AI VIETNAM
Free AI Course 2020

Numpy

Introduction and applications to data processing (draft version)

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Ph.D. in Computer Science

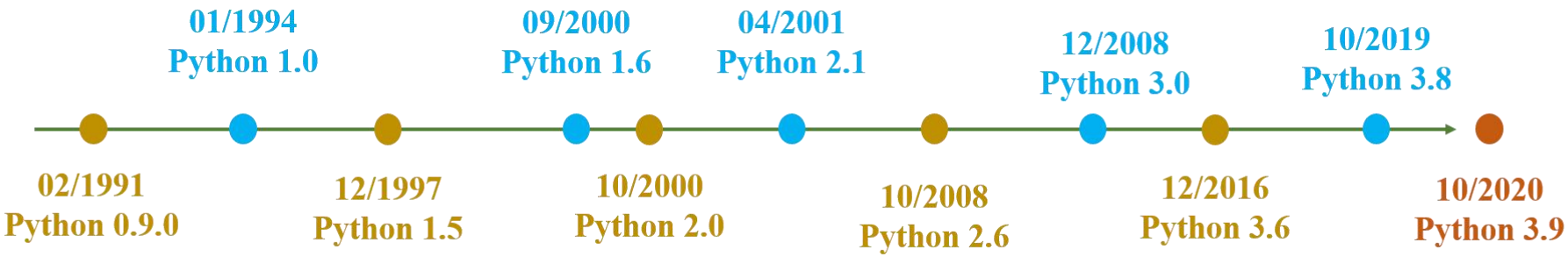
Year 2020

Outline

- Introduction to Numpy
- Numpy Array Indexing
- Numpy Array Operations
- Broadcasting
- Data Processing

Introduction

❖ Numpy is a Python library



Ý tưởng từ 1980s

Bắt đầu cài đặt
từ 12/1989

Guido van Rossum

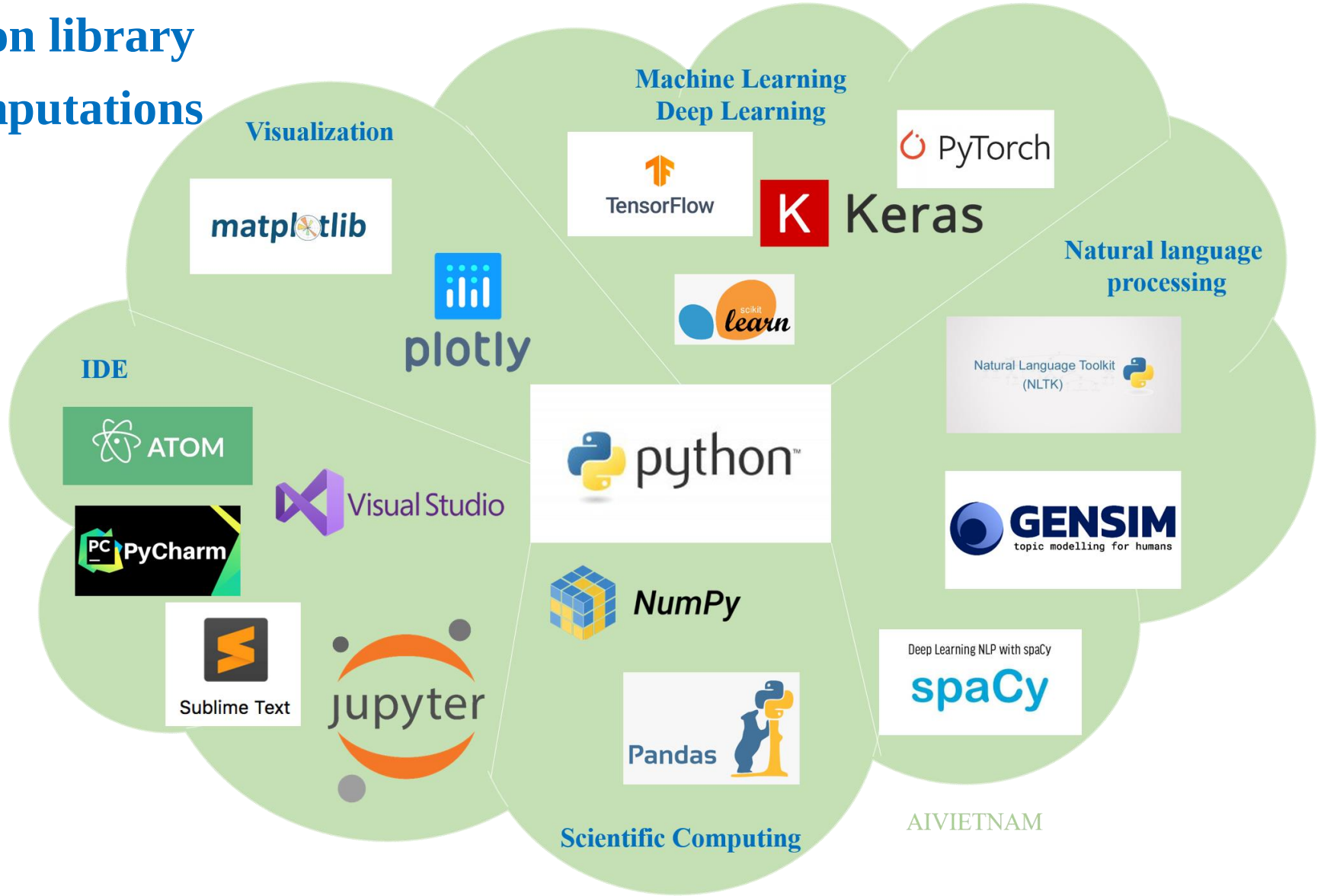
228,855 python packages
(PyPI)

Được đặt tên theo
nhóm hài Monty Python

Hỗ trợ rất mạnh cho
Data Science và Machine Learning

Introduction

- Numpy is a Python library
- For scientific computations



Introduction

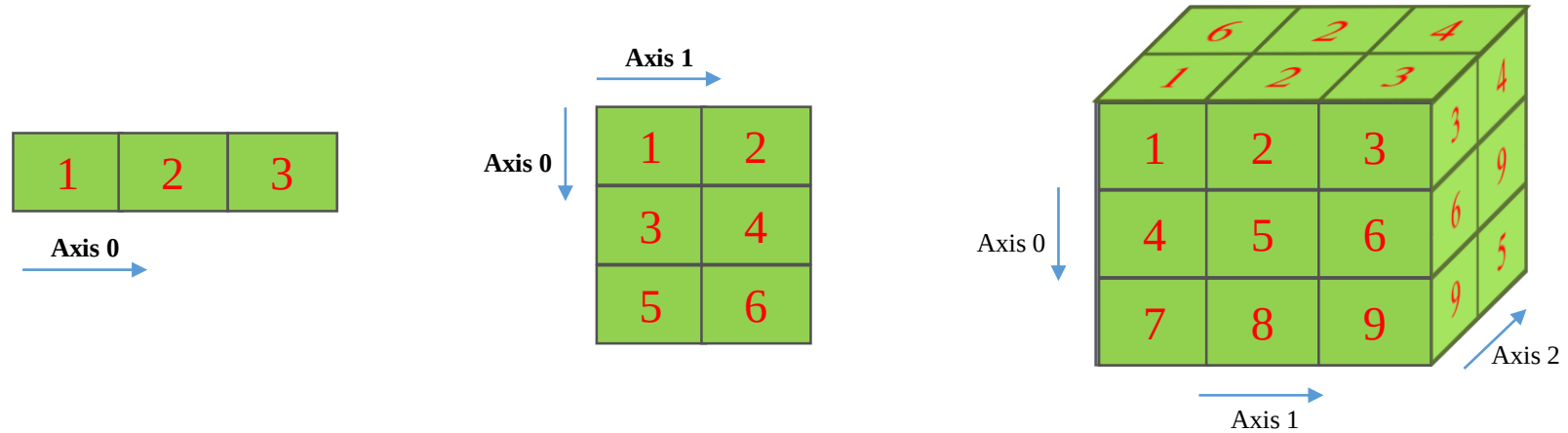
- Numpy is a Python library
- For scientific computations
- Numpy array ⟷ Tensor in Tensorflow and Pytorch


```python
import tensorflow as tf
import numpy as np

# create a numpy array
arr_np = np.arange(10)
print(arr_np)
print(arr_np.shape)
print('----------------------------')

# convert from numpy array to tensor
arr_tf = tf.convert_to_tensor(arr_np)
print(arr_tf)
print(arr_tf.shape)
print('----------------------------')

# convert from tensor to numpy array
arr_np_back = arr_tf.numpy()
print(arr_np_back)
print(arr_np_back.shape)
```

```
[0 1 2 3 4 5 6 7 8 9]
(10,)
----------------------------
tf.Tensor([0 1 2 3 4 5 6 7 8 9], shape=(10,), dtype=int64)
(10,)
----------------------------
[0 1 2 3 4 5 6 7 8 9]
(10,)
```

