Disclaimer

If a student turns on their microphone or camera or uses the public chat feature, this constitutes consent for the student's video image or sound audio to be uploaded with the office hour or tutorial on university approved platforms such as D2L. If the student wishes to ensure that their questions/faces/voices are not recorded in the video, they should instead use private chat to ask questions.

ENEL 645 – Python Bootcamp

Python 3 and efficient array processing with Numerical Python (NumPy)

Roberto Souza
Assistant Professor
Electrical and Computer Engineering
Schulich School of Engineering

January 2022

UNIVERSITY OF CALGARY

Outline

- Learning Objectives
- Python
  - What it is? And why use it?
  - Python variables, data types and syntax
  - Hands-on
- Numerical Python (NumPy)
  - NumPy array slicing
  - Hands-on
- Review of the Concepts
- Homework

Learning Objectives

- Introduction to Python:
  - Data types
  - Syntax

- Numerical programming in Python:
  - NumPy library
  - Efficient NumPy array processing

This is just an introduction! Students are advised to go through the first two tutorials in the class GitHub repository.

Tutorials:

- Tutorial 01: Introduction to Python
- Tutorial 02: Introduction to NumPy
- Tutorial 2.1: Avoid loops!

What is Python?

- Programming language created in 1991
  - Interpreted:
    - Does not convert code into machine language prior to running
    - Potentially slower performance. Avoid **explicit loops** at all cost!
  - High-level
    - Strong abstraction from the details of the computer
  - General-purpose
    - Applied on a range of domains: backend web development, scientific computing, data analysis, and **machine learning (ML)**

Why use Python?

Lasagne

Caffe

TensorFlow

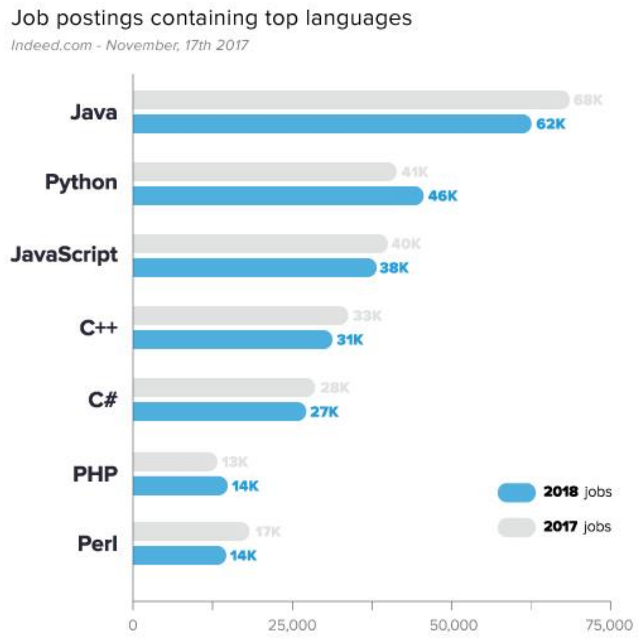
Caffe2

theano

K Keras

PYTORCH

- It is the ML language
- Preferred by data scientists and engineers - professions in high-demand



Source: https://www.codingdojo.com/

Why use Python?

- High productivity
- Programming paradigms
  - Object-oriented and structured programming
- Robust standard and non-standard libraries
  - NumPy, Pandas, OpenCV, Scikit-learn, Scikit-image, etc.
- Maintainable code
  - Readable and clean
- Installing libraries is easy
  - pip install <*library name*>
- Compatible with major platforms
- Large community
  - Fastest growth in past years compared to other languages

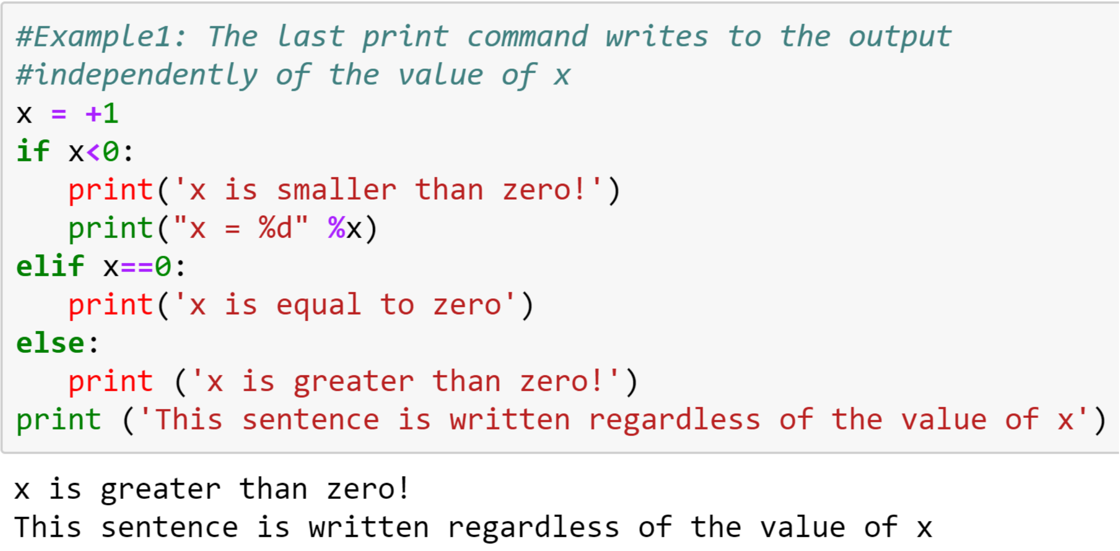
Python Variables and Data Types

- No need to pre-declare variables and their types

Variable type	Description	Syntax example
int	Integer variable	a = 103458
float	Floating point variable	pi = 3.14159265
bool	Boolean variable - True or False	a = False
complex	Complex number variable	c = 2+3j
str	UNICODE string	a = "Example"
list	Heterogeneous list (any type of elements)	my_list = [4,'me',1]
tuple	Heterogeneous tuple (values can't change)	my_tuple = (1,'I',2)
dict	Associative set of values	dic = {'me':1,'you':2}
set	Unordered collection of unique items	a = {5,2,3,1,4}

