Лекция 3. Инструменти за Data Science с езика Python - numpy, cupy, scipy, matplotlib.

DTSC001 „Прогнозиране чрез анализ на данни I“

ИНСТИТУТ *за* СЪВРЕМЕННИ ФИЗИЧЕСКИ ИЗСЛЕДВАНИЯ

НОВ БЪЛГАРСКИ УНИВЕРСИТЕТ

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`https://facebook.com/nbudatascience`

План

Numpy

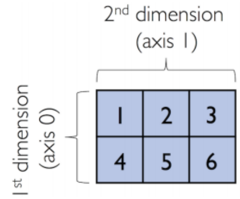
CuPy

Matplotlib

Numpy

N-мерни масиви

```
>>> import numpy as np
>>> lst = [[1, 2, 3], [4, 5, 6]]
>>> ary2d = np.array(lst)
>>> ary2d
array([[1, 2, 3],
       [4, 5, 6]])
```



```
>>> ary2d.dtype
dtype('int64')
```

N-мерни масиви

```
>>> float32_ary = ary2d.astype(np.float32)
>>> float32_ary
array([[1., 2., 3.],
[4., 5., 6.]], dtype=float32)
>>> float32_ary.dtype
dtype('float32')

>>> ary2d.size
6
>>> ary2d.ndim
2
>>> ary2d.shape
(2, 3)
>>> np.array([1, 2, 3]).shape
(3,)
```

Numpy - dtype, size, ndim, shape, nbytes

```
arr = np.arange(8).reshape(2,4) #  the total number of
    elements is unchanged
print(arr)

print('Data type                :', arr.dtype)
print('Total number of elements :', arr.size)
print('Number of dimensions     :', arr.ndim)
print('Shape (dimensionality)   :', arr.shape)
print('Memory used (in bytes)   :', arr.nbytes)
```

Създаване на NumPy масиви

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

Създаване на NumPy масиви 2

```python
np.zeros(5, float)
np.zeros(3, int)
np.zeros(3, complex)
print('5 ones:', np.ones(5))
a = np.empty(4) # random
a.fill(5.5)
```

Създаване на NumPy масиви 3

```
>>> np.arange(4., 10.)
array([4., 5., 6., 7., 8., 9.])

>>> np.arange(5)
array([0, 1, 2, 3, 4])

>>> np.arange(1., 11., 2)
array([1., 3., 5., 7., 9.])

>>> np.linspace(0., 1., num=5)
array([0.  , 0.25, 0.5 , 0.75, 1.  ])
```

Задача

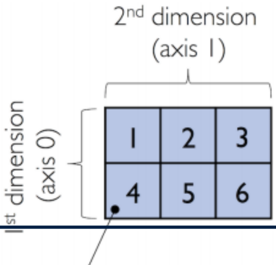
Намерете сумата на матриците

$$\begin{pmatrix} 1 & 2 & 3 \\ 6 & 8 & 9 \end{pmatrix} + \begin{pmatrix} 3 & 5 & 6 \\ 7 & 4 & 2 \end{pmatrix}$$

използвайки `numpy`.

Индексиране на NumPy масиви

```
>>> ary = np.array([1, 2, 3])
>>> ary[0]
1
>>> ary[:2] # equivalent to ary[0:2]
array([1, 2])
>>> ary = np.array([[1, 2, 3],
... [4, 5, 6]])
>>> ary[0, 0] # upper left
1
```



Индексиране на NumPy масиви 2

```
>>> ary[-1, -1] # lower right
6
>>> ary[0, 1] # first row, second column
2
>>> ary[0] # entire first row
array([1, 2, 3])
>>> ary[:, 0] # entire first column
array([1, 4])
>>> ary[:, :2] # first two columns
array([[1, 2],
[4, 5]])
>>> ary[0, 0]
1
```

```
print('Slicing in the second row:', arr[1, 2:4])
print('All rows, third column   :', arr[:, 2])
print('First row:  ', arr[0])
print('Second row: ', arr[1])
```

Конструкция на numpy масив

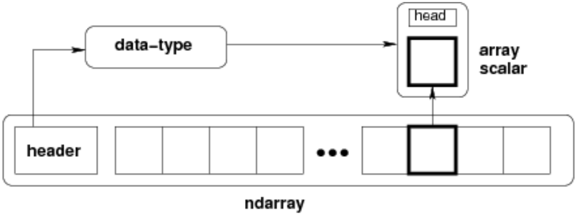


Рис.: `https://docs.scipy.org/doc/numpy-1.13.0/reference/arrays.html`

Ufuncs

B Python:

```
>>> lst = [[1, 2, 3], [4, 5, 6]]
>>>   for row_idx, row_val in enumerate(lst):
...     for col_idx, col_val in enumerate(row_val):
...         lst[row_idx][col_idx] += 1
>>> lst
[[2, 3, 4], [5, 6, 7]]
>>> lst = [[1, 2, 3], [4, 5, 6]]
>>> [[cell + 1 for cell in row] for row in lst]
```

