

Introduction to Python (for neuroscience)

NSP bootcamp
Daniel Denman
Assistant Professor, Department of Physiology and Biophysics

Plan for Wed AM

- Introduction (45 min)
- Set up Python environments (5 - 15 min)
- Break

Plan for Wed PM

- Brief introduction to git with VS code (15 mins)
- Introduction to Python syntax and data analysis notebooks (60-90 min).

Plan for Thur PM

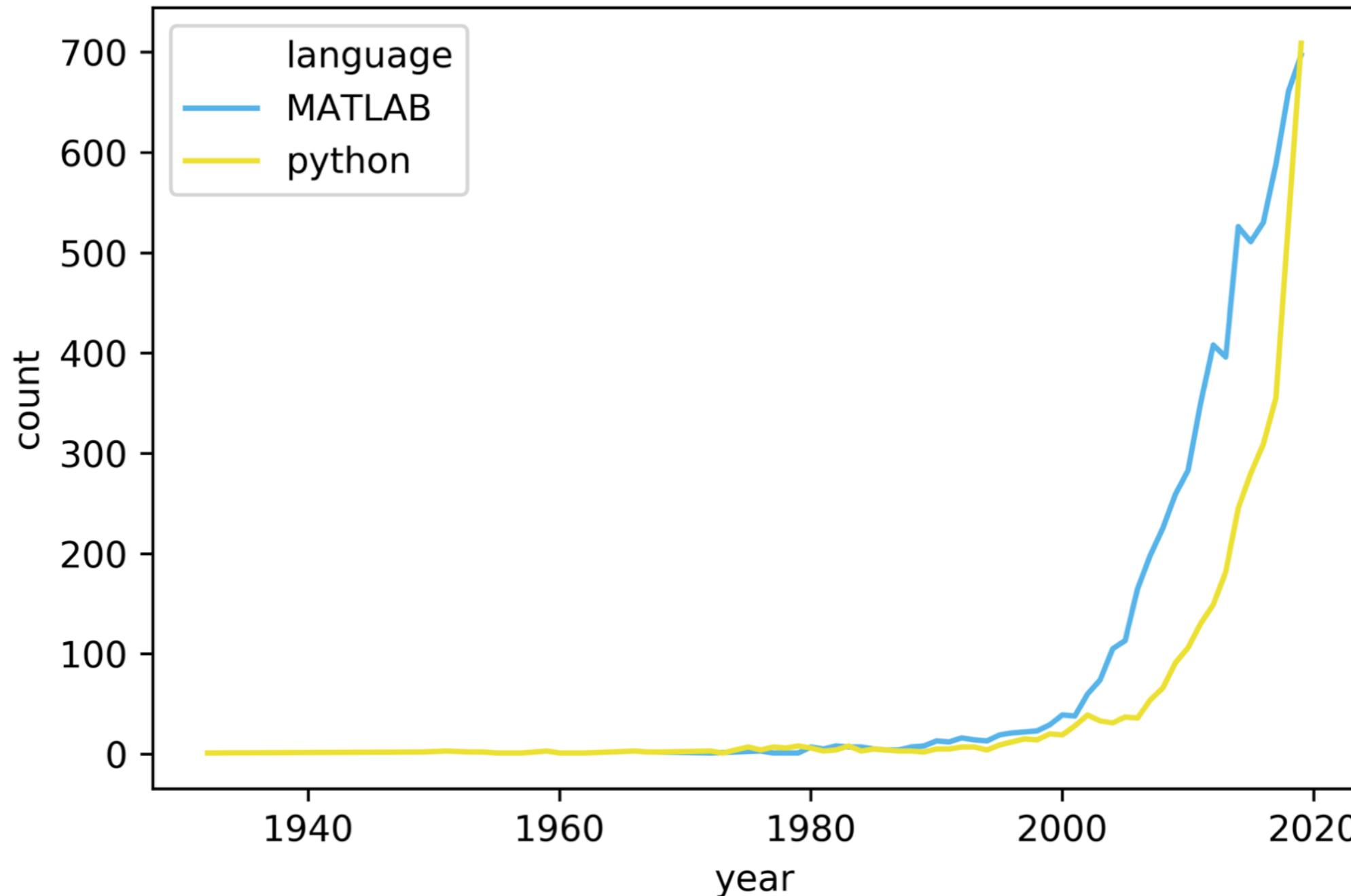
- Small group data analysis notebooks - practice your new skills!!

why code?

- Python or MATLAB? **yes.**
- Python was developed to make it easier for people to automate simple tasks (“scripting”).
 - MATLAB can also “script”
 - Both also have a more data-analysis focused modes (like notebooks/live scripts)
- You ***could*** do things by hand, but **why not have a computer do it?**

history: languages used for neuroscience

history: languages used for neuroscience



history: languages used for neuroscience

Volume 16 Issue 12, December 2019



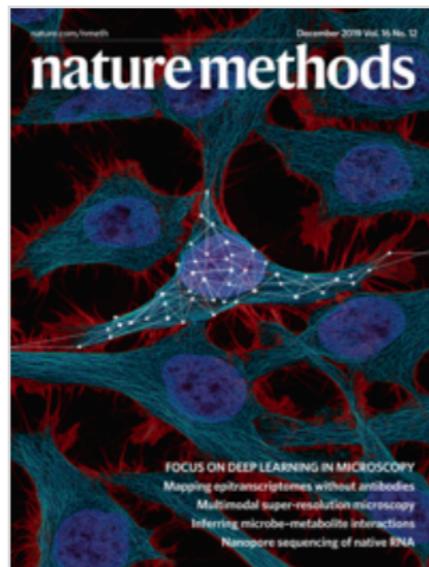
Focus on Deep Learning in Microscopy

Artwork representing the application of deep learning methods in microscopy.