Syntax: Flow Control Statements

- Blocks, such as "if", "for" are delimited by **code indentation** and not delimiters like "{}" "BEGIN...END“
- Main flow control commands:
    - if/else
    - For
- Avoid **explicit loops** at all cost in Python!



```
#Example1: The last print command writes to the output
#independently of the value of x
x = +1
if x<0:
    print('x is smaller than zero!')
    print("x = %d" %x)
elif x==0:
    print('x is equal to zero')
else:
    print ('x is greater than zero!')
print ('This sentence is written regardless of the value of x')
```

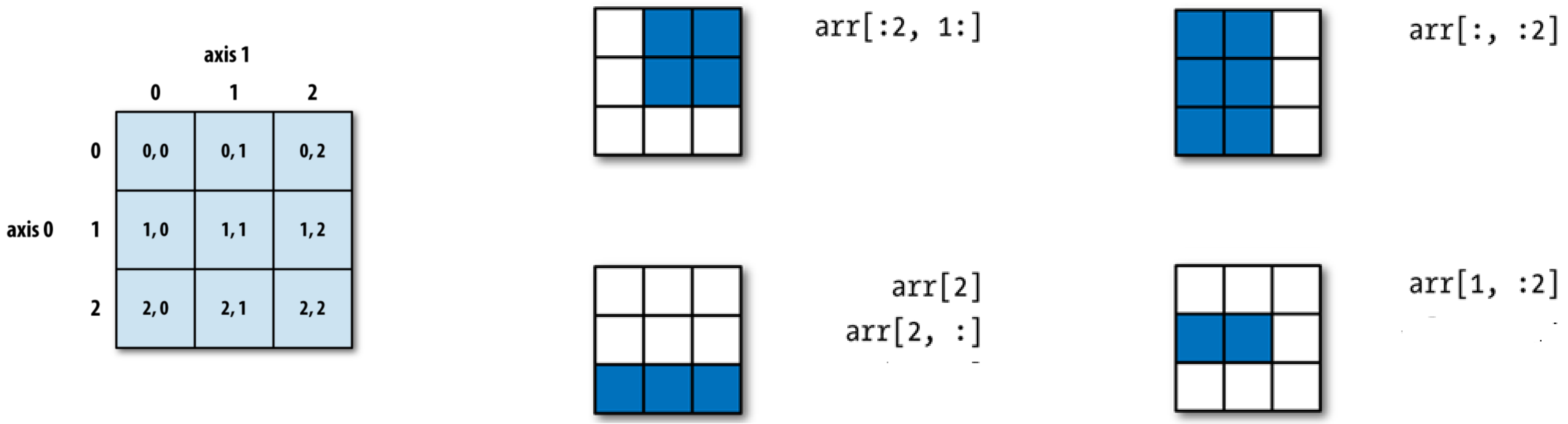
```
x is greater than zero!
This sentence is written regardless of the value of x
```

Numerical Python (NumPy)

- *NumPy* is a Python library
- It has functions for efficient multi-dimensional array processing
- It is the basis for scientific computing with Python
  - ML applications are all built upon NumPy arrays (*ndarray*)
- NumPy functions are compiled (i.e., faster)
  - Let the NumPy functions do the looping for you!

NumPy Slicing

- NumPy slicing
  - Compiled NumPy functions implicitly do the looping for you
  - Notation: [begin:end:step]
  - End element is not included



		axis 1		
		0	1	2
	0	0, 0	0, 1	0, 2
axis 0	1	1, 0	1, 1	1, 2
	2	2, 0	2, 1	2, 2

```
arr[:2, 1:]
```

```
arr[:, :2]
```

```
arr[2]
arr[2, :]
```

```
arr[1, :2]
```

Summary

- Python is a high productivity language with a rich set of libraries, especially related to ML
- Flow control statements are defined by indentation
- NumPy array processing style can lead to efficient code
- Avoid **explicit loops** at all cost!

Thank you!

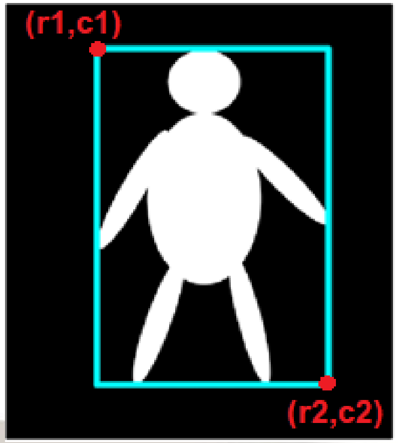
Questions?

Homework

- **Assignment:**

Write a function that receives as input a 2D Boolean NumPy array and outputs the coordinates of the minimal bounding-box that encloses all non-zero elements in the input array. Try to make your code clear and with fast execution.

Tip: search for the functions ***nonzero*** and ***where*** in the NumPy documentation.



- **Rules:**

1. All solutions will be visible to all students from initial development to the final code;
2. If you got your implementation idea from someone else, give credit to that person;
3. If you have a suggestion to improve a friend's code, leave a suggestion.