Introduction

- Numpy is a Python library
- For scientific computations
- Numpy array ⟷ Tensor in Tensorflow and Pytorch
- Numpy arrays are multi-dimensional arrays

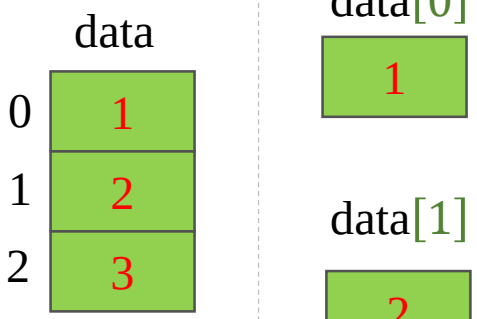


Introduction

❖ Create Numpy array

❖ From List

```
arr_np = np.array(python_list)
```



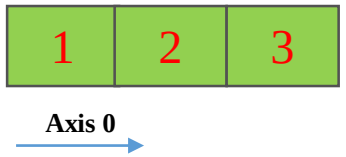

```python
# aivietnam.ai
# tạo ndarray từ list

import numpy as np

# tạo list
l = list(range(1, 4))

# tạo ndarray
data = np.array(l)

print(data)
print(data[0])
print(data[1])
```

```
[1 2 3]
1
2
```

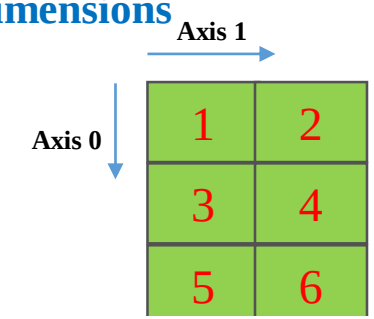
Introduction

❖ Common attributes

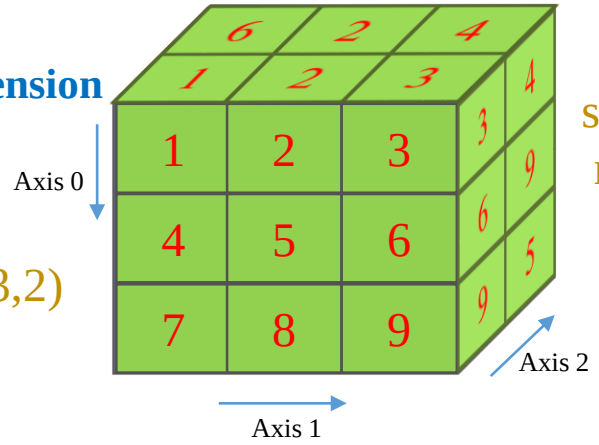
- ❖ dtype: data type
- ❖ shape: return a tuple of #elements in each dimension
- ❖ ndim: return #dimensions



shape=(3,)
ndim=1



shape=(3,2)
ndim=2



shape=(3,3,2)
ndim=2

```python
# aivietnam.ai
# tạo ndarray từ list

import numpy as np

# tạo list
list1D = [1,2,3]

# tạo ndarray
data = np.array(list1D)

print(data)
print(data.shape)
```

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

```python
# aivietnam.ai
# tạo ndarray từ list

import numpy as np

# tạo list
list2D = [[1,2],[3,4],[5,6]]

# tạo ndarray
data = np.array(list2D)

print(data)
print(data.shape)
```

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

```python
# aivietnam.ai
# tạo ndarray từ list

import numpy as np

# tạo list
list3D = [[[1,6], [2,2], [3,4
           [[4,7], [5,2], [6,9
           [[7,7], [8,2], [9,5

# tạo ndarray
data = np.array(list3D)

#print(data)
print(data.shape)
```

```
(3, 3, 2)
```

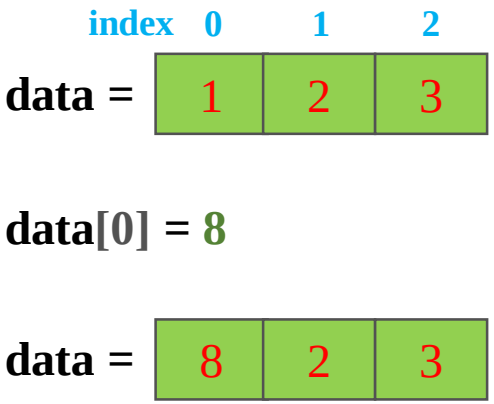
dtype example

```python
# aivietnam.ai
# tạo ndarray từ list

import numpy as np

# tạo ndarray
data1 = np.array([1,2,3])
print(data1.dtype)

data2 = np.array([1.,2.,3.])
print(data2.dtype)

data3 = np.array([1,2,3], dtype=np.int64)
print(data3.dtype)
```

```
int32
float64
int64
```

Introduction

❖ Update an element



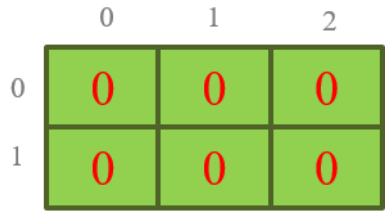

```python
# aivietnam.ai
# thay đổi giá trị phần tử

import numpy as np

# tạo list
l = list(range(1, 4))

# tạo ndarray
data = np.array(l)
print(data)

data[0] = 8
print(data)
```

```
[1 2 3]
[8 2 3]
```

Introduction

❖Create Numpy array

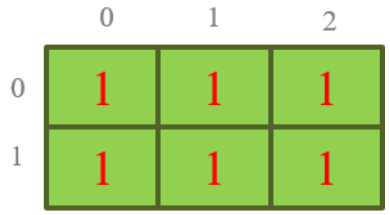
zeros() function




```
# aivietnam.ai
# Tạo một numpy array
# với tất cả phần tử là 0

import numpy as np

# shape: 2 dòng, 3 cột
arr = np.zeros((2,3))
print(arr)
```

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

ones() function




```
# aivietnam.ai
# Tạo một numpy array với
# tất cả phần tử là 1

import numpy as np

# numpy.ones(shape)
# shape: 2 dòng, 3 cột
arr = np.ones((2,3))
print(arr)
```

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

full() function

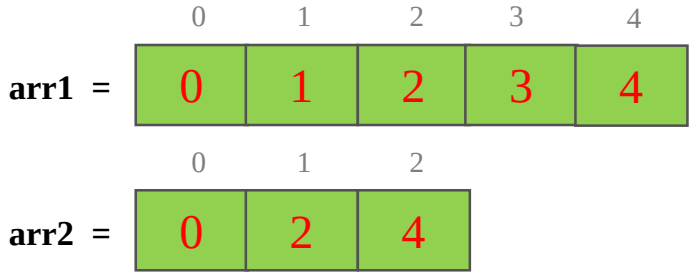

```
# aivietnam.ai
# Tạo một numpy array với tất
# cả phần tử là hằng số fill_value

import numpy as np

# numpy.full(shape, fill_value)
# shape: 2 dòng, 3 cột
arr = np.full((2,3), 9)
print(arr)
```

```
[[9 9 9]
 [9 9 9]]
```

