# 第十一章 Numpy库

## 11.1 为什么要用Numpy

### 11.1.1 低效的Python for循环

【例】 求100万个数的倒数

In [9]:

```
def compute_reciprocals(values):
    res = []
    for value in values:      # 每遍历到一个元素，就要判断其类型，并查找适用于该数据类型的正确
        res.append(1/value)
    return res


values = list(range(1, 1000000))
%timeit compute_reciprocals(values)
```

```
145 ms ± 13.7 ms per loop (mean ± std. dev. of 7 runs, 10 loops each)
```

%timeit： ipython中统计运行时间的魔术方法（多次运行取平均值）

In [10]:

```
import numpy as np

values = np.arange(1, 1000000)
%timeit 1/values
```

```
5.99 ms ± 33.9 µs per loop (mean ± std. dev. of 7 runs, 100 loops each)
```

**实现相同计算，Numpy的运行速度是Python循环的25倍，产生了质的飞跃**

### 11.1.2 Numpy为什么如此高效

**Numpy 是由C语言编写的**

**1、编译型语言VS解释型语言**

C语言执行时，对代码进行整体编译，速度更快

**2、连续单一类型存储VS分散多变类型存储**

（1）Numpy数组内的数据类型必须是统一的，如全部是浮点型，而Python列表支持任意类型数据的填充

（2）Numpy数组内的数据**连续存储在内存中**，而Python列表的数据**分散在内存中**

**这种存储结构，与一些更加高效的底层处理方式更加的契合**

**3、多线程VS线程锁**

Python语言执行时有线程锁，无法实现真正的多线程并行，而C语言可以

### 11.1.3 什么时候用Numpy

**在数据处理的过程中，遇到使用“Python for循环” 实现一些向量化、矩阵化操作的时候，要优先考虑用Numpy**

如： 1、两个向量的点乘

2、矩阵乘法

## 11.2 Numpy数组的创建

### 11.2.1 从列表开始创建

In [11]:

```
import numpy as np

x = np.array([1, 2, 3, 4, 5])
print(x)
```

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

In [12]:

```
print(type(x))
print(x.shape)
```

```
<class 'numpy.ndarray'>
(5,)
```

- 设置数组的数据类型

In [13]:

```
x = np.array([1, 2, 3, 4, 5], dtype="float32")
print(x)
print(type(x[0]))
```

```
[1. 2. 3. 4. 5.]
<class 'numpy.float32'>
```

- 二维数组

In [15]:

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

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

## 11.2.2 从头创建数组

### （1）创建长度为5的数组，值都为0

In [16]:

```
np.zeros(5, dtype=int)
```

Out[16]:

```
array([0, 0, 0, 0, 0])
```

### （2）创建一个2*4的浮点型数组，值都为1

In [17]:

```
np.ones((2, 4), dtype=float)
```

Out[17]:

```
array([[1., 1., 1., 1.],
       [1., 1., 1., 1.]])
```

### （3）创建一个3*5的数组，值都为8.8

In [18]:

```
np.full((3, 5), 8.8)
```

Out[18]:

```
array([[8.8, 8.8, 8.8, 8.8, 8.8],
       [8.8, 8.8, 8.8, 8.8, 8.8],
       [8.8, 8.8, 8.8, 8.8, 8.8]])
```

### （4）创建一个3*3的单位矩阵

In [19]:

```
1 np.eye(3)
```

Out[19]:

```
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
```

**(5) 创建一个线性序列数组，从1开始，到15结束，步长为2**

In [20]:

```
1 np.arange(1, 15, 2)
```

Out[20]:

```
array([ 1,  3,  5,  7,  9, 11, 13])
```

**(6) 创建一个4个元素的数组，这四个数均匀的分配到0~1**

In [21]:

```
1 np.linspace(0, 1, 4)
```

Out[21]:

```
array([0.        , 0.33333333, 0.66666667, 1.        ])
```

**(7) 创建一个10个元素的数组，形成1~10^9的等比数列**

In [22]:

```
1 np.logspace(0, 9, 10)
```

Out[22]:

```
array([1.e+00, 1.e+01, 1.e+02, 1.e+03, 1.e+04, 1.e+05, 1.e+06, 1.e+07,
       1.e+08, 1.e+09])
```

