Lecture 1 – Python Basics

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Week 1 - Tuesday

$\overline{09.00 - 10.30}$	Intro to Python (lecture + exercise + break)		
	Basic variables		
	Data structures (dictionary, list, numpy array,)		
	I/O, Visualization		
10:30 -	Study group work, catch up		

Todays Learning Objectives

- Get familiar with colaboratory
- Define and access variables in Python
- Explain which different Python data types there are
- Write down a list of common Python modules
- Draw a 2D as well as a 3D image in Python

Why Python?

- For Data Science software, why choose Python?
- Criteria:
 - Ease of prototyping/development
 - Performance (speed/memory)
 - Environment (IDE, debug, profiler)
 - Open source communities
 - Data Science relevancy
 - Cost (\$)
- Performance + IDE

- ··· + Ease + Data Science → Matlab
- ··· + Communities + Cost → Python

Computational environment

- Many to choose from
 - Anaconda Spyder IDE, Jupyter, JupyterLab
 - Atom with Hydrogen
 - Colaboratory -<u>https://colab.research.google.com/notebooks/welcome.ipynb</u>

CO Welcome to Colaboratory!

Colaboratory is a free Jupyter notebook environment that requires no setup and runs entirely in the cloud.

With Colaboratory you can write and execute code, save and share your analyses, and access powerful computing resources, all for free from your browser.

Fundamentals

Python:

- Open source general-purpose language.
- Object Oriented, Procedural, Functional
- Great interactive environment ("interpreter")
- Lots of toolboxes, particularly for Data Science
- Easy to interface with C/ObjC/Java/Fortran
- Easy-ish to interface with C++ (via SWIG)

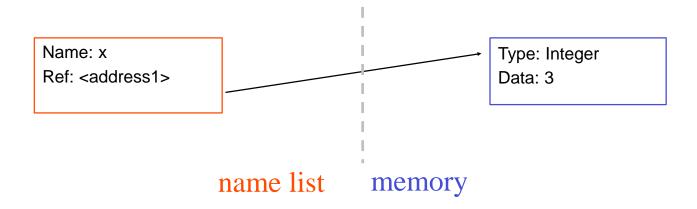
· · · before getting to the above, we need to start with the basics.

Data Types (a subset)

Simple types: None int, bool, float, complex Sequences: String, Tuples, byte (immutable) List, byte array (mutable) Sets: Set (mutable) Frozenset (immutable) Mappings: Dictionary Numpy arrays

How are variables constructed?

- Understanding Reference Semantics
 - There is a lot going on when we type: x = 3
 - First, an integer 3 is created and stored in memory
 - A name x is created
 - An reference to the memory location storing the 3 is then assigned to the name x
 - So: When we say that the value of x is 3, we mean that x now refers to the integer 3



Understanding Reference Semantics II

- Assignment manipulates references
 - x = y does not make a copy of the object y references
 - x = y makes x reference the object y references
- Very useful; but beware!
- Example:

```
>>> a = [1, 2, 3] # a now references the list [1, 2, 3]
>>> b = a # b now references what a references
>>> a.append(4) # this changes the list a references
>>> print b # if we print what b references,
[1, 2, 3, 4] # b has changed as well...
```

Immutable vs Mutable I

- When a variable (object) is immutable, you can't change the value.
- What will happen, if you try?

··· it takes practice before this becomes intuitive!

Time to try out Colaboratory...

The VERY basics

Open a browser to Colaboratory



- Sign-in (or create a log-in if you haven't yet)
- Download and include the notebook titled "Lecture_1_Pythonbasics.ipynb"

Exercise



Using Colaboratory:

- 1. Make variables containing your name, height, family members and their ages.
- 2. Consider choice of data types
- 3. Display the variables and their types
- 4. Change their values (mutable?)
- 5. Add a new family member

Numpy

- Python library for numerical computations.
- A "list" in Python is very general (contain mixed types, change length, ...). This is flexible, but not optimal for fast computations.
- The numpy library includes:
- numpy.array type that allows typed, multi-dimensional arrays
- Many optimized numerical function

Exercises



- Pick among the following:
 - Make a random 3x3 matrix, invert it, and check that the multiplication of original and inverted is the identity matrix
 - Make a random 5x5 integer matrix, and sort the rows by the contents of the 1st column.
 - Using the nobel_prize_winners, find the years and names for all winners in chemistry.