Introduction

❖Create Numpy array

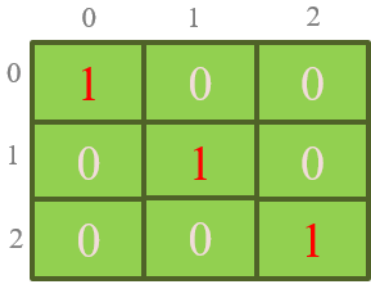
arange() function




```python
# aivietnam.ai
import numpy as np

# np.arange(start=0, stop, step=1)
arr1 = np.arange(5)
print(arr1)

arr2 = np.arange(0, 5, 2)
print(arr2)
```

```
[0 1 2 3 4]
[0 2 4]
```

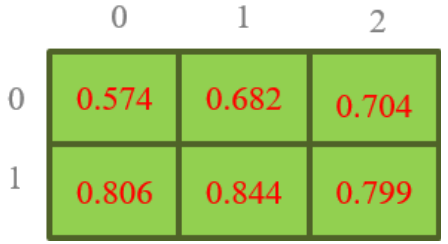
eye() function




```python
# aivietnam.ai
# Tạo một numpy array với đường chéo là số 1
# số 0 được điền vào những ô phần tử còn lại

import numpy as np

# numpy.eye(N)
# shape: 3 dòng, 3 cột
arr = np.eye(3)
print(arr)
```

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

random() function



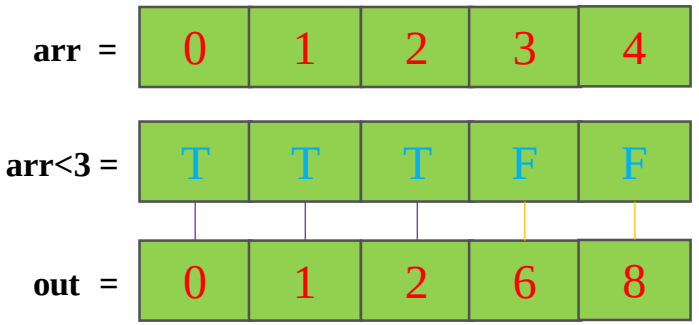

```python
# aivietnam.ai
# Tạo một numpy array với
# giá trị ngẫu nhiên

import numpy as np

# np.random.random(size)
# shape: 2 dòng, 3 cột; với
# phần tử có giá trị ngẫu nhiên
arr = np.random.random((2,3))
print(arr)
```

```
[[0.57488062 0.68266312 0.70438569]
 [0.80661973 0.84413356 0.79905247]]
```

Introduction

❖Some important functions

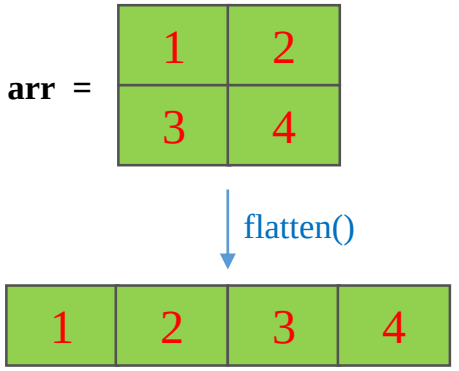
where() function




```python
# aivietnam.ai
import numpy as np

# create an array
arr = np.arange(5)
print(arr)

# condition
condition = arr < 3
out = np.where(condition, arr, arr*2)

print(condition)
print(out)
```

```
[0 1 2 3 4]
[ True  True  True False False]
[0 1 2 6 8]
```

flatten() function




```python
# aivietnam.ai
import numpy as np

arr = np.array([[1,2], [3,4]])
out = arr.flatten()

print(arr)
print(out)
```

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

Introduction

❖Some important functions

reshape() function

data

1	2	3
4	5	6

data_rs

1	2
3	4
5	6

```python
# aivietnam.ai
import numpy as np

# tạo list
l = [[1,2,3],
     [4,5,6]]

# tạo ndarray
data = np.array(l)
print('data\n', data)
print('data shape\n', data.shape)

# reshape
data_rs = np.reshape(data, (3,2))
print('data_rs\n', data_rs)
print('data_rs shape\n', data_rs.shape)
```

```
data
 [[1 2 3]
 [4 5 6]]
data shape
 (2, 3)
data_rs
 [[1 2]
 [3 4]
 [5 6]]
data_rs shape
 (3, 2)
```

Outline

- Introduction to Numpy
- Numpy Array Indexing
- Numpy Array Operations
- Broadcasting
- Data Processing

Array Indexing

❖ Slicing

arr[for_axis_0, for_axis_1, …]

‘**:**’: get all the elements
‘**a:b**’: get the elements from a^{th} to b^{th}

data

	0	1
0	1	2
1	3	4
2	5	6

data[0, 1]

	0	1
0	1	2
1	3	4
2	5	6

data[1: 3]

	0	1
0	1	2
1	3	4
2	5	6

data[0: 1 , 0]

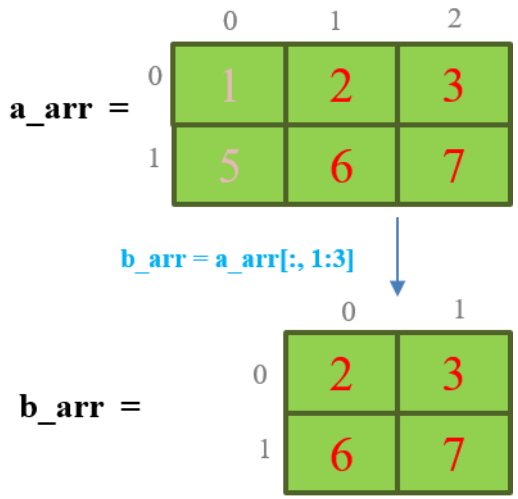
	0	1
0	1	2
1	3	4
2	5	6

data[: , :]

	0	1
0	1	2
1	3	4
2	5	6

Array Indexing

❖ Slicing



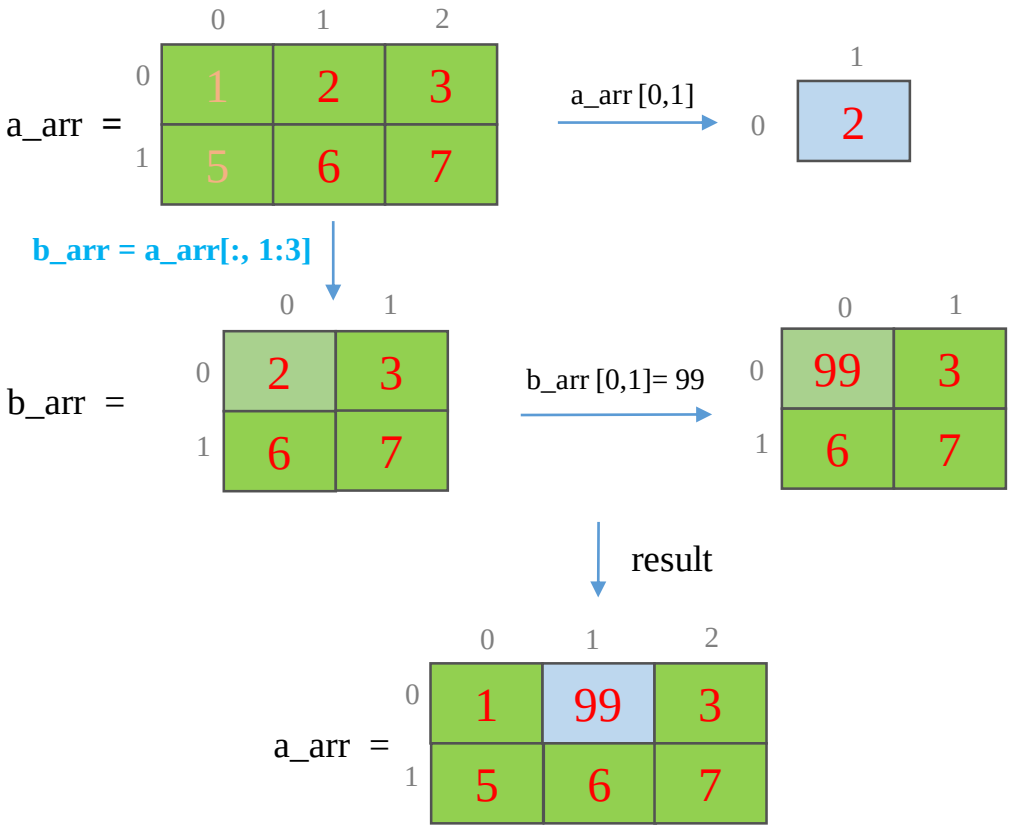

```python
# aivietnam.ai
import numpy as np

# Khởi tạo numpy array a_arr
a_arr = np.array([[1,2,3],
                  [5,6,7]])

# Sử dụng slicing để tạo mảng b_arr
# bằng cách lấy tất cả các dòng và cột 1,2
b_arr = a_arr[:, 1:3]

print(a_arr)
print(b_arr)
```

```
[[1 2 3]
 [5 6 7]]
[[2 3]
 [6 7]]
```