**(8) 创建一个3*3的，在0~1之间均匀分布的随机数构成的数组**

In [23]:

```
1 np.random.random((3,3))
```

Out[23]:

```
array([[0.24347952, 0.41715541, 0.41363866],
       [0.44869706, 0.18128167, 0.18568051],
       [0.05705023, 0.0689205 , 0.74837661]])
```

**(9) 创建一个3*3的，均值为0，标准差为1的正态分布随机数构成的数组**

In [24]:

```
np.random.normal(0, 1, (3,3))
```

Out[24]:

```
array([[-0.38530465,  0.17474932,  0.31129291],
       [ 1.61626424, -2.18883854,  0.54043825],
       [-0.9141666 , -0.03804043, -0.6645122 ]])
```

### （10）创建一个3*3的，在[0,10)之间随机整数构成的数组

In [25]:

```
np.random.randint(0, 10, (3,3))
```

Out[25]:

```
array([[9, 1, 9],
       [0, 3, 9],
       [8, 5, 4]])
```

### （11）随机重排列

In [26]:

```
x = np.array([10, 20, 30, 40])
np.random.permutation(x)        # 生产新列表
```

Out[26]:

```
array([20, 40, 10, 30])
```

In [27]:

```
print(x)
np.random.shuffle(x)            # 修改原列表
print(x)
```

```
[10 20 30 40]
[20 40 10 30]
```

### （12）随机采样

- 按指定形状采样

In [28]:

```
x = np.arange(10, 25, dtype = float)
x
```

Out[28]:

```
array([10., 11., 12., 13., 14., 15., 16., 17., 18., 19., 20., 21., 22.,
       23., 24.])
```

In [29]:

```
np.random.choice(x, size=(4, 3))
```

Out[29]:

```
array([[19., 23., 22.],
       [22., 21., 13.],
       [15., 21., 17.],
       [14., 23., 19.]])
```

- 按概率采样

In [30]:

```
np.random.choice(x, size=(4, 3), p=x/np.sum(x))
```

Out[30]:

```
array([[15., 21., 20.],
       [23., 17., 18.],
       [23., 15., 17.],
       [19., 24., 22.]])
```

# 11.3 Numpy数组的性质

## 11.3.1 数组的属性

In [31]:

```
x = np.random.randint(10, size=(3, 4))
x
```

Out[31]:

```
array([[5, 5, 2, 7],
       [2, 3, 0, 8],
       [3, 8, 1, 7]])
```

### 1、数组的形状shape

In [32]:

```
x.shape
```

Out[32]:

```
(3, 4)
```

### 2、数组的维度ndim

In [33]:

```
x.ndim
```

Out[33]:

2

In [34]:

```
y = np.arange(10)
y
```

Out[34]:

array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])

In [35]:

```
y.ndim
```

Out[35]:

1

#### 3、数组的大小size

In [36]:

```
x.size
```

Out[36]:

12

#### 4、数组的数据类型dtype

In [37]:

```
x.dtype
```

Out[37]:

dtype('int32')

## 11.3.2 数组索引

#### 1、一维数组的索引

In [38]:

```
x1 = np.arange(10)
x1
```

Out[38]:

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

In [39]:

```
x1[0]
```

Out[39]:

```
0
```

In [40]:

```
x1[5]
```

Out[40]:

```
5
```

In [41]:

```
x1[-1]
```

Out[41]:

```
9
```

**2、多维数组的索引——以二维为例**

In [42]:

```
x2 = np.random.randint(0, 20, (2,3))
x2
```

Out[42]:

```
array([[11,  3, 11],
       [ 6,  1,  5]])
```

In [43]:

```
x2[0, 0]
```

Out[43]:

```
11
```

In [44]:

```
x2[0][0]
```

Out[44]:

```
11
```

**注意：numpy数组的数据类型是固定的，向一个整型数组插入一个浮点值，浮点值会向下进行取整**

In [46]:

```
x2[0, 0] = 1.618
```

In [47]:

```
x2
```

Out[47]:

```
array([[ 1,  3, 11],
       [ 6,  1,  5]])
```

## 11.3.3 数组的切片

### 1、一维数组——跟列表一样

In [48]:

```
x1 = np.arange(10)
x1
```

Out[48]:

