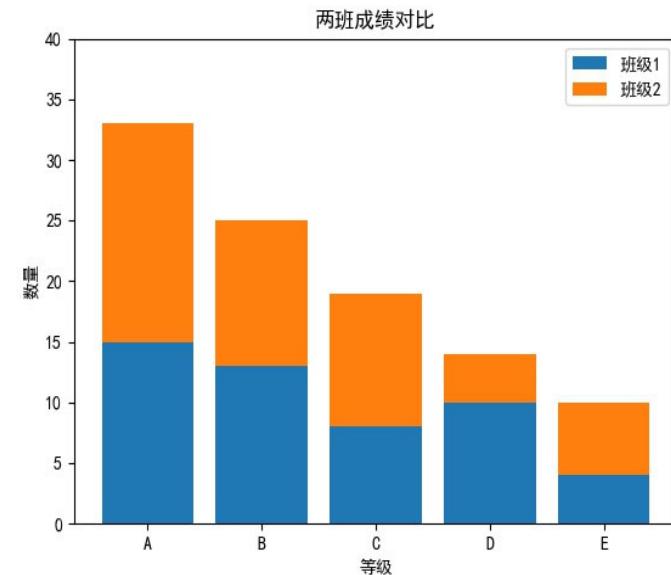
堆积条形图

```

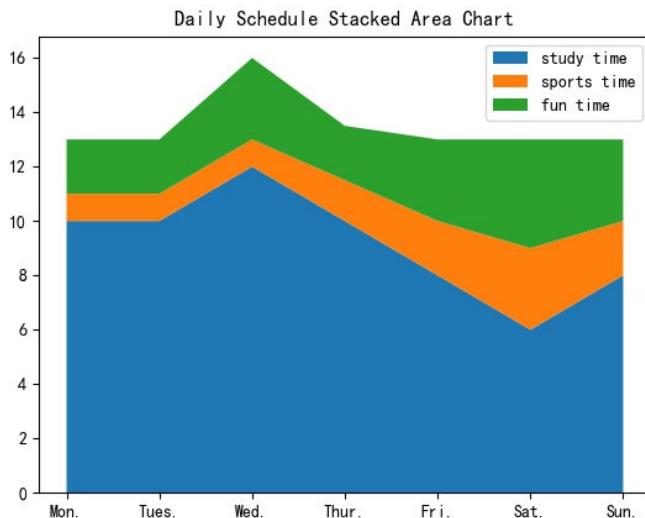
import matplotlib as mpl
import numpy as np
import matplotlib.pyplot as plt

mpl.rcParams['font.sans-serif'] = ['SimHei']
mpl.rcParams['axes.unicode_minus'] = False
N = 5
ind = np.arange(N)
stu_counts1 = np.array([15, 13, 8, 10, 4])
stu_counts2 = np.array([18, 12, 11, 4, 6])
plt.bar(ind, stu_counts1, label = '班级1')
plt.bar(ind, stu_counts2, bottom = stu_counts1, label = '班级2')
plt.title('两班成绩对比')
plt.xlabel('等级')
plt.ylabel('数量')
plt.xticks(ind, ('A', 'B', 'C', 'D', 'E'))
plt.yticks(np.arange(0, 41, 5))
plt.legend(loc = 'best')
plt.show()