Array Indexing

❖ Slicing

❖ Mutable

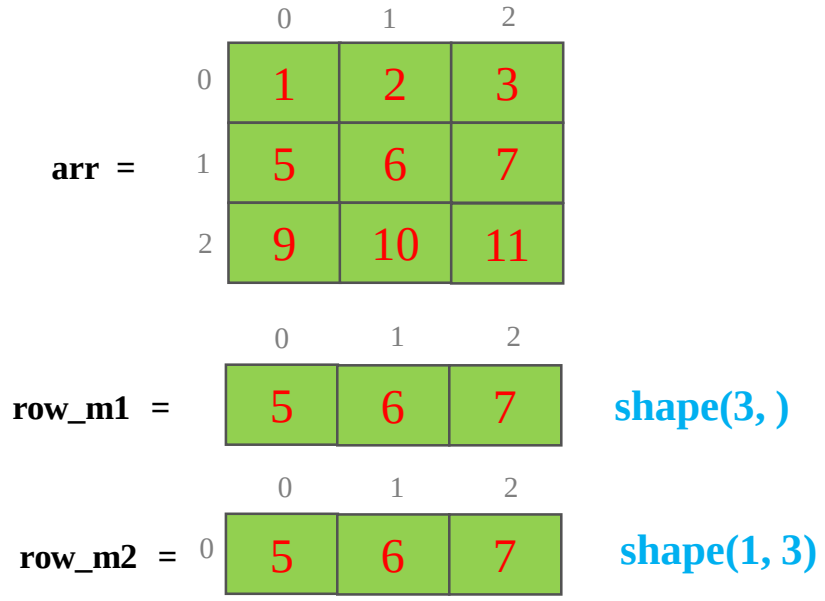



```python
# aivietnam.ai
import numpy as np

# Khởi tạo numpy array a_arr
a_arr = np.array([[1,2,3],
                  [5,6,7]])
print('a_arr \n', a_arr)

# Sử dụng slicing để tạo mảng b_arr
b_arr = a_arr[:, 1:3]
print('b_arr \n', b_arr)

print('before changing \n', a_arr[0, 1])
b_arr[0, 0] = 99
print('after changing \n', a_arr[0, 1])
```

```
a_arr
 [[1 2 3]
 [5 6 7]]
b_arr
 [[2 3]
 [6 7]]
before changing
 2
after changing
 99
```

Array Indexing

❖Get a row

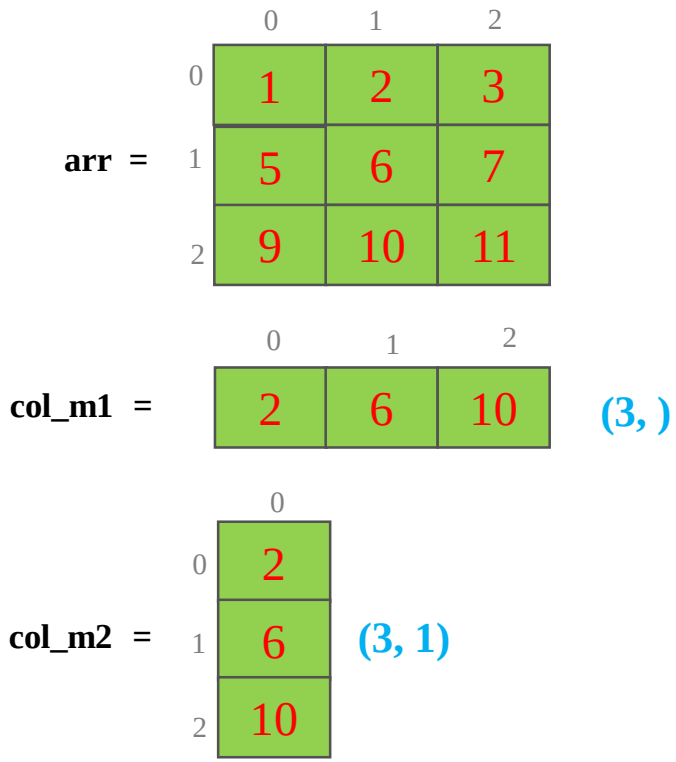



```
1  # aivietnam.ai
2  import numpy as np
3
4  # Tạo một numpy array có shape (3, 3) với giá trị
5  # [[ 1  2  3]
6  #  [ 5  6  7]
7  #  [ 9 10 11]]
8  arr = np.array([[1, 2, 3],
9                  [5, 6, 7],
10                 [9,10,11]])
11
12 # Hai cách truy cập dữ liệu ở dòng index=1
13 # cách 1: số chiều giảm
14 row_m1 = arr[1, :]
15
16 # cách 2: số chiều được giữa nguyên
17 row_m2 = arr[1:2, :]
18
19 print(row_m1, row_m1.shape)
20 print(row_m1, row_m2.shape)
```

```
[5 6 7] (3,)
[5 6 7] (1, 3)
```

Array Indexing

❖ Get a column

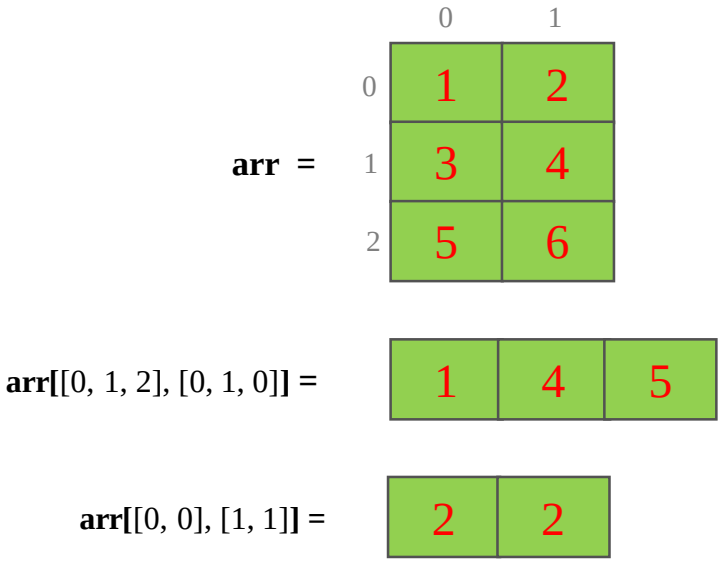



```
1  # aivietnam.ai
2  import numpy as np
3
4  # Tạo một numpy array có shape (3, 3) với giá trị
5  arr = np.array([[1,2,3],
6                  [5,6,7],
7                  [9,10,11]])
8
9  # Hai cách truy cập dữ liệu ở cột index=1 của mảng
10 # cách 1: số chiều giảm
11 col_m1 = arr[:, 1]
12
13 # cách 2: số chiều được giữa nguyên
14 col_m2 = arr[:, 1:2]
15
16 print(col_m1, col_m1.shape)
17 print(col_m2, col_m2.shape)
```

```
[ 2  6 10] (3,)
[[ 2]
 [ 6]
 [10]] (3, 1)
```