Image: National Institutes of Health/Stocktrek Images/Getty. Cover design: Erin DeWalt

history: languages used for neuroscience

Volume 16 Issue 12, December 2019



Analysis | Published: 21 October 2019

Nucleus segmentation across imaging experiments: the 2018 Data Science Bowl

Juan C. Caicedo, Allen Goodman, Kyle W. Karhohs, Beth A. Cimini, Jeanelle Ackerman, Marzieh Haghghi, CherKeng Heng, Tim Becker, Minh Doan, Claire McQuin, Mohammad Rohban, Shantanu Singh & Anne E. Carpenter [✉](#)

Nature Methods **16**, 1247–1253(2019) | Cite this article

3257 Accesses | 1 Citations | 41 Altmetric | Metrics

2 out top 3 entries used python

history: languages used for neuroscience

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Artwork representing the application of deep learning methods in microscopy.

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5/7 software papers used python

1 used R

1 used ImageJ (Java)

history: languages used for neuroscience



Article | Published: 27 July 2020

Cumulus provides cloud-based data analysis for large-scale single-cell and single-nucleus RNA-seq

Bo Li , Joshua Gould, Yiming Yang, Siranush Sarkizova, Marcin Tabaka, Orr Ashenberg, Yanay Rosen, Michal Slyper, Monika S. Kowalczyk, Alexandra-Chloé Villani, Timothy Tickle, Nir Hacohen, Orit Rozenblatt-Rosen & Aviv Regev

history: languages used for neuroscience

Aug 2024	Aug 2023	Change	Programming Language	Ratings	Change
1	1		 Python	18.04%	+4.71%
2	3	▲	 C++	10.04%	-0.59%
3	2	▼	 C	9.17%	-2.24%
4	4		 Java	9.16%	-1.16%
5	5		 C#	6.39%	-0.65%
6	6		 JavaScript	3.91%	+0.62%
7	8	▲	 SQL	2.21%	+0.68%
8	7	▼	 Visual Basic	2.18%	-0.45%
9	12	▲	 Go	2.03%	+0.87%
10	14	▲	 Fortran	1.79%	+0.75%
11	13	▲	 MATLAB	1.72%	+0.67%
12	23	▲	 Delphi/Object Pascal	1.63%	+0.83%
13	10	▼	 PHP	1.46%	+0.19%

history

- First released in 1991
- A “scripting” or “high-level” language, designed for readability and productivity
 - simple syntax, use of white space
- Major release: Python 2.7, July 2010
- Use increases
- “data science” after era of “Big Data”
- Support for Python 2.7 ended Jan 1, 2020
- New releases of the python interpreter come out every 1 year or so (3.13 scheduled for Oct 2024)



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“Benevolent Dictator for Life”

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overview

Some plusses

Some minuses

overview

Some plusses

- **Free**
- **Readable syntax**

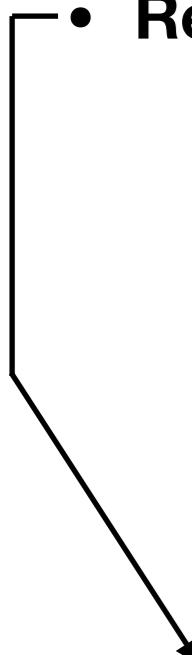
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- **Huge community**
- **Used across science *and* outside of science**