```



堆积面积图

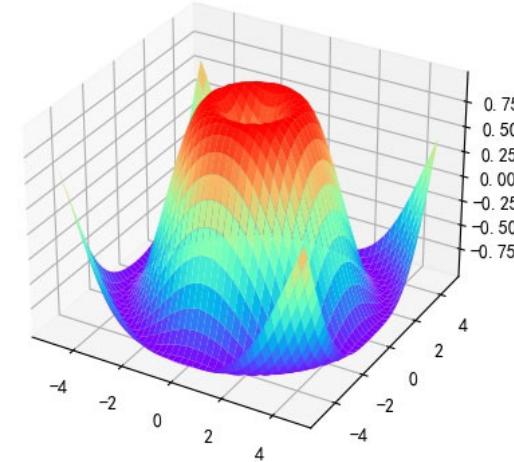


```
import matplotlib.pyplot as plt
```

```
x = ['Mon.', 'Tues.', 'Wed.', 'Thur.', 'Fri.', 'Sat.',  
     'Sun.'][y1 = [10, 10, 12, 10, 8, 6, 8]  
y2 = [1, 1, 1, 1.5, 2, 3, 2]  
y3 = [2, 2, 3, 2, 3, 4, 3]  
labels = ['study time', 'sports time', 'fun time']  
plt.stackplot(x, y1, y2, y3, labels = labels)  
plt.title('Daily Schedule Stacked Area Chart')  
plt.legend(loc = 'best')  
plt.show()
```

```
import numpy as np  
import matplotlib.pyplot as plt  
from matplotlib import cm  
from mpl_toolkits.mplot3d import Axes3D
```

```
X = np.arange(-5, 5, 0.25)  
Y = np.arange(-5, 5, 0.25)  
X, Y = np.meshgrid(X, Y)  
R = np.sqrt(X**2 + Y**2)  
Z = np.sin(R)
```



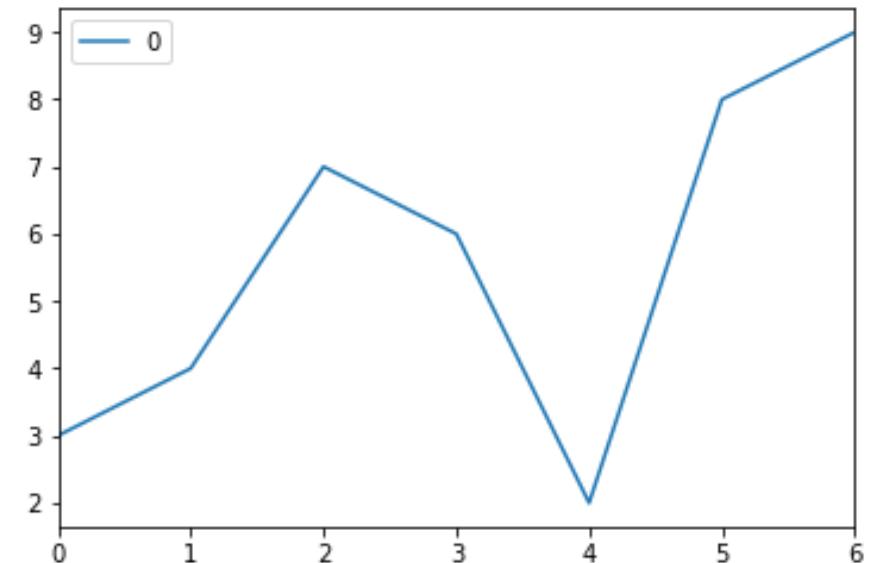
```
fig = plt.figure()  
ax = plt.subplot(projection = '3d')  
ax.plot_surface(X, Y, Z, rstride=1, cstride=1, cmap='rainbow')  
plt.show()
```

10.4.4 其他相关可视化库

pandas绘图

S
ource

```
>>> import pandas as pd  
>>> data = [3, 4, 7, 6, 2, 8, 9]  
>>> pDF = pd.DataFrame(data)  
>>> pDF.plot()
```