Array Indexing

❖ Using Lists as indices

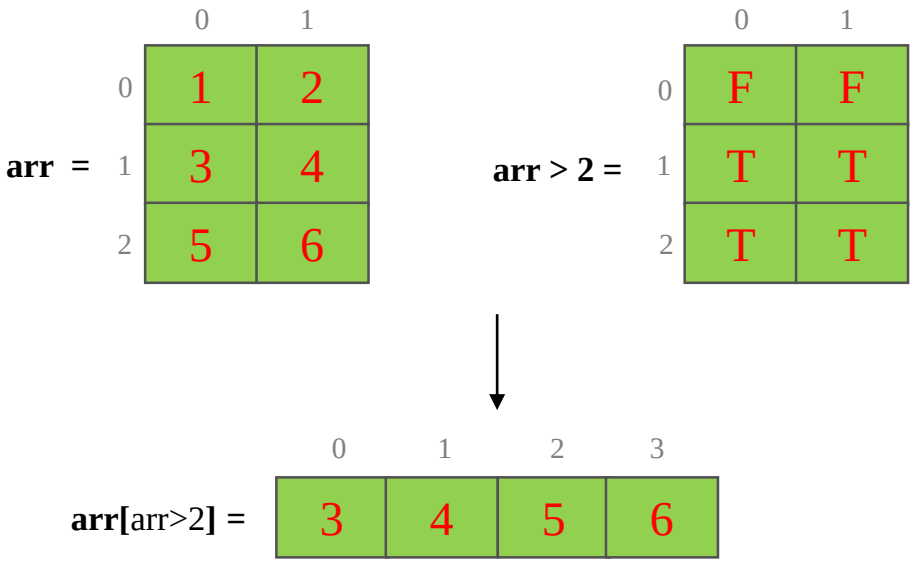



```python
# aivietnam.ai
import numpy as np

# tạo arr
arr = np.array([[1,2],
                [3, 4],
                [5, 6]])

# lấy giá trị vị trí (0,0), (1,1) và (2,0)
out1 = arr[[0, 1, 2], [0, 1, 0]]
print('out1:\n', out1)

# Có thể truy xuất tới 1 phần tử nhiều hơn 1 lần
out2 = arr[[0, 0], [1, 1]]
print('out2:\n', out2)
```

```
out1:
 [1 4 5]
out2:
 [2 2]
```

Array Indexing

❖ Boolean indices




```python
# aivietnam.ai
import numpy as np

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

# Tìm các phần tử lớn hơn 2
bool_idx = (arr > 2)
print(bool_idx)
```

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

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- Introduction to Numpy
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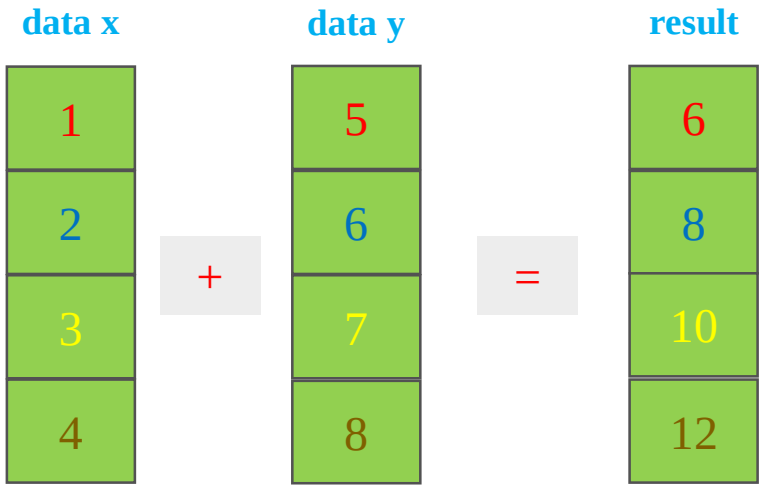
Numpy Array Operations

❖ Addition

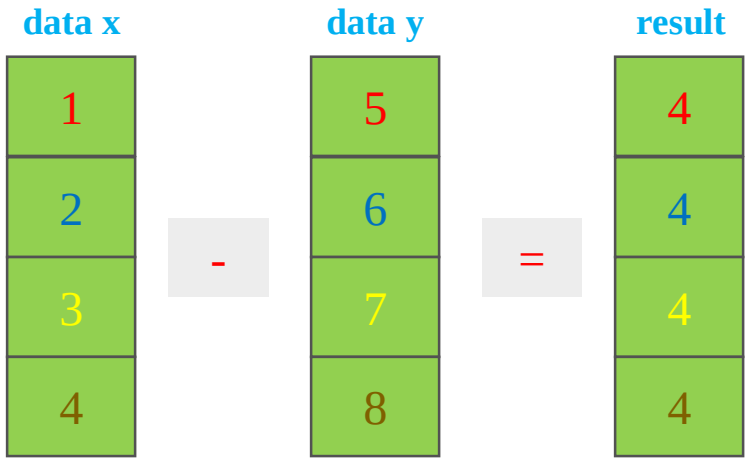



```python
# aivietnam.ai
import numpy as np

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

print('data x \n', x)
print('data y \n', y)

# Tổng của 2 mảng
print('method 1 \n', x + y)
print('method 2 \n', np.add(x, y))
```

```
data x
 [1 2 3 4]
data y
 [5 6 7 8]
method 1
 [ 6  8 10 12]
method 2
 [ 6  8 10 12]
```

Numpy Array Operations

❖ Subtraction

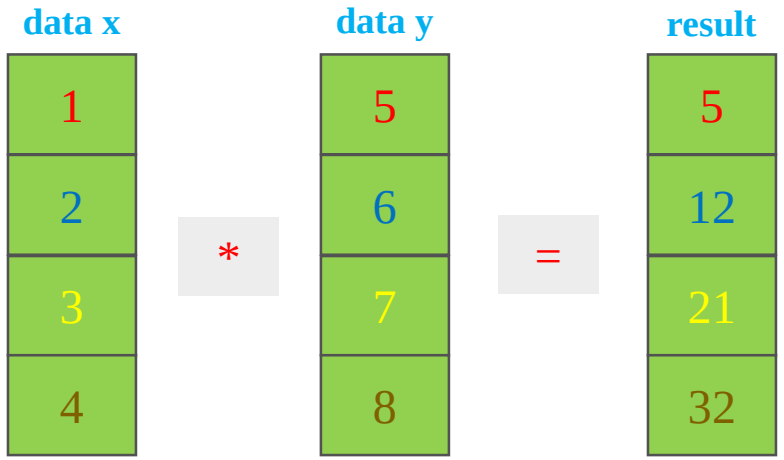



```python
# aivietnam.ai
import numpy as np

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

print('data x \n', x)
print('data y \n', y)

# Hiệu 2 mảng
print('method 1 \n', x - y)
print('method 2 \n', np.subtract(x, y))
```

```
data x
 [5 6 7 8]
data y
 [1 2 3 4]
method 1
 [4 4 4 4]
method 2
 [4 4 4 4]
```

Numpy Array Operations

❖ Multiplication

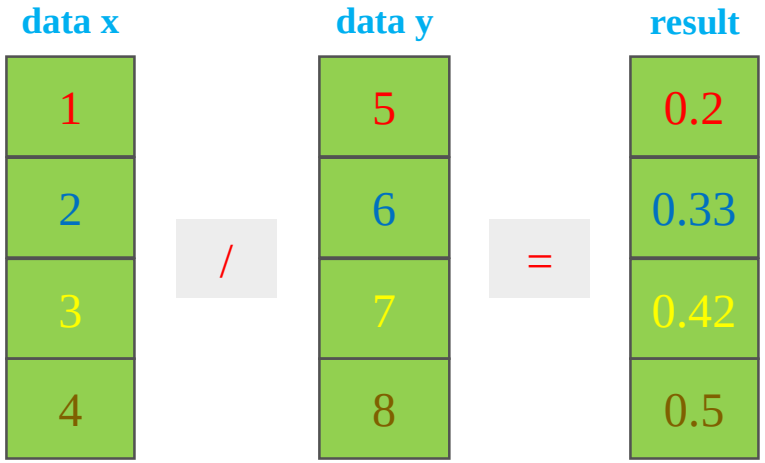



```python
# aivietnam.ai
import numpy as np

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

print('data x \n', x)
print('data y \n', y)

# Tích các phần tử tương ứng giữa x và y
print('method 1 \n', x*y)
print('method 2 \n', np.multiply(x, y))
```

```
data x
 [1 2 3 4]
data y
 [5 6 7 8]
method 1
 [ 5 12 21 32]
method 2
 [ 5 12 21 32]
```