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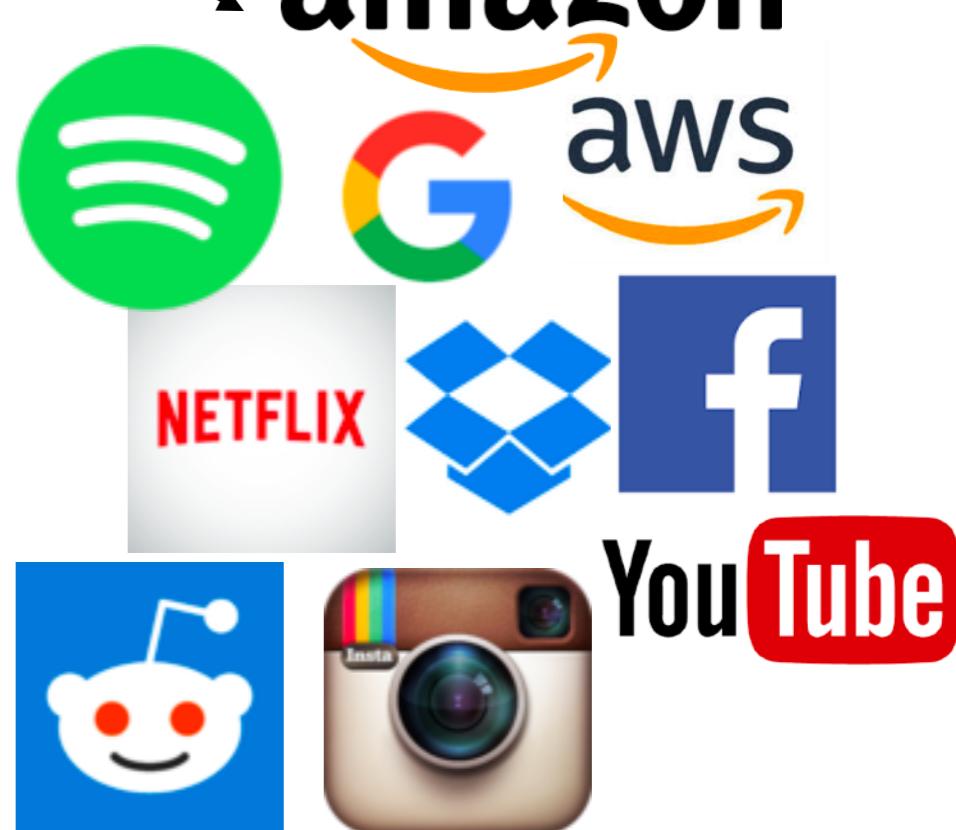
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- **Slow[er] to execute (than C)**
- **White space matters (which some find to be a pain)**
- **Activation barrier due to open source standards / capitalism**
- ***Sometimes problematic + insular culture; see “BDFL”**
*editorial opinion



overview: Python language basics

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“high-level” :

you don’t need to know how a computer *actually* works to use Python.
Memory addressing, pointers, call stacks - blah blah computer science

garbage collected:

you, the programmer do not usually need to worry about cleaning up your
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Standard library



Often written in C (again, you, the programmer, don’t need to care about this), these are functions and tools that ship with Python. Widely useful, and already vetted. Backwards compatible.

overview: packages



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Find, install and publish Python packages with the Python Package Index

Search projects



Or [browse projects](#)

476,679 projects

4,795,572 releases

8,942,074 files

733,864 users

Packages

In addition to the standard library, the true power of python is the extensive world of packages available. These are sets of tools you can use with Python to do just about anything!

Some are general tools, the hammers or screwdrivers of using python for science:
numpy, matplotlib, pandas, seaborn

Others are specialized: **scikit-learn, PIL, scanpy, Suite2P, DeepLabCut, PyTom**

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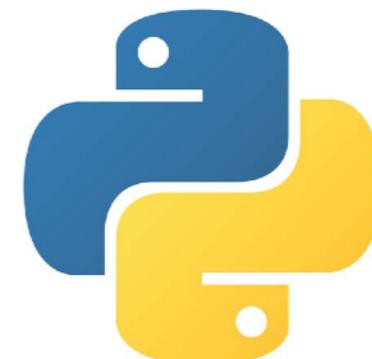
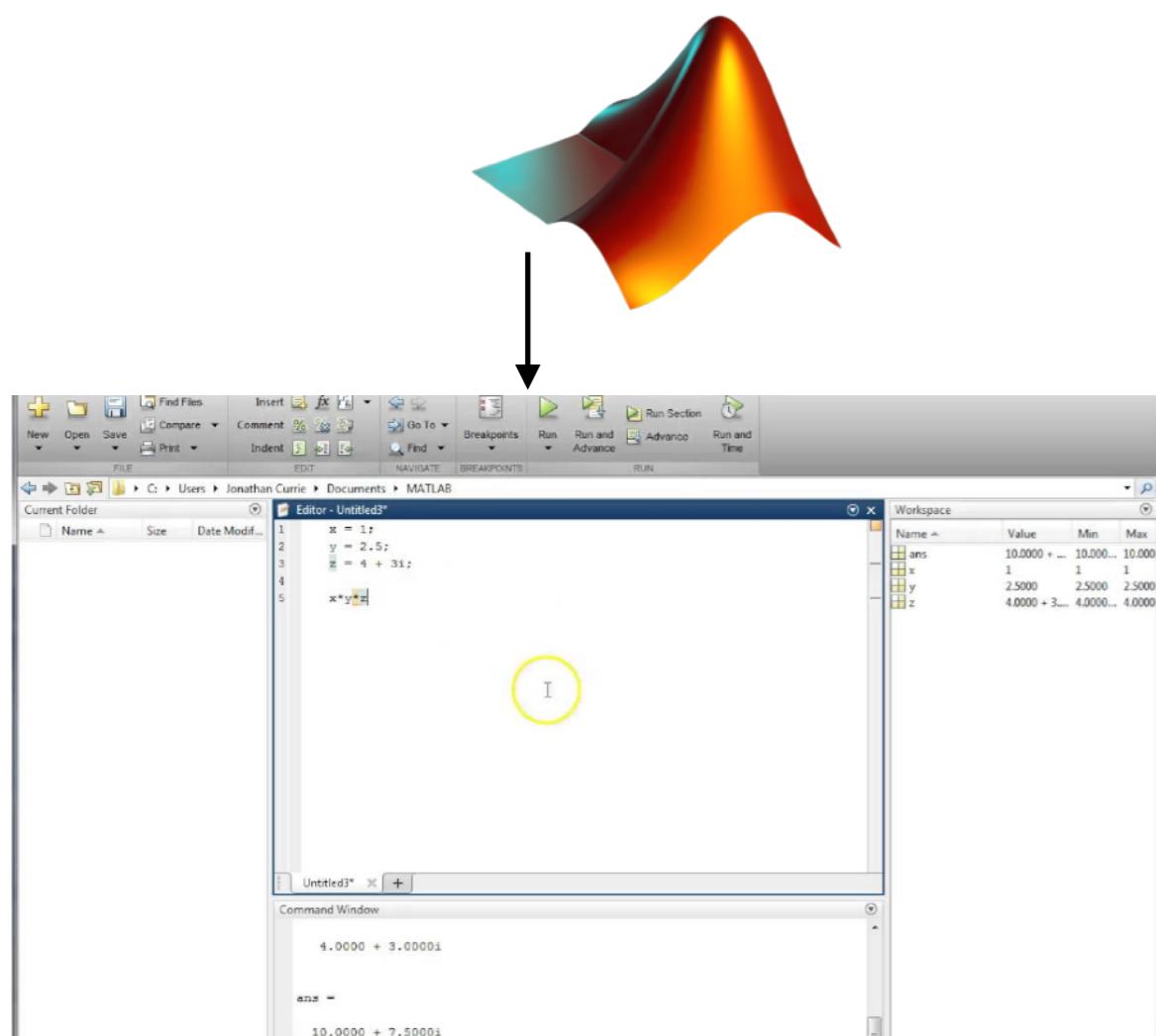
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overview: but, like, what _is_ it?