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

In [49]:

```
x1[:3]
```

Out[49]:

```
array([0, 1, 2])
```

In [50]:

```
x1[3:]
```

Out[50]:

```
array([3, 4, 5, 6, 7, 8, 9])
```

In [51]:

```
x1[::-1]
```

Out[51]:

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

### 2、多维数组——以二维为例

In [52]:

```
x2 = np.random.randint(20, size=(3,4))
x2
```

Out[52]:

```
array([[14,  9, 15,  8],
       [18,  8, 16, 17],
       [ 0,  8,  2, 17]])
```

In [53]:

```
x2[:2, :3]              # 前两行，前三列
```

Out[53]:

```
array([[14,  9, 15],
       [18,  8, 16]])
```

In [54]:

```
x2[:2, 0:3:2]        # 前两行 前三列（每隔一列）
```

Out[54]:

```
array([[14, 15],
       [18, 16]])
```

In [55]:

```
x2[::-1, ::-1]
```

Out[55]:

```
array([[17,  2,  8,  0],
       [17, 16,  8, 18],
       [ 8, 15,  9, 14]])
```

### 3、获取数组的行和列

In [56]:

```
x3 = np.random.randint(20, size=(3,4))
x3
```

Out[56]:

```
array([[ 8, 13, 15,  7],
       [19, 13, 17,  6],
       [11,  2,  0, 12]])
```

In [57]:

```
x3[1, :]   #第一行  从0开始计数
```

Out[57]:

```
array([19, 13, 17,  6])
```

In [58]:

```
x3[1]    # 第一行简写
```

Out[58]:

```
array([19, 13, 17,  6])
```

In [59]:

```
x3[:, 2]  # 第二列   从0开始计数
```

Out[59]:

```
array([15, 17,  0])
```

**4、切片获取的是视图，而非副本**

In [60]:

```
x4 = np.random.randint(20, size=(3,4))
x4
```

Out[60]:

```
array([[ 5, 14,  7,  2],
       [ 8, 12,  9,  3],
       [19,  0, 10,  7]])
```

In [61]:

```
x5 = x4[:2, :2]
x5
```

Out[61]:

```
array([[ 5, 14],
       [ 8, 12]])
```

**注意：视图元素发生修改，则原数组亦发生相应修改**

In [62]:

```
x5[0, 0] = 0
x5
```

Out[62]:

```
array([[ 0, 14],
       [ 8, 12]])
```

In [63]:

```
x4
```

Out[63]:

```
array([[ 0, 14,  7,  2],
       [ 8, 12,  9,  3],
       [19,  0, 10,  7]])
```

**修改切片的安全方式：copy**

In [64]:

```
x4 = np.random.randint(20, size=(3,4))
x4
```

Out[64]:

```
array([[18, 14, 10, 12],
       [10, 16,  7, 19],
       [ 3, 16,  3, 12]])
```

In [65]:

```
x6 = x4[:2, :2].copy()
x6
```

Out[65]:

```
array([[18, 14],
       [10, 16]])
```

In [66]:

```
x6[0, 0] = 0
x6
```

Out[66]:

```
array([[ 0, 14],
       [10, 16]])
```

In [67]:

```
x4
```

Out[67]:

```
array([[18, 14, 10, 12],
       [10, 16,  7, 19],
       [ 3, 16,  3, 12]])
```

### 11.3.4 数组的变形

In [68]:

```
x5 = np.random.randint(0, 10, (12,))
x5
```

Out[68]:

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

In [69]:

```
x5.shape
```

Out[69]:

```
(12,)
```

In [70]:

```
x6 = x5.reshape(3, 4)
x6
```

Out[70]:

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

**注意：reshape返回的是视图，而非副本**

In [71]:

```
x6[0, 0] = 0
x5
```

Out[71]:

```
array([0, 8, 5, 9, 2, 6, 2, 9, 4, 5, 1, 7])
```

**一维向量转行向量**

In [72]:

```
x7 = x5.reshape(1, x5.shape[0])
x7
```

Out[72]:

```
array([[0, 8, 5, 9, 2, 6, 2, 9, 4, 5, 1, 7]])
```

In [73]:

```
x8 = x5[np.newaxis, :]
x8
```

Out[73]:

```
array([[0, 8, 5, 9, 2, 6, 2, 9, 4, 5, 1, 7]])
```

### 一维向量转列向量

In [74]:

```
x7 = x5.reshape(x5.shape[0], 1)
x7
```

Out[74]:

```
array([[0],
       [8],
       [5],
       [9],
       [2],
       [6],
       [2],
       [9],
       [4],
       [5],
       [1],
       [7]])
```