Numpy Array Operations

❖ Division

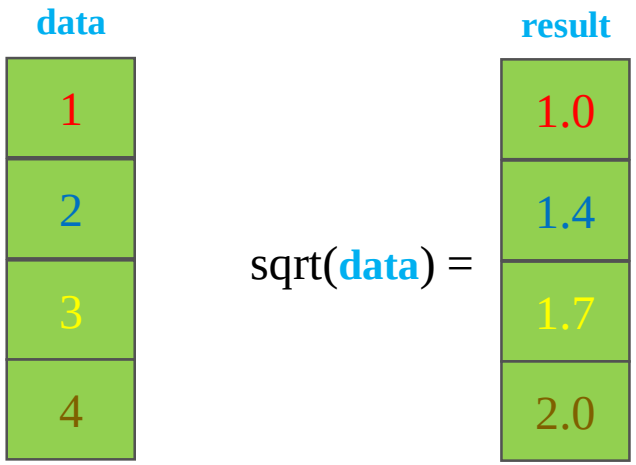



```python
# aivietnam.ai
import numpy as np

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

print('data x \n', x)
print('data y \n', y)

# Phép chia các từng phần tương ứng x cho y
print('method 1 \n', x / y)
print('method 2 \n', x // y)
print('method 3 \n', np.divide(x, y))
```

```
data x
 [5 6 7 8]
data y
 [1 2 3 4]
method 1
 [5.         3.         2.33333333 2.        ]
method 1
 [5 3 2 2]
method 2
 [5.         3.         2.33333333 2.        ]
```

Numpy Array Operations

❖ Square root

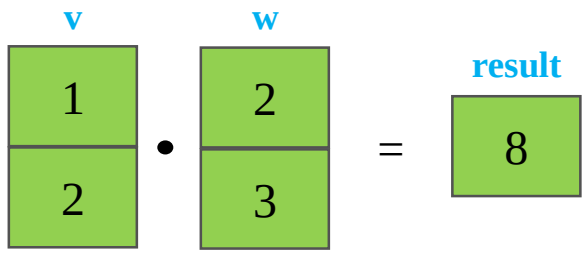



```python
# aivietnam.ai
import numpy as np

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

print('data \n', data)

# Căn bậc 2 từng phần tử trong data
print('sqrt \n', np.sqrt(data))
```

```
data
 [1 2 3 4]
sqrt
 [1.         1.41421356 1.73205081 2.        ]
```

Numpy Array Operations

❖ Inner product

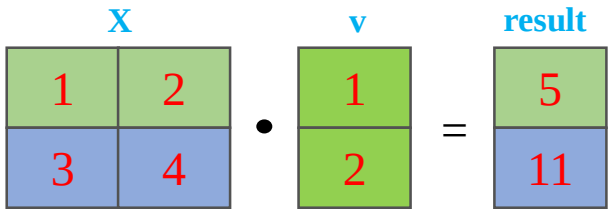


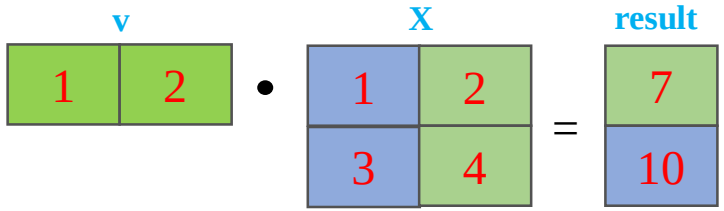

```python
# aivietnam.ai
import numpy as np

v = np.array([1, 2])
w = np.array([2, 3])

# Tính inner product giữa v và w
print('method 1 \n', v.dot(w))
print('method 2 \n', np.dot(v, w))
```

```
method 1
8

method 2
8
```

Numpy Array Operations

❖ Vector-matrix multiplication



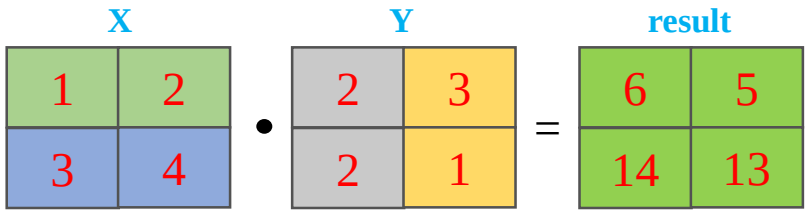


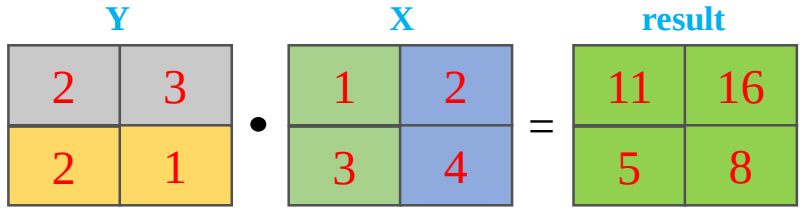

```python
# aivietnam.ai
import numpy as np

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

print('matrix X \n', X)
print('vector v \n', v)

# phép nhân giữa ma trận và vector
print('method 1: X.dot(v) \n', X.dot(v))
print('method 1: v.dot(X) \n', v.dot(X))
#print('\n method 2: X.dot(v) \n', np.dot(X, v))
#print('\n method 2: v.dot(X) \n', np.dot(v, X))
```

```
matrix X
 [[1 2]
 [3 4]]
vector v
 [1 2]
method 1: X.dot(v)
 [ 5 11]
method 1: v.dot(X)
 [ 7 10]
```

Numpy Array Operations

❖ Matrix-matrix multiplication



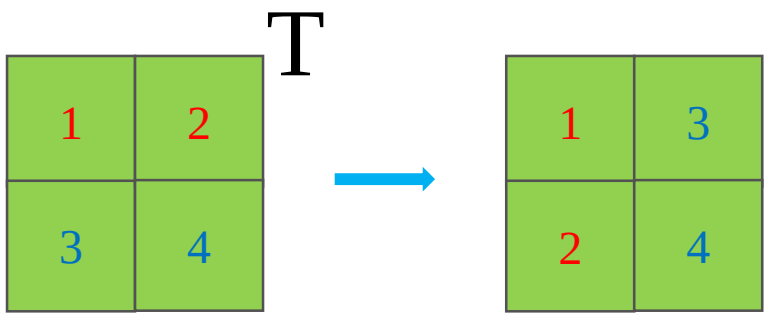



```python
# aivietnam.ai
import numpy as np

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

# Phép nhân giữa hai ma trận
print('method 1 \n', X.dot(Y))
print('method 1 \n', Y.dot(X))
#print('method 2 \n', np.dot(X, Y))
#print('method 2 \n', np.dot(Y, X))
```

```
method 1
 [[ 6  5]
 [14 13]]
method 1
 [[11 16]
 [ 5  8]]
```

Numpy Array Operations

❖ Transpose

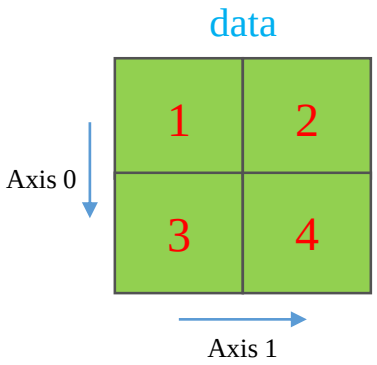



```python
# aivietnam.ai
import numpy as np

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

#chuyển vị
print(X.T)
```