B numpy

```
>>> ary = np.array([[1, 2, 3], [4, 5, 6]])
>>> ary = np.add(ary, 1)
>>> ary
array([[2, 3, 4],
       [5, 6, 7]])
```

`add, subtract, divide, multiply, and exp`

Ufuncs 2

Кратък запис

```
>>> ary + 1
array([[3, 4, 5],
       [6, 7, 8]])
>>> ary**2
array([[ 4, 9, 16],
       [25, 36, 49]])
```

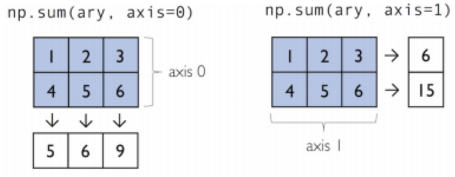
Сумиране по колони и редове

```
>>> ary = np.array([[1, 2, 3],
...                 [4, 5, 6]])
>>> np.add.reduce(ary) # column sumns
array([5, 7, 9])
>>> np.add.reduce(ary, axis=1) # row sums
array([ 6, 15])
```

Ufuncs 3

Кратък запис

```
>>> ary.sum(axis=0) # column sums
array([5, 7, 9])
>>> ary.sum()
21
```



Ufunc 4

- mean (computes arithmetic average)
- std (computes the standard deviation)
- var (computes variance)
- sort (sorts an array)
- argsort (returns indices that would sort an array)
- min (returns the minimum value of an array)
- max (returns the maximum value of an array)
- argmin (returns the index of the minimum value)
- argmax (returns the index of the maximum value)
- array equal (checks if two arrays have the same shape and elements)

Numpy - min, max, prod, mean, std

```
print('Minimum and maximum :', arr.min(), arr.max())
print('Sum and product of all elements :', arr.sum(),
    arr.prod())
print('Mean and standard deviation  :', arr.mean(), arr
    .std())
```

Задача

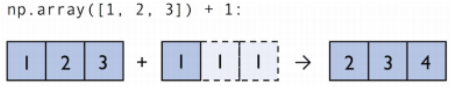
Чрез `numpy` да се създаде матрицата

$$\begin{pmatrix} 3 & 5 & 6 & 9 & 0 & 15 \\ 7 & 4 & 2 & 6 & 21 & 5 \end{pmatrix}$$

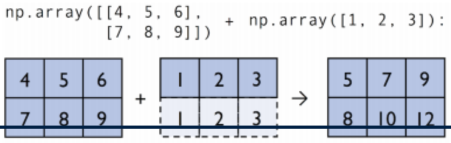
и да се намерят:

- най-малките елементи от всеки ред, както и техните индекси ;
- дисперсията на всеки ред

Broadcasting



```
>>> ary1 = np.array([1, 2, 3])
>>> ary2 = np.array([4, 5, 6])
>>> ary1 + ary2
array([5, 7, 9])
>>> ary3 = np.array([[4, 5, 6],
...                  [7, 8, 9]])
>>> ary3 + ary1 # similarly, ary1 + ary3
array([[ 5, 7, 9],
       [ 8, 10, 12]])
```



Индексиране – Memory Views and Copies 1

Views

```
>>> ary = np.array([[1, 2, 3],
...                 [4, 5, 6]])
>>> first_row = ary[0]
>>> first_row += 99
>>> ary
array([[100, 101, 102],
       [  4,   5,   6]])
```

Индексиране – Memory Views and Copies 2

Views

```
>>> ary = np.array([[1, 2, 3],
... [4, 5, 6]])
>>> center_col = ary[:, 1]
>>> center_col += 99
>>> ary
array([[ 1, 101, 3],
[ 4, 104, 6]])
```

Индексиране – Memory Views and Copies 3

Copy

```
>>> ary = np.array([[1, 2, 3],
... [4, 5, 6]])
>>> second_row = ary[1].copy()
>>> second_row += 99
>>> ary
array([[1, 2, 3],
[4, 5, 6]])
```

Индексиране

```
>>> ary = np.array([[1, 2, 3],
...                 [4, 5, 6]])
>>> ary[:, [0, 2]] # first and and last column
array([[1, 3],
       [4, 6]])
```

Индексиране

```
>>> this_is_a_copy = ary[:, [0, 2]]
>>> this_is_a_copy += 99
>>> ary
array([[1, 2, 3],
       [4, 5, 6]])
>>> ary[:, [2, 0]] # first and and last column
array([[3, 1],
       [6, 4]])
```