BREAK

10 minutes

Visualization 2D

Matplotlib

- A python 2D plotting library
- Publication quality figures in several hardcopy formats and interactive environments
- Package matplotlib.pyplot provides a MATLAB-like plotting framework
- Typical imports:
 - import matplotlib.pyplot as plt
 - import numpy as np
- matplotlib.org

Exercise



- Read image python.png and show it
- Play with color maps
- (ask Google or see https://matplotlib.org/users/image tutorial.html for inspiration)

Medical Image file formats

- Loads of different formats are being used since we also deal with very different modalities ranging from microscopy data to brain image
- Some of the most common:
 - Analyze
 - Neuroimaging Informatics Technology Initiative (Nifti)
 - Minc
 - Digital Imaging and Communications in Medicine (Dicom)
 See https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3948928/ for details

ImageIO

- provides an easy interface to read and write a wide range of image data, e.g.
 - tiff, jpg, png,dicom
 - For a full list see https://imageio.readthedocs.io/en/stable/formats.html
- cross-platform
- runs on Python 2.7 and 3.4+

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N-dimensional images – Visualization in 3D

Examples:

- im[row,col] -> gray 2D image
- vol[pln, row, col] -> gray 3D image
- im[row,col,ch] -> color images
- im_ts[time, row, col, ch] -> video

Slicing

• Picking out a specific slice of a 3D image

Exercise



- Use a for loop to plot every 60th slice of vol on a separate subplot.
- Using plt.subplots(), initialize a subplots grid with 1 row and 4 columns.
- Plot every 60th slice of vol in grayscale. To get the appropriate index, multiply ii by 60.
- Turn off the ticks, labels, and frame for each subplot.
- Render the figure.

Different orientations - Visualization 3D

 Choosing a specific orientation of the image to look at, e.g. for 3D brain images the sagittal, coronal or horizontal view

Exercise



- Plot images that slice along the second and third dimensions of vol.
- Slice a 2D plane from vol where "axis 1" is 125.
- Slice a 2D plane from vol where "axis 2" is 125.
- Note, this can distort the aspect ratio if the image wasn't uniformly sampled! You can check the sampling rate in the meta information using vol.meta['sampling']

Other types of medical images...

- Unfortunately, ImageIO cannot read other common medical image formats than dicom.
- So you may need to use Nibabel to read data. Note though, Nibabel does not support dicom!
- Therefore, we
 - Either need to be aware of both packages and choose depending on our available file format.
 - Or convert any dicom images we meet to one of the other common file formats, most notably nifty.

Exercise



- Look at the nifty version of the same dicom image that we plotted in colaboratory.
- Why does this look different than our previous plotting of the image?
- Optional: Write a function that depending on image type either uses ImageIO or nibabel to load the image

Background material

For Python Basics:

www.python.org

The official site offers documentation, tutorials, references to book, etc.

http://cs231n.github.io/python-numpy-tutorial/

A nice tutorial on Python basics including some numpy/scipy

Background material

 Whirlwind tour of Python: <u>https://github.com/jakevdp/WhirlwindTourOfP</u> <u>ython</u>

 For Data Science in Python: http://github.com/jakevdp/PythonDataScience Handbook

Both are excellent books, freely available online with Jupyter notebooks for the examples.

Background material

Intro to Colaboratory:
 <u>http://www.youtube.com/watch?time_continue</u>
 =5&v=inN8seMm7UI

- Colaboratory website:
 http://colab.research.google.com/notebooks/welcome.
 ipynb
- Colaboratory basic features: <u>https://colab.research.google.com/notebooks/basic_features_overview.ipynb</u>

Questions?

Rest of today and Thursday

- Today:
 - Random separation in study groups
 - Continue with Python exercises
 - Download image data
- Thursday:
 - Intro to imaging modalities
 - X-ray and CT

Next week

- Tuesday:
 - MRI

- Thursday:
 - Expert lecture by Adam Espe Hansen, Professor in Radiology, Rigshospital
 - PET and SPECT

- Monday, September 14th:
 - Hand-in 1 due!