In [75]:

```
x8 = x5[:, np.newaxis]
x8
```

Out[75]:

```
array([[0],
       [8],
       [5],
       [9],
       [2],
       [6],
       [2],
       [9],
       [4],
       [5],
       [1],
       [7]])
```

### 多维向量转一维向量

In [76]:

```
x6 = np.random.randint(0, 10, (3, 4))
x6
```

Out[76]:

```
array([[3, 7, 6, 4],
       [4, 5, 6, 3],
       [7, 6, 2, 3]])
```

### flatten返回的是副本

In [77]:

```
x9 = x6.flatten()
x9
```

Out[77]:

```
array([3, 7, 6, 4, 4, 5, 6, 3, 7, 6, 2, 3])
```

In [78]:

```
x9[0]=0
x6
```

Out[78]:

```
array([[3, 7, 6, 4],
       [4, 5, 6, 3],
       [7, 6, 2, 3]])
```

### ravel返回的是视图

In [79]:

```
x10 = x6.ravel()
x10
```

Out[79]:

```
array([3, 7, 6, 4, 4, 5, 6, 3, 7, 6, 2, 3])
```

In [80]:

```
x10[0]=0
x6
```

Out[80]:

```
array([[0, 7, 6, 4],
       [4, 5, 6, 3],
       [7, 6, 2, 3]])
```

**reshape返回的是视图**

In [81]:

```
x11 = x6.reshape(-1)
x11
```

Out[81]:

```
array([0, 7, 6, 4, 4, 5, 6, 3, 7, 6, 2, 3])
```

In [82]:

```
x11[0]=10
x6
```

Out[82]:

```
array([[10,  7,  6,  4],
       [ 4,  5,  6,  3],
       [ 7,  6,  2,  3]])
```

## 11.3.5 数组的拼接

In [84]:

```
x1 = np.array([[1, 2, 3],
               [4, 5, 6]])
x2 = np.array([[7, 8, 9],
               [0, 1, 2]])
```

**1、水平拼接——非视图**

In [85]:

```
x3 = np.hstack([x1, x2])
x3
```

Out[85]:

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

In [86]:

```
x3[0][0] = 0
x1
```

Out[86]:

```
array([[1, 2, 3],
       [4, 5, 6]])
```

In [87]:

```
x4 = np.c_[x1, x2]
x4
```

Out[87]:

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

In [88]:

```
x4[0][0] = 0
x1
```

Out[88]:

```
array([[1, 2, 3],
       [4, 5, 6]])
```

### 2、垂直拼接——非视图

In [216]:

```
x1 = np.array([[1, 2, 3],
               [4, 5, 6]])
x2 = np.array([[7, 8, 9],
               [0, 1, 2]])
```

In [89]:

```
x5 = np.vstack([x1, x2])
x5
```

Out[89]:

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

In [90]:

```
x6 = np.r_[x1, x2]
x6
```

Out[90]:

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

## 11.3.6 数组的分裂

### 1、split的用法

In [91]:

```
x6 = np.arange(10)
x6
```

Out[91]:

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

In [92]:

```
x1, x2, x3 = np.split(x6, [2, 7])
print(x1, x2, x3)
```

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

### 2、hsplit的用法

In [97]:

```
x7 = np.arange(1, 26).reshape(5, 5)
x7
```

Out[97]:

```
array([[ 1,  2,  3,  4,  5],
       [ 6,  7,  8,  9, 10],
       [11, 12, 13, 14, 15],
       [16, 17, 18, 19, 20],
       [21, 22, 23, 24, 25]])
```

In [99]:

```
left, middle, right = np.hsplit(x7, [2,4])
print("left:\n", left)             # 第0~1列
print("middle:\n", middle)         # 第2~3列
print("right:\n", right)           # 第4列
```

```
left:
 [[ 1  2]
 [ 6  7]
 [11 12]
 [16 17]
 [21 22]]
middle:
 [[ 3  4]
 [ 8  9]
 [13 14]
 [18 19]
 [23 24]]
right:
 [[ 5]
 [10]
 [15]
 [20]
 [25]]
```