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

Numpy Array Operations

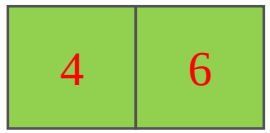
❖ Summation



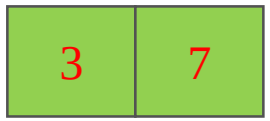
sum(data)

10

sum(data, axis=0)



sum(data, axis=1)




```python
# aivietnam.ai
import numpy as np

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

# Tổng các phần tử của mảng
print(np.sum(X))

 # Tính tổng theo từng cột
print(np.sum(X, axis=0))

# Tính tổng theo từng dòng
print(np.sum(X, axis=1))
```

```
10
[4 6]
[3 7]
```

Numpy Array Operations

❖ Max and min

data

1
2
3

.max( ) = 3

data

1
2
3

.min( ) = 1

```
1  # aivietnam.ai
2  import numpy as np
3
4  data = np.array([1, 2, 3])
5
6  print(data.max())
7  print(data.min())
```

```
3
1
```

1	2
3	4
5	6

.max(axis=0) = | 5 | 6 |

1	2
3	4
5	6

.min(axis=0) = | 1 | 2 |

1	2
3	4
5	6

.max(axis=1) = | 2 | 4 | 6 |

1	2
3	4
5	6

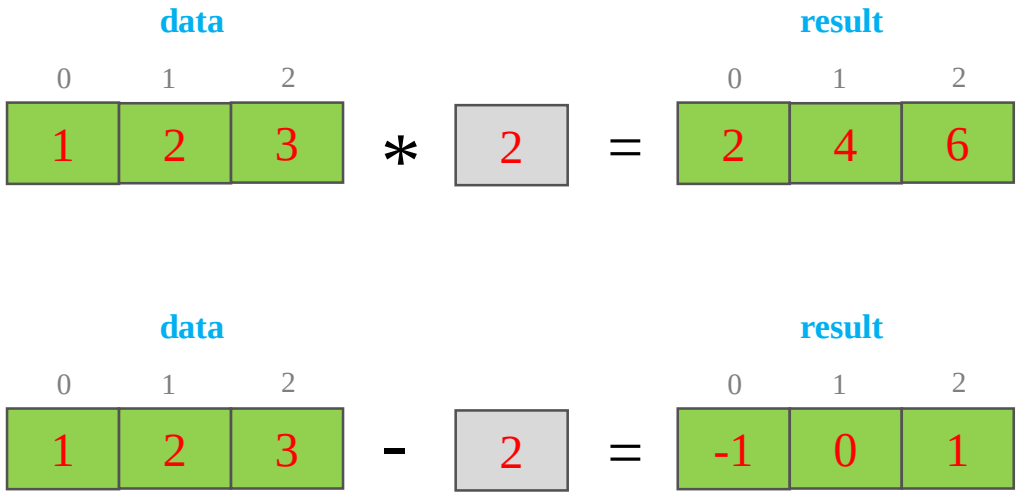
.min(axis=1) = | 1 | 3 | 5 |

Outline

- Introduction to Numpy
- Numpy Array Indexing
- Numpy Array Operations
- Broadcasting
- Data Processing

Broadcasting

❖ Vector and a scalar

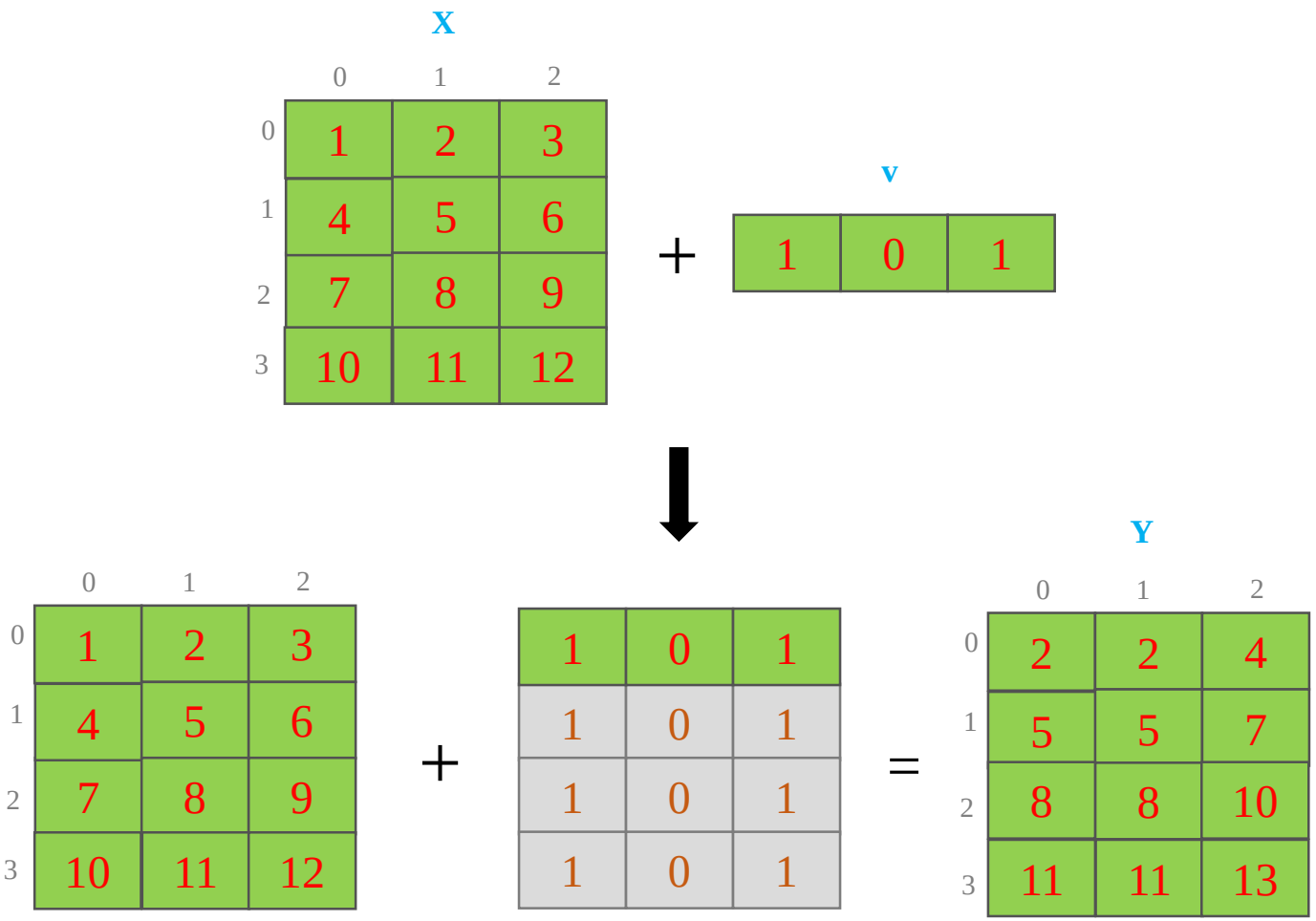



```python
# aivietnam.ai
import numpy as np

# create data
data = np.array([1,2,3])
factor = 2

# broadcasting
result_multiplication = data*factor
result_minus = data - factor

print(data)
print(result_multiplication)
print(result_minus)
```

```
[1 2 3]
[2 4 6]
[-1  0  1]
```

Broadcasting

❖ Matrix and vector




```python
# aivietnam.ai
import numpy as np

X = np.array([[1, 2, 3],
              [4, 5, 6],
              [7, 8, 9],
              [10, 11, 12]])
v = np.array([1, 0, 1])

Y = X + v
print(Y)
```

```
[[ 2  2  4]
 [ 5  5  7]
 [ 8  8 10]
 [11 11 13]]
```

Outline

- Introduction to Numpy
- Numpy Array Indexing
- Numpy Array Operations
- Broadcasting
- Data Processing