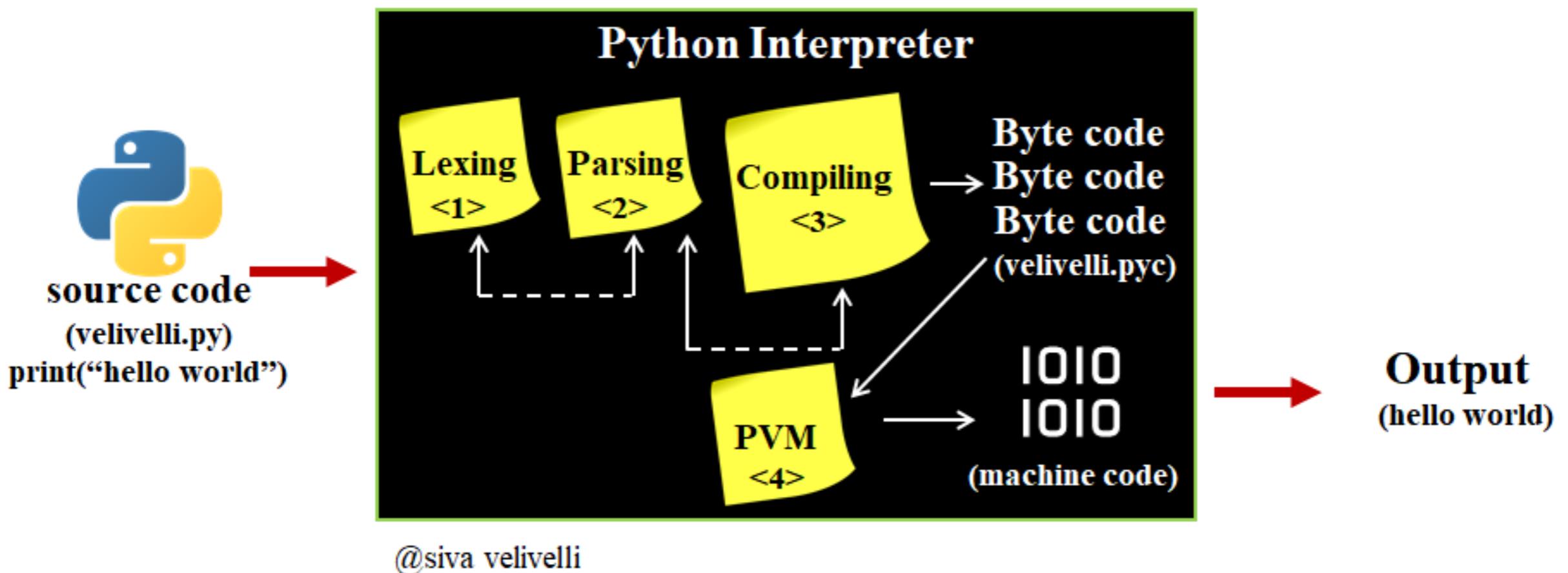


Uh, this isn't anywhere

Do I need to install it?
No but I can?