### 3、vsplit的用法

In [100]:

```
x7 = np.arange(1, 26).reshape(5, 5)
x7
```

Out[100]:

```
array([[ 1,  2,  3,  4,  5],
       [ 6,  7,  8,  9, 10],
       [11, 12, 13, 14, 15],
       [16, 17, 18, 19, 20],
       [21, 22, 23, 24, 25]])
```

In [101]:

```
upper, middle, lower = np.vsplit(x7, [2,4])
print("upper:\n", upper)          # 第0~1行
print("middle:\n", middle)        # 第2~3行
print("lower:\n", lower)          # 第4行
```

```
upper:
 [[ 1  2  3  4  5]
 [ 6  7  8  9 10]]
middle:
 [[11 12 13 14 15]
 [16 17 18 19 20]]
lower:
 [[21 22 23 24 25]]
```

# 11.4 Numpy四大运算

## 11.4.1 向量化运算

### 1、与数字的加减乘除等

In [102]:

```
x1 = np.arange(1,6)
x1
```

Out[102]:

```
array([1, 2, 3, 4, 5])
```

In [103]:

```
print("x1+5", x1+5)
print("x1-5", x1-5)
print("x1*5", x1*5)
print("x1/5", x1/5)
```

```
x1+5 [ 6  7  8  9 10]
x1-5 [-4 -3 -2 -1  0]
x1*5 [ 5 10 15 20 25]
x1/5 [0.2 0.4 0.6 0.8 1. ]
```

In [104]:

```
print("-x1", -x1)
print("x1**2", x1**2)
print("x1//2", x1//2)
print("x1%2", x1%2)
```

```
-x1 [-1 -2 -3 -4 -5]
x1**2 [ 1  4  9 16 25]
x1//2 [0 1 1 2 2]
x1%2 [1 0 1 0 1]
```

## 2、绝对值、三角函数、指数、对数

### (1) 绝对值

In [105]:

```
x2 = np.array([1, -1, 2, -2, 0])
x2
```

Out[105]:

```
array([ 1, -1,  2, -2,  0])
```

In [106]:

```
abs(x2)
```

Out[106]:

```
array([1, 1, 2, 2, 0])
```

In [107]:

```
np.abs(x2)
```

Out[107]:

```
array([1, 1, 2, 2, 0])
```

### (2) 三角函数

In [108]:

```
theta = np.linspace(0, np.pi, 3)
theta
```

Out[108]:

```
array([0.        , 1.57079633, 3.14159265])
```

In [109]:

```
print("sin(theta)", np.sin(theta))
print("con(theta)", np.cos(theta))
print("tan(theta)", np.tan(theta))
```

```
sin(theta) [0.0000000e+00 1.0000000e+00 1.2246468e-16]
con(theta) [ 1.000000e+00  6.123234e-17 -1.000000e+00]
tan(theta) [ 0.00000000e+00  1.63312394e+16 -1.22464680e-16]
```

In [110]:

```
x = [1, 0 ,-1]
print("arcsin(x)", np.arcsin(x))
print("arccon(x)", np.arccos(x))
print("arctan(x)", np.arctan(x))
```

```
arcsin(x) [ 1.57079633  0.         -1.57079633]
arccon(x) [0.         1.57079633 3.14159265]
arctan(x) [ 0.78539816  0.         -0.78539816]
```

### (3) 指数运算

In [111]:

```
x = np.arange(3)
x
```

Out[111]:

```
array([0, 1, 2])
```

In [112]:

```
np.exp(x)
```

Out[112]:

```
array([1.        , 2.71828183, 7.3890561 ])
```

### (4) 对数运算

In [113]:

```
x = np.array([1, 2, 4, 8 ,10])
print("ln(x)", np.log(x))
print("log2(x)", np.log2(x))
print("log10(x)", np.log10(x))
```

```
ln(x) [0.         0.69314718 1.38629436 2.07944154 2.30258509]
log2(x) [0.         1.         2.         3.         3.32192809]
log10(x) [0.         0.30103    0.60205999 0.90308999 1.        ]
```