Data Processing

❖Text data

❖ IRIS data

sepal_length	sepal_width	petal_length	petal_width	species
5.1	3.5	1.4	0.2	Iris-setosa
4.9	3	1.4	0.2	Iris-setosa
4.7	3.2	1.3	0.2	Iris-setosa
4.6	3.1	1.5	0.2	Iris-setosa
5	3.6	1.4	0.2	Iris-setosa
5.4	3.9	1.7	0.4	Iris-setosa
4.6	3.4	1.4	0.3	Iris-setosa
5	3.4	1.5	0.2	Iris-setosa
4.4	2.9	1.4	0.2	Iris-setosa
4.9	3.1	1.5	0.1	Iris-setosa

Data Processing

❖Text data

❖ IRIS data

col 0	col 1	col 2	col 3	col 4
sepal_length	sepal_width	petal_length	petal_width	species

Demo

```
# aivietnam.ai
# Đọc file IRIS.csv

import numpy as np
import numpy.core.defchararray as np_f

# lấy các đặc trưng và lưu vào biến X
X = np.genfromtxt('IRIS.csv', delimiter=',',
                  dtype='float', usecols=[0,1,2,3],
                  skip_header=1)
print(X.shape)

# lấy species và lưu vào biến y
y = np.genfromtxt('IRIS.csv', delimiter=',',
                  dtype='str', usecols=4, skip_header=1)

# thay chuỗi bằng số
categories = np.unique(y)
for i in range(categories.size):
    y = np_f.replace(y, categories[i], str(i))

# đưa về kiểu float
y = y.astype('float')
print(y)
```

```
(150, 4)
[0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
 1. 1. 1. 1. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.
 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.
 2. 2. 2. 2. 2. 2.]
```

Data Processing

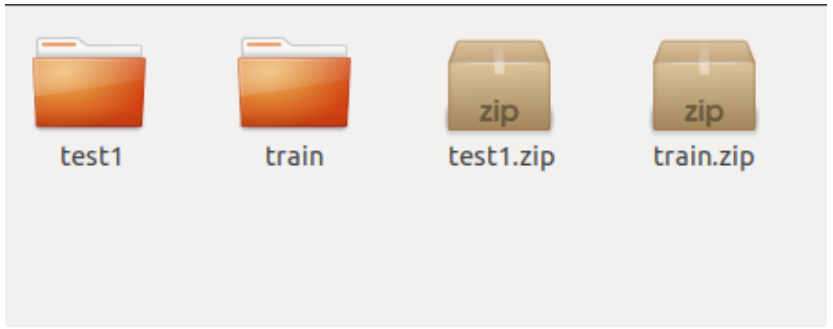
❖ Images in binary

Name	Size
t10k-images-idx3-ubyte.gz	4.4 MB
t10k-labels-idx1-ubyte.gz	5.1 kB
train-images-idx3-ubyte.gz	26.4 MB
train-labels-idx1-ubyte.gz	29.5 kB

Demo

Data Processing

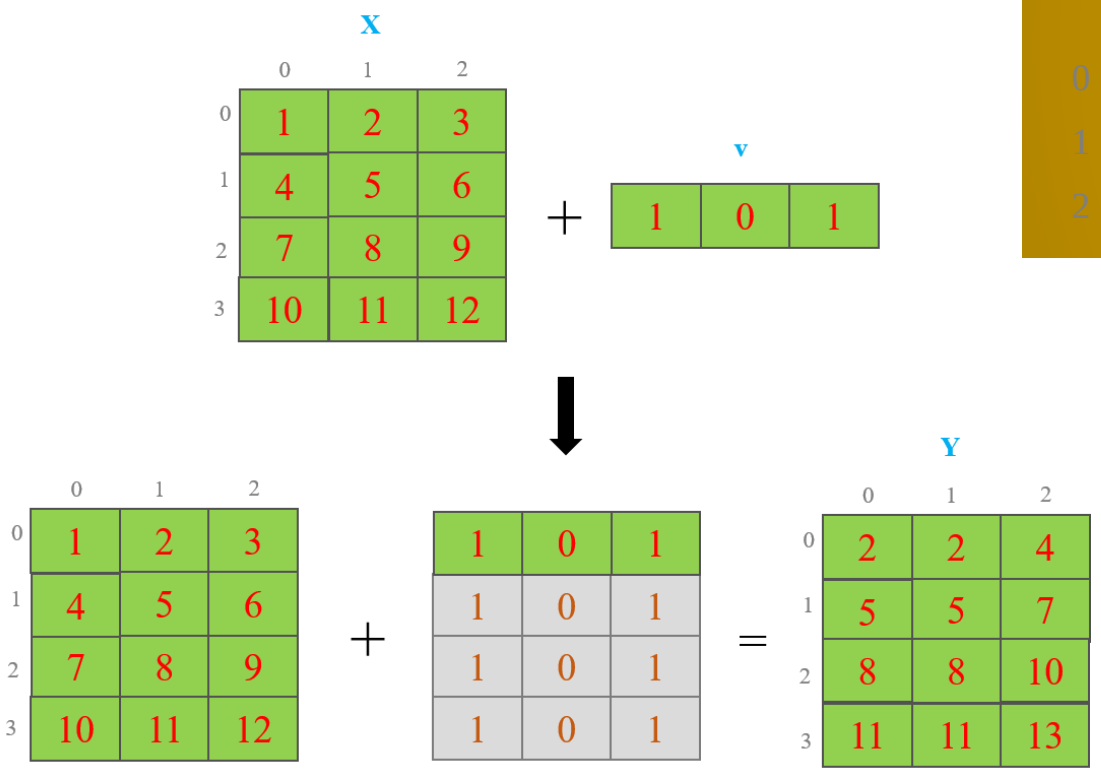
❖ Images in files



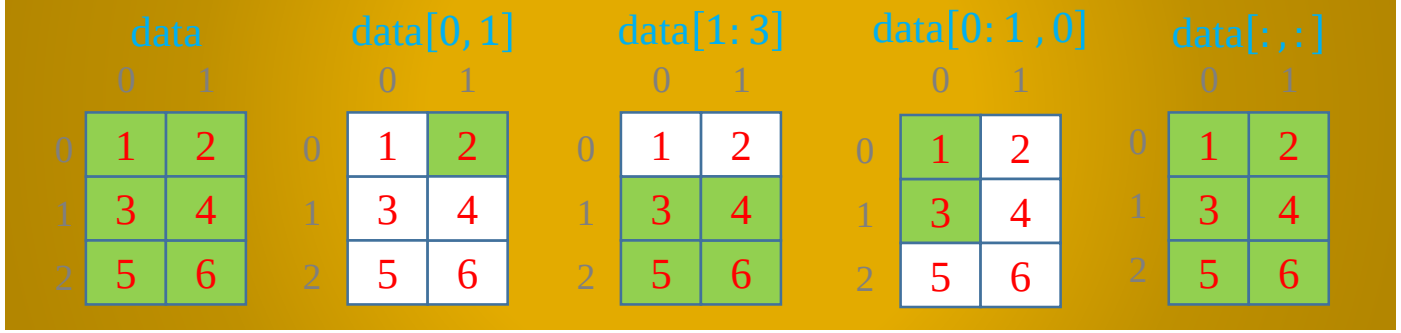
Demo

Summary

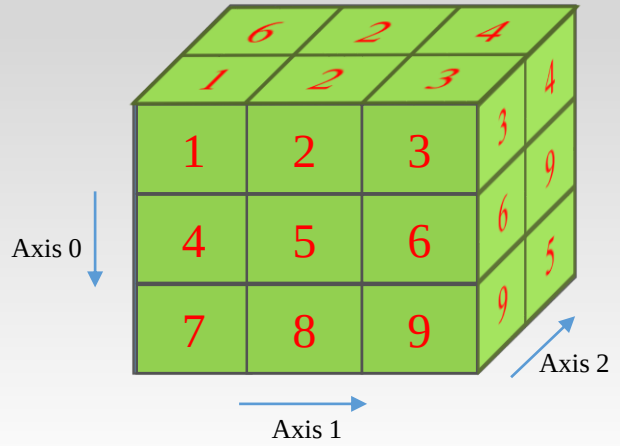
Broadcasting



Indexing



Multi-dimension Array




Thank you!