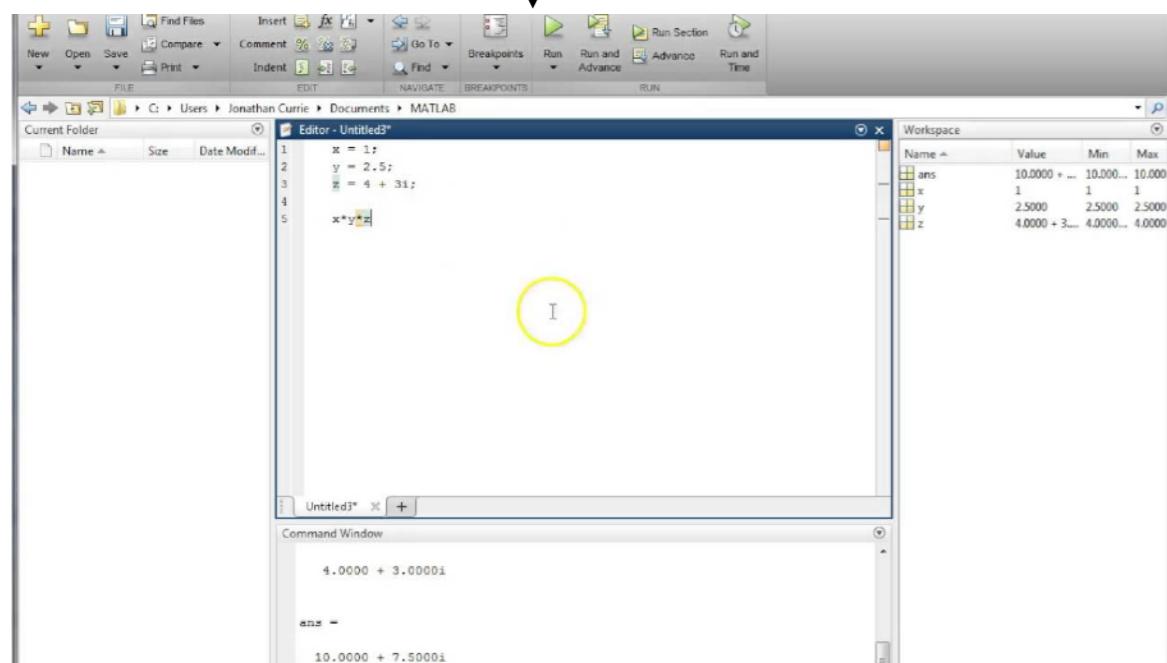
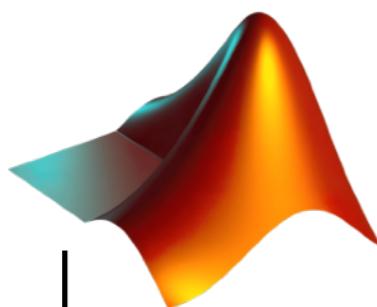
I do want to install it, and multiple times?
Except if I use it in the cloud? What?

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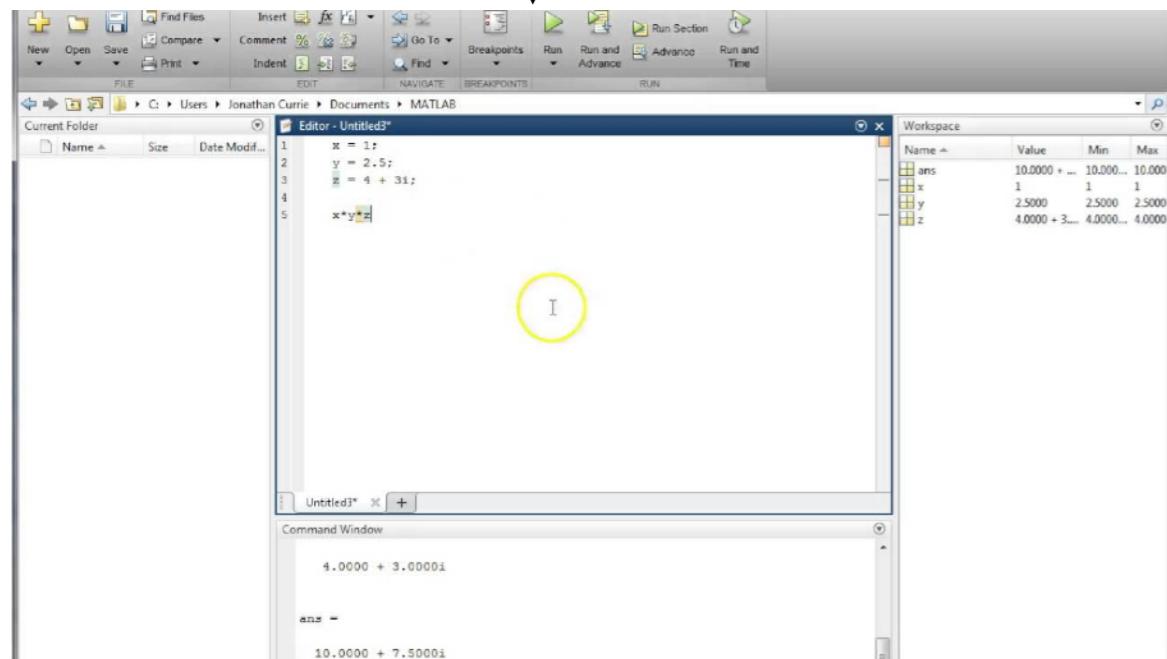
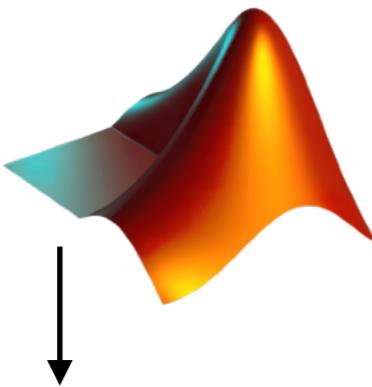