## 3、两个数组的运算

In [114]:

```
x1 = np.arange(1,6)
x1
```

Out[114]:

```
array([1, 2, 3, 4, 5])
```

In [115]:

```
x2 = np.arange(6,11)
x2
```

Out[115]:

```
array([ 6,  7,  8,  9, 10])
```

In [116]:

```
print("x1+x2:", x1+x2)
print("x1-x2:", x1-x2)
print("x1*x2:", x1*x2)
print("x1/x2:", x1/x2)
```

```
x1+x2: [ 7  9 11 13 15]
x1-x2: [-5 -5 -5 -5 -5]
x1*x2: [ 6 14 24 36 50]
x1/x2: [0.16666667 0.28571429 0.375      0.44444444 0.5        ]
```

### 11.4.2 矩阵运算

In [132]:

```
x = np.arange(9).reshape(3, 3)
x
```

Out[132]:

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

- 矩阵的转置

In [138]:

```
y = x.T
y
```

Out[138]:

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

- 矩阵乘法

In [139]:

```
x = np.array([[1, 0],
              [1, 1]])
y = np.array([[0, 1],
              [1, 1]])
```

In [140]:

```
x.dot(y)
```

Out[140]:

```
array([[0, 1],
       [1, 2]])
```

In [141]:

```
np.dot(x, y)
```

Out[141]:

```
array([[0, 1],
       [1, 2]])
```

In [142]:

```
y.dot(x)
```

Out[142]:

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

In [143]:

```
np.dot(y, x)
```

Out[143]:

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

**注意跟x*y的区别**

In [144]:

```
x*y
```

Out[144]:

```
array([[0, 0],
       [1, 1]])
```

## 11.4.3 广播运算

In [145]:

```
x = np.arange(3).reshape(1, 3)
x
```

Out[145]:

```
array([[0, 1, 2]])
```

In [146]:

```
x+5
```

Out[146]:

```
array([[5, 6, 7]])
```

**规则**

如果两个数组的形状在维度上不匹配

那么数组的形式会沿着维度为1的维度进行扩展以匹配另一个数组的形状。

In [147]:

```
x1 = np.ones((3,3))
x1
```

Out[147]:

```
array([[1., 1., 1.],
       [1., 1., 1.],
       [1., 1., 1.]])
```

In [148]:

```
x2 = np.arange(3).reshape(1, 3)
x2
```

Out[148]:

```
array([[0, 1, 2]])
```

In [149]:

```
x1+x2
```

Out[149]:

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

In [150]:

```
x3 = np.logspace(1, 10, 10, base=2).reshape(2, 5)
x3
```

Out[150]:

```
array([[   2.,    4.,    8.,   16.,   32.],
       [  64.,  128.,  256.,  512., 1024.]])
```

In [151]:

```
x4 = np.array([[1, 2, 4, 8, 16]])
x4
```

Out[151]:

```
array([[ 1,  2,  4,  8, 16]])
```

In [152]:

```
x3/x4
```

Out[152]:

```
array([[ 2.,  2.,  2.,  2.,  2.],
       [64., 64., 64., 64., 64.]])
```

In [153]:

```
x5 = np.arange(3).reshape(3, 1)
x5
```

Out[153]:

```
array([[0],
       [1],
       [2]])
```

In [154]:

```
x6 = np.arange(3).reshape(1, 3)
x6
```

Out[154]:

```
array([[0, 1, 2]])
```

In [155]:

```
x5+x6
```

Out[155]:

```
array([[0, 1, 2],
       [1, 2, 3],
       [2, 3, 4]])
```

## 11.4.4 比较运算和掩码

### 1、比较运算

In [156]:

```
x1 = np.random.randint(100, size=(10,10))
x1
```

Out[156]:

```
array([[37, 44, 58, 79,  1, 24, 85, 90, 27, 56],
       [74, 68, 88, 27, 46, 34, 92,  1, 35, 45],
       [84, 80, 83, 72, 98, 15,  4, 77, 14, 98],
       [19, 85, 98, 32, 47, 50, 73,  3, 24,  2],
       [ 5, 28, 26, 31, 48, 43, 72, 73, 53, 64],
       [81, 87, 56, 59, 24, 42, 84, 34, 97, 65],
       [74,  9, 41, 54, 78, 62, 53, 49,  8, 70],
       [63, 44, 33, 35, 26, 83,  7, 14, 65, 84],
       [57, 10, 62,  8, 74, 47, 90, 25, 78, 48],
       [36, 31, 45, 39, 66, 82, 42, 25, 33, 84]])
```