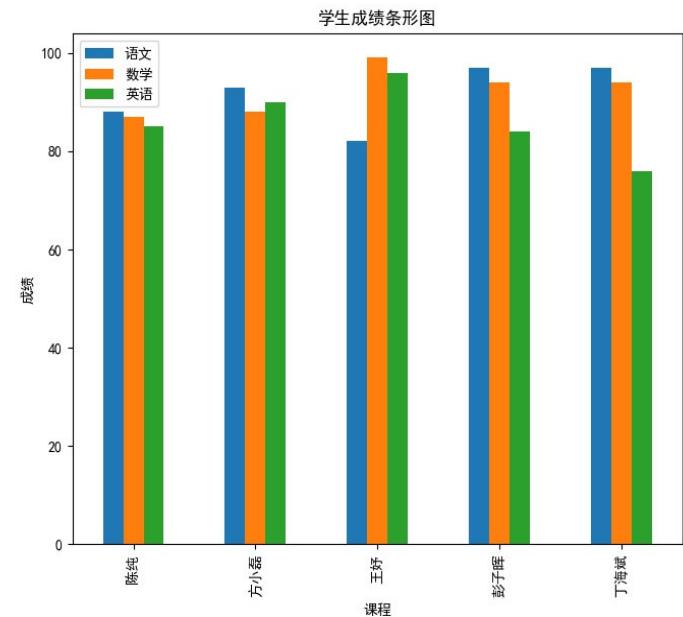


pandas绘图

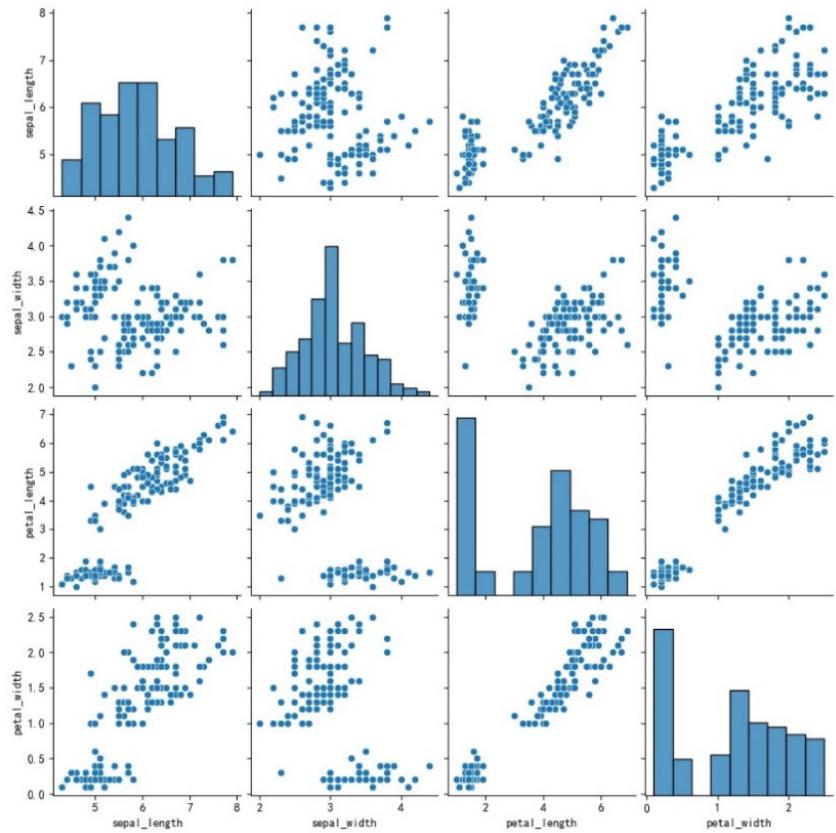
F ile

```
# Filename: Prog10-15.py
import pandas as pd

df = pd.read_csv('score.csv', index_col =
姓名', encoding = 'gb2312')
ax = df.iloc[:, :3].plot(kind = 'bar')
ax.set_title('学生成绩条形图')
ax.set_xlabel('课程', ylabel = '成绩')
plt.show()
```