@siva velivelli

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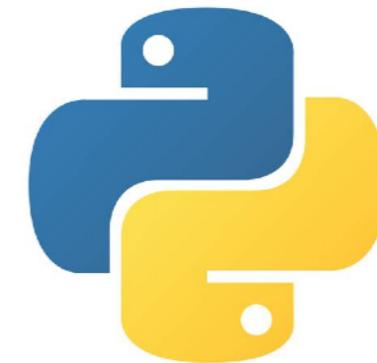
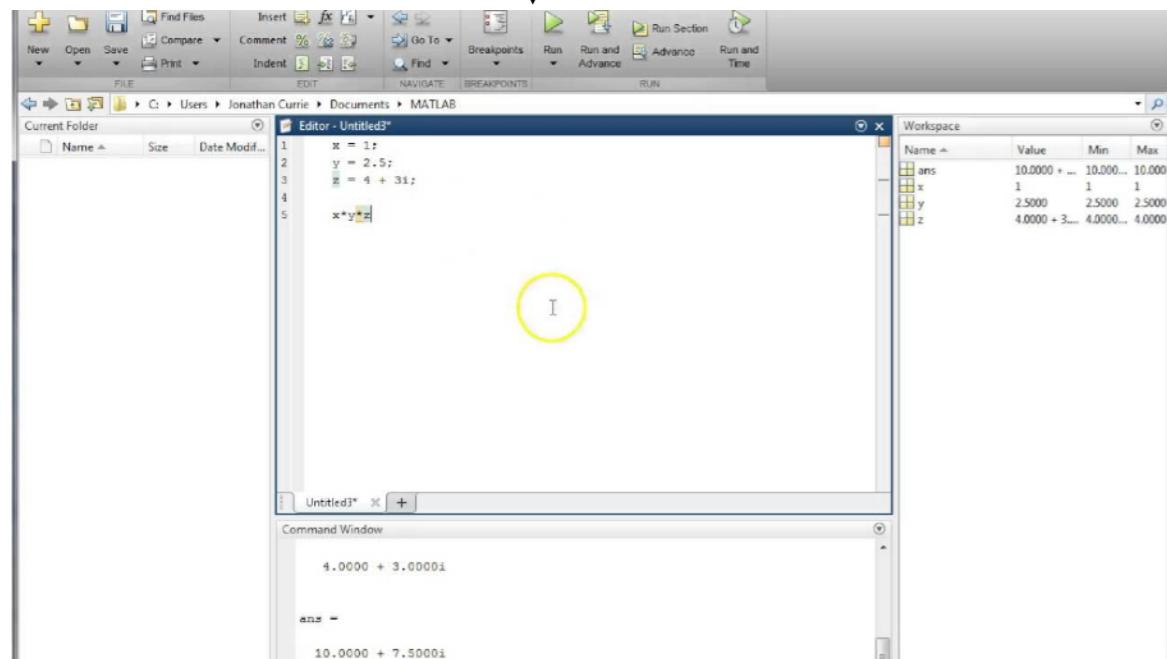
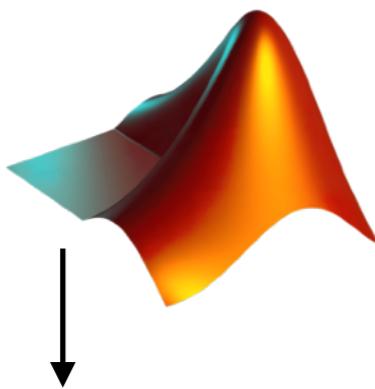


Your computer comes with a default Python interpreter.

You can also install other ones and configure which one you want to use, when.