In [157]:

```
x1 > 50
```

Out[157]:

```
array([[False, False,  True,  True, False, False,  True,  True, False,
         True],
       [ True,  True,  True, False, False, False,  True, False, False,
        False],
       [ True,  True,  True,  True,  True, False, False,  True, False,
         True],
       [False,  True,  True, False, False, False,  True, False, False,
        False],
       [False, False, False, False, False, False,  True,  True,  True,
         True],
       [ True,  True,  True,  True, False, False,  True, False,  True,
         True],
       [ True, False, False,  True,  True,  True,  True, False, False,
         True],
       [ True, False, False, False, False,  True, False, False,  True,
         True],
       [ True, False,  True, False,  True, False,  True, False,  True,
        False],
       [False, False, False, False,  True,  True, False, False, False,
         True]])
```

### 2、操作布尔数组

In [158]:

```
x2 = np.random.randint(10, size=(3, 4))
x2
```

Out[158]:

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

In [159]:

```
print(x2 > 5)
np.sum(x2 > 5)
```

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

Out[159]:

```
5
```

In [160]:

```
np.all(x2 > 0)
```

Out[160]:

```
True
```

In [161]:

```
np.any(x2 == 6)
```

Out[161]:

```
True
```

In [163]:

```
np.all(x2 < 9, axis=1)    # 按行进行判断
```

Out[163]:

```
array([False,  True, False])
```

In [164]:

```
x2
```

Out[164]:

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

In [165]:

```
(x2 < 9) & (x2 >5)
```

Out[165]:

```
array([[False, False, False, False],
       [ True,  True, False, False],
       [False, False, False,  True]])
```

In [166]:

```
np.sum((x2 < 9) & (x2 >5))
```

Out[166]:

```
3
```

#### 3、将布尔数组作为掩码

In [167]:

```
x2
```

Out[167]:

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

In [168]:

```
x2 > 5
```

Out[168]:

```
array([[False, False, False,  True],
       [ True,  True, False, False],
       [ True, False, False,  True]])
```

In [169]:

```
x2[x2 > 5]
```

Out[169]:

```
array([9, 8, 8, 9, 6])
```

### 11.4.5 花哨的索引

#### 1、一维数组

In [170]:

```
x = np.random.randint(100, size=10)
x
```

Out[170]:

```
array([43, 69, 67,  9, 11, 27, 55, 93, 23, 82])
```

**注意：结果的形状与索引数组ind一致**

In [171]:

```
ind = [2, 6, 9]
x[ind]
```

Out[171]:

```
array([67, 55, 82])
```

In [172]:

```
ind = np.array([[1, 0],
                [2, 3]])
x[ind]
```

Out[172]:

```
array([[69, 43],
       [67,  9]])
```

**2、多维数组**

In [173]:

```
x = np.arange(12).reshape(3, 4)
x
```

Out[173]:

```
array([[ 0,  1,  2,  3],
       [ 4,  5,  6,  7],
       [ 8,  9, 10, 11]])
```

In [174]:

```
row = np.array([0, 1, 2])
col = np.array([1, 3, 0])
x[row, col]                # x(0, 1) x(1, 3) x(2, 0)
```

Out[174]:

```
array([1, 7, 8])
```

In [175]:

```
row[:, np.newaxis]        # 列向量
```

Out[175]:

```
array([[0],
       [1],
       [2]])
```

In [176]:

```
x[row[:, np.newaxis], col]     # 广播机制
```

Out[176]:

```
array([[ 1,  3,  0],
       [ 5,  7,  4],
       [ 9, 11,  8]])
```