Индексиране

```
>>> ary = np.array([[1, 2, 3],
... [4, 5, 6]])
>>> greater3_mask = ary > 3
>>> greater3_mask
array([[False, False, False],
[ True, True, True]])

>>> ary[greater3_mask]
array([4, 5, 6])

>>> ary[(ary > 3) & (ary % 2 == 0)]
array([4, 6])
```

Генератори на случайни числа

```
>>> np.random.seed(123)
>>> np.random.rand(3)
array([0.69646919, 0.28613933, 0.22685145])

>>> rng1 = np.random.RandomState(seed=123)
>>> rng1.rand(3)
array([0.69646919, 0.28613933, 0.22685145])
```

Reshaping Arrays

```
>>> ary1d = np.array([1, 2, 3, 4, 5, 6])
>>> ary2d_view = ary1d.reshape(2, 3)
>>> ary2d_view
array([[1, 2, 3],
       [4, 5, 6]])
>>> np.may_share_memory(ary2d_view, ary1d)
True

>>> ary1d.reshape(2, -1)
array([[1, 2, 3],
[4, 5, 6]])
>>> ary1d.reshape(-1, 2)
array([[1, 2],
[3, 4],
[5, 6]])
```

Reshaping Arrays

```
>>> ary = np.array([[[1, 2, 3],
...                  [4, 5, 6]]])
>>> ary.reshape(-1)
array([1, 2, 3, 4, 5, 6])

>>> ary = np.array([1, 2, 3])
>>> # stack along the first axis
>>> np.concatenate((ary, ary))
array([1, 2, 3, 1, 2, 3])

>>> ary = np.array([[1, 2, 3]])
>>> # stack along the first axis (here: rows)
>>> np.concatenate((ary, ary), axis=0)
array([[1, 2, 3],
[1, 2, 3]])
```

Reshaping Arrays

```
>>> # stack along the second axis (here: column)
>>> np.concatenate((ary, ary), axis=1)
array([[1, 2, 3, 1, 2, 3]])
>>> ary = np.array([[1, 2, 3]])

>>> # stack along the first axis (here: rows)
>>> np.concatenate((ary, ary), axis=0)
array([[1, 2, 3],
       [1, 2, 3]])
```

Comparison Operators and Masks

```
>>> ary = np.array([1, 2, 3, 4])
>>> mask = ary > 2
>>> mask
array([False, False, True, True])
>>> ary[mask]
array([3, 4])
>>> mask
array([False, False, True, True])
>>> mask.sum()
2

>>> np.where(ary > 2, 1, 0)
array([0, 0, 1, 1])
```

Comparison Operators and Masks

```
>>> ary = np.array([1, 2, 3, 4])
>>> mask = ary > 2
>>> ary[mask] = 1
>>> ary[~mask] = 0
>>> ary
array([0, 0, 1, 1])
```

- `A: & or np.bitwise and`
- `Or: | or np.bitwise or`
- `Xor: ^ or np.bitwise xor`
- `Not: ~ or np.bitwise not`

Comparison Operators and Masks

```
>>> ary = np.array([1, 2, 3, 4])
>>> (ary > 3) | (ary < 2)

>>> ~((ary > 3) | (ary < 2))
array([False, True, True, False])
```

Линейна алгебра с NumPy масиви

```
>>> row_vector = np.array([1, 2, 3])
>>> row_vector
array([1, 2, 3])

>>> column_vector = np.array([[1, 2, 3]]).reshape(-1, 1)
>>> column_vector
array([[1],
[2],
[3]])

>>> row_vector[:, np.newaxis]
array([[1],
[2],
[3]])
```

Линейна алгебра с NumPy масиви 2

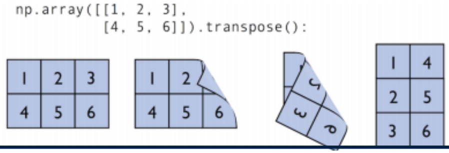
```
>>> matrix = np.array([[1, 2, 3],
... [4, 5, 6]])
>>> np.matmul(matrix, column_vector)
array([[14],
[32]])
>>> np.matmul(matrix, row_vector)
array([14, 32])
>>> np.matmul(row_vector, row_vector)
14

>>> np.dot(row_vector, row_vector)
14
>>> np.dot(matrix, row_vector)
array([14, 32])
```

Линейна алгебра с NumPy масиви 3

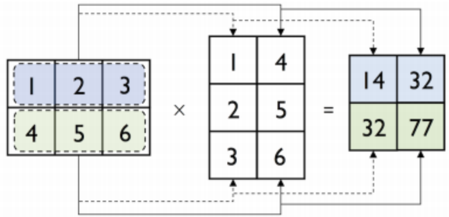
```
>>> np.dot(matrix, column_vector)
array([[14],
       [32]])

>>> matrix = np.array([[1, 2, 3],
...                      [4, 5, 6]])
>>> matrix.transpose()
array([[1, 4],
    [2, 5],
    [3, 6]])
```


```
np.array([[1, 2, 3],
          [4, 5, 6]]).transpose():
```

Линейна алгебра с NumPy масиви 3

```
>>> np.matmul(matrix, matrix.transpose())
array([[14, 32],
[32, 77]])
```



```
>>> matrix.T
array([[1, 4],
[2, 5],
[3, 6]])
```

Има и специален тип matrix .