They are in folders on your computer

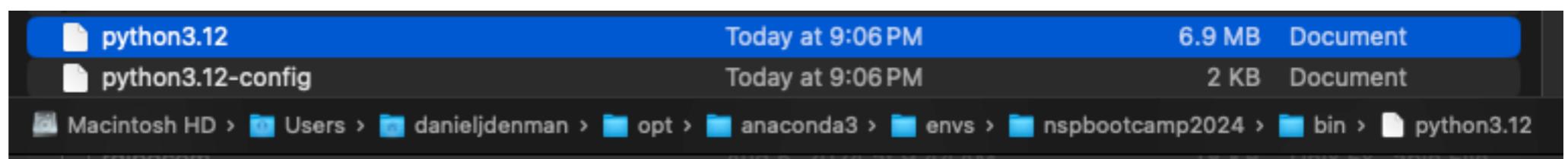
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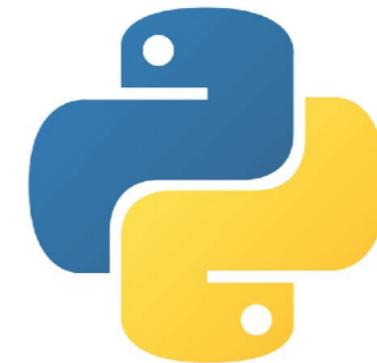
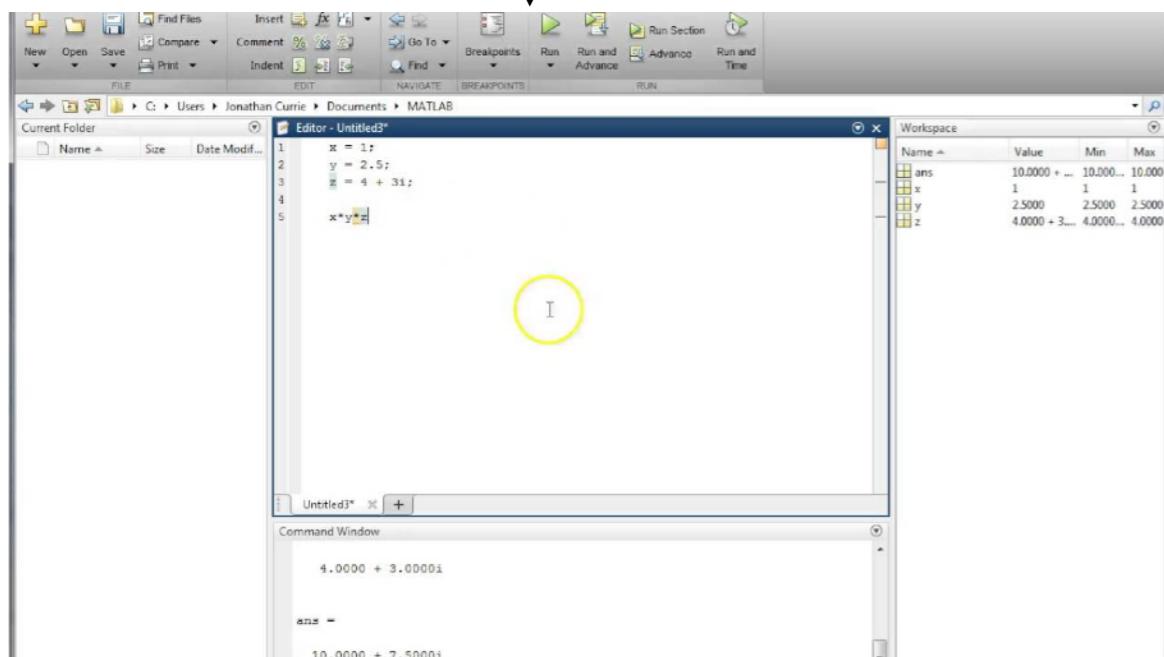
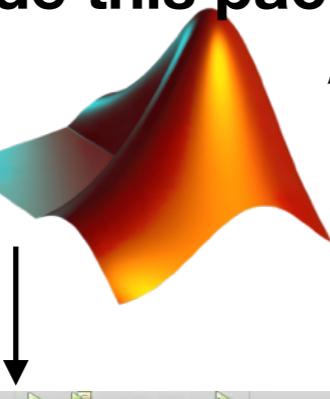
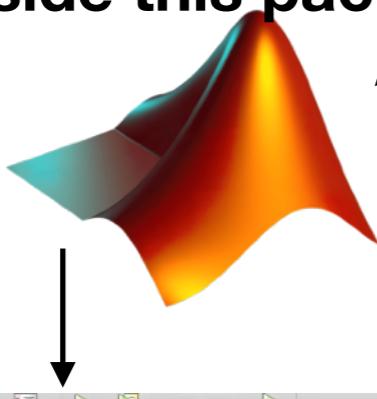
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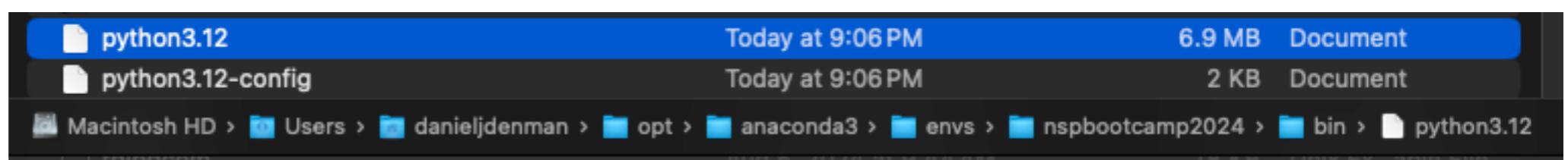
MATLAB has an interpreter too! It is just hidden inside this packaged app