# 11.5 其他Numpy通用函数

## 11.5.1 数值排序

In [402]:

```
x = np.random.randint(20, 50, size=10)
x
```

Out[402]:

```
array([48, 27, 44, 24, 34, 21, 24, 30, 34, 46])
```

- 产生新的排序数组

In [403]:

```
np.sort(x)
```

Out[403]:

```
array([21, 24, 24, 27, 30, 34, 34, 44, 46, 48])
```

In [404]:

```
x
```

Out[404]:

```
array([48, 27, 44, 24, 34, 21, 24, 30, 34, 46])
```

- 替换原数组

In [406]:

```
x.sort()
x
```

Out[406]:

```
array([21, 24, 24, 27, 30, 34, 34, 44, 46, 48])
```

- 获得排序索引

In [407]:

```
x = np.random.randint(20, 50, size=10)
x
```

Out[407]:

```
array([27, 36, 35, 28, 34, 20, 21, 49, 48, 30])
```

In [409]:

```
i = np.argsort(x)
i
```

Out[409]:

```
array([5, 6, 0, 3, 9, 4, 2, 1, 8, 7], dtype=int64)
```

### 11.5.2 最大最小值

In [411]:

```
x = np.random.randint(20, 50, size=10)
x
```

Out[411]:

```
array([48, 31, 30, 44, 48, 33, 44, 48, 39, 35])
```

In [413]:

```
print("max:", np.max(x))
print("min:", np.min(x))
```

```
max: 48
min: 30
```

In [414]:

```
print("max_index:", np.argmax(x))
print("min_index:", np.argmin(x))
```

```
max_index: 0
min_index: 2
```

### 11.5.3 数值求和、求积

In [183]:

```
x = np.arange(1,6)
x
```

Out[183]:

```
array([1, 2, 3, 4, 5])
```

In [417]:

```
x.sum()
```

Out[417]:

```
15
```

In [419]:

```
np.sum(x)
```

Out[419]:

```
15
```

In [177]:

```
x1 = np.arange(6).reshape(2,3)
x1
```

Out[177]:

```
array([[0, 1, 2],
       [3, 4, 5]])
```

- 按行求和

In [178]:

```
np.sum(x1, axis=1)
```

Out[178]:

```
array([ 3, 12])
```

- 按列求和

In [179]:

```
np.sum(x1, axis=0)
```

Out[179]:

```
array([3, 5, 7])
```

- 全体求和

In [181]:

```
1 np.sum(x1)
```

Out[181]:

15

- 求积

In [184]:

```
1 x
```

Out[184]:

array([1, 2, 3, 4, 5])

In [420]:

```
1 x.prod()
```

Out[420]:

120

In [421]:

```
1 np.prod(x)
```

Out[421]:

120

### 11.5.4 中位数、均值、方差、标准差

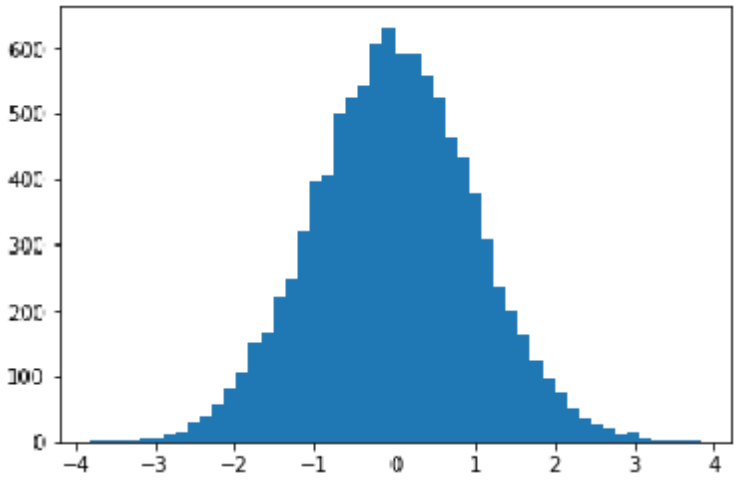
In [424]:

```
1 x = np.random.normal(0, 1, size=10000)
```

In [425]:

```
import matplotlib.pyplot as plt

plt.hist(x, bins=50)
plt.show()
```




- 中位数

In [427]:

```
np.median(x)
```

Out[427]:

-0.01024418366119727

- 均值

In [428]:

```
x.mean()
```

Out[428]:

-0.004164442327293362

In [430]:

```
np.mean(x)
```

Out[430]:

-0.004164442327293362

- 方差

In [431]:

```
1 x.var()
```

Out[431]:

1.0221853234535774

In [432]:

```
1 np.var(x)
```

Out[432]:

1.0221853234535774

- 标准差

In [433]:

```
1 x.std()
```

Out[433]:

1.0110318112965473

In [434]:

```
1 np.std(x)
```

Out[434]:

1.0110318112965473