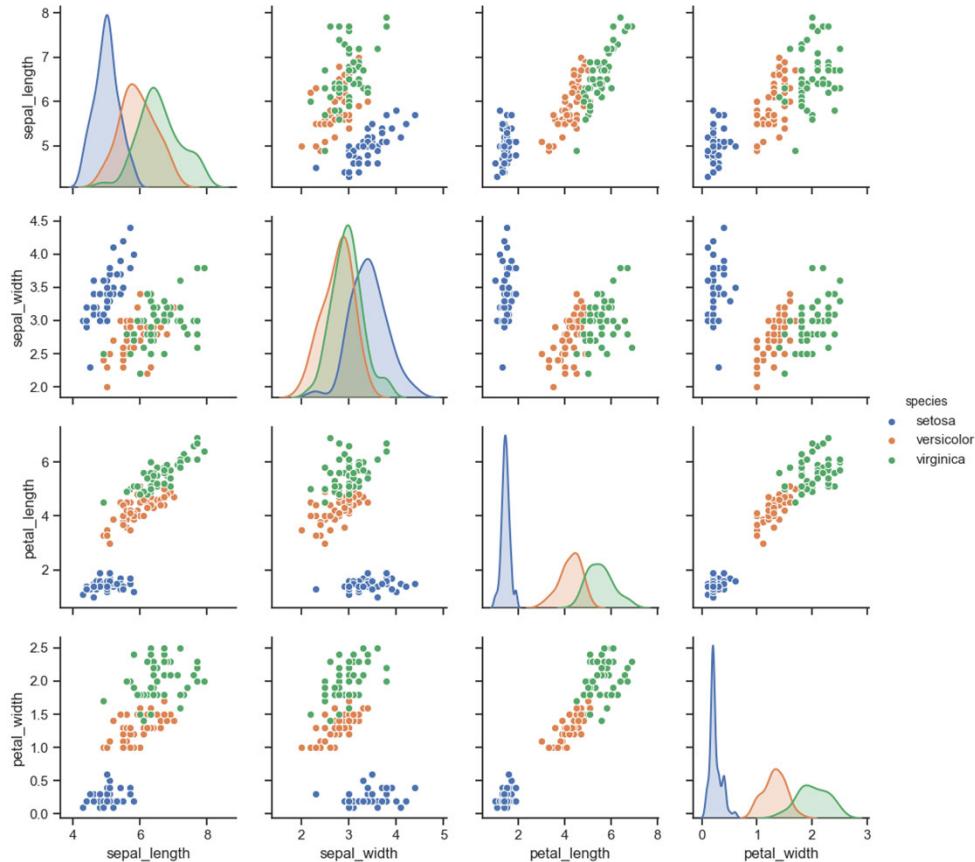
seaborn — 多变量图



```
import seaborn as sns  
import matplotlib.pyplot as plt
```

```
iris_df = sns.load_dataset('iris')  
sns.pairplot(iris_df)  
plt.show()
```

seaborn — 多变量图

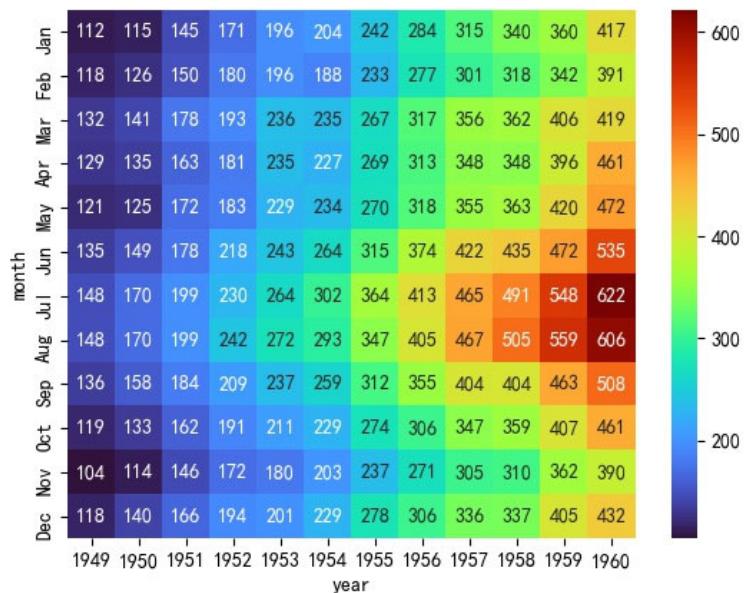


```
import seaborn as sns
```

```
sns.set(style="ticks")
```

```
df = sns.load_dataset("iris")
sns.pairplot(df, hue="species")
plt.show()
```

seaborn — 热力图



```
import seaborn as sns  
import matplotlib.pyplot as plt
```

```
flights_df = sns.load_dataset('flights')  
flights = flights_df.pivot('month', 'year', 'passengers')  
sns.heatmap(flights, annot = True, fmt = 'd', cmap =  
'turbo')  
plt.show()
```

10.5

小结

- SciPy简介
- NumPy包
- pandas包
- Matplotlib及其他相关可视化包