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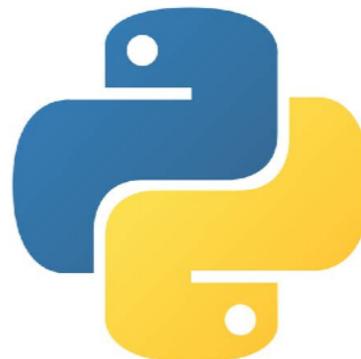
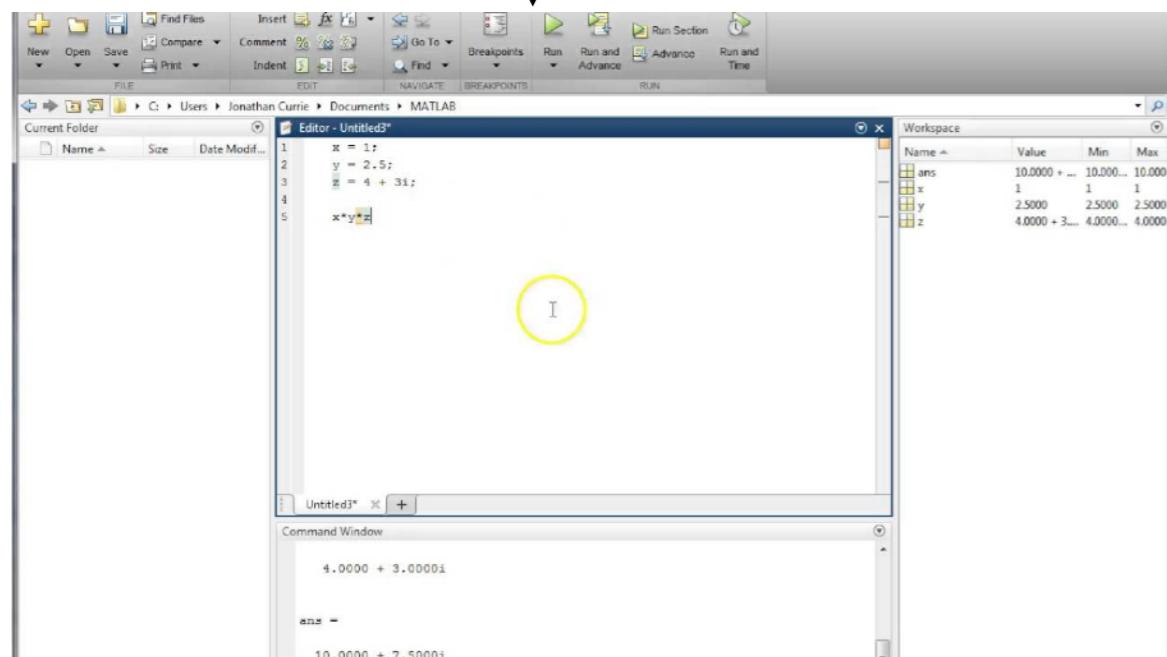
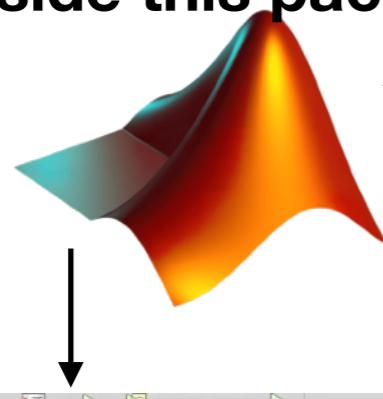
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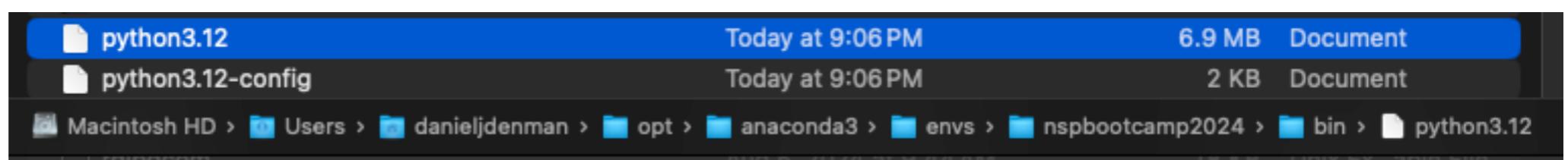
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All platforms for data analysis are going to work this way, with varying levels of packaging/abstraction/convenience (Excel, jmp, R, MATLAB, python on your computer, something running on a cloud server...) that translate what you write to a machine execution



overview: levels



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System

```
>Last login: Wed Dec 18 16:26:32 on ttys002
The default interactive shell is now zsh.
To update your account to use zsh, please run `chsh -s /bin/zsh`.
For more details, please visit https://support.apple.com/kb/HT208050.
(base) djd-mbpro:~ danieljdenman$ python
Python 3.7.4 (default, Aug 13 2019, 15:17:50)
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Native in Mac OS X, Linux; in Windows store (free)



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Containerized





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 4  # from direct.showbase.DirectObject import DirectObject
 5  from direct.interval.MetaInterval import Sequence
 6  from direct.interval.LerpInterval import LerpFunc
 7  from direct.interval.FunctionInterval import Func
 8  from panda3d.core import Mat4, WindowProperties, CardMaker, NodePath, TextureStage, MovieTexture, MovieVideo
 9
10 import sys,glob,time,datetime,os
11 from math import pi, sin, cos
12 from numpy.random import randint, exponential
13 from numpy import arange, concatenate
14 import numpy as np
15 from pyglet.window import key
16
17 try:
18     from toolbox.toolbox.IO.nidaq import DigitalInput,DigitalOutput, AnalogInput, AnalogOutput
19     have_nidaq=True
20 except:# Exception, e:
21     print("could not import iodaq.")
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24 MOUSE_ID = 'test'
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26 #this is used to change whether the mouse's running and licking control the rewards.
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ANACONDA®

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