Numpy. Матрично умножение.

```
v1 = np.array([2, 3, 4])
v2 = np.array([1, 0, 1])
print(v1, '.', v2, '=', v1.dot(v2))
print(v1, '.', v2, '=', v1 @ v2)

A = np.arange(6).reshape(2, 3)
print(A, 'x', v1, '=', A @ v1)

print(A @ A.T)

print(A.T @ A)

print(v1, '.', v2, '=', v1 @ v2)
```

Задача

....

Примери от линейната алгебра, решени с NumPy

https://www.w3resource.com/python-exercises/numpy/linear-algebra

Numpy (http://numpy.org) Двумерен масив

```
np.arange(1, 100, 5)
print("A linear grid between 0 and 1:", np.linspace(0,
    1, 5))
print("A logarithmic grid between 10**1 and 10**4: ",
    np.logspace(1, 4, 4))
np.random.randn(5) # standard normal distribution
np.random.normal(10, 3, 5)

lst2 = [[1, 2], [3, 4]]
arr2 = np.array([[1, 2], [3, 4]])
print(lst2[0][1])
print(arr2[0,1])

np.array([[1,2,3],[4,5,6]], order='F')
np.zeros((2,3))
np.random.normal(10, 3, (2, 4))
```

Numpy - axis

```
print('For the following array:\n', arr)
print('The sum of elements along the rows is:', arr.sum
    (axis=1))
print('The sum of elements along the columns is:', arr.
    sum(axis=0))

np.zeros((3,4,5,6)).sum(2).shape

print('Array:\n', arr)
print('Transpose:\n', arr.T)
```

Numpy (http://numpy.org)

```
arr1 = np.arange(4)
arr2 = np.arange(10, 14)
print(arr1, '+', arr2, '=', arr1+arr2)
print(arr1, '*', arr2, '=', arr1*arr2)

arr1 + 1.5*np.ones(4)
arr1 + 1.5

b = np.array([2, 3, 4, 5])
print(arr, '\n\n+', b , '\n---------------\n', arr + b)
```

Numpy (http://numpy.org)

```python
c = np.array([4, 6])
c[:, np.newaxis]

print(c.shape)
print((c[:, np.newaxis]).shape)

arr + c[:, np.newaxis]

x = np.linspace(0, 2*np.pi, 100)
y = np.sin(x)
```

CuPy

https://cupy.dev/

Matplotlib

Matplotlib (https://matplotlib.org/)

```python
import matplotlib.pyplot as plt

x = np.linspace(0, 2*np.pi)
y = np.sin(x)
plt.figure()
plt.plot(x,y, label='sin(x)')
plt.legend()
plt.grid()
plt.title('Harmonic')
plt.xlabel('x')
plt.ylabel('y')

plt.plot(x, y, linewidth=2)

plt.plot(x, y, 'o', markersize=5, color='r');
```

Matplotlib (https://matplotlib.org/)

```
mu, sigma = 100, 15
x = mu + sigma * np.random.randn(10000)

# the histogram of the data
n, bins, patches = plt.hist(x, 50, normed=1, facecolor=
    'g', alpha=0.75)

plt.xlabel('Smarts')
plt.ylabel('Probability')
plt.title('Histogram of IQ')
# This will put a text fragment at the position given:
plt.text(55, .027, r'$\mu=100,\ \sigma=15$', fontsize
    =14)
plt.axis([40, 160, 0, 0.03])
plt.grid()
```

Matplotlib (https://matplotlib.org/)

```
from matplotlib import cm

plt.imshow(np.random.rand(5, 10), cmap=cm.gray,
    interpolation='nearest');

img = plt.imread('stinkbug.png')
print('Dimensions of the array img:', img.shape)
plt.imshow(img);
```

Matplotlib (https://matplotlib.org/)

```
from mpl_toolkits.mplot3d.axes3d import Axes3D
from matplotlib import cm

fig = plt.figure()
ax = fig.add_subplot(1, 1, 1, projection='3d')
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)
surf = ax.plot_surface(X, Y, Z, rstride=1, cstride=1,
    cmap=cm.viridis,
          linewidth=0, antialiased=False)
ax.set_zlim3d(-1.01, 1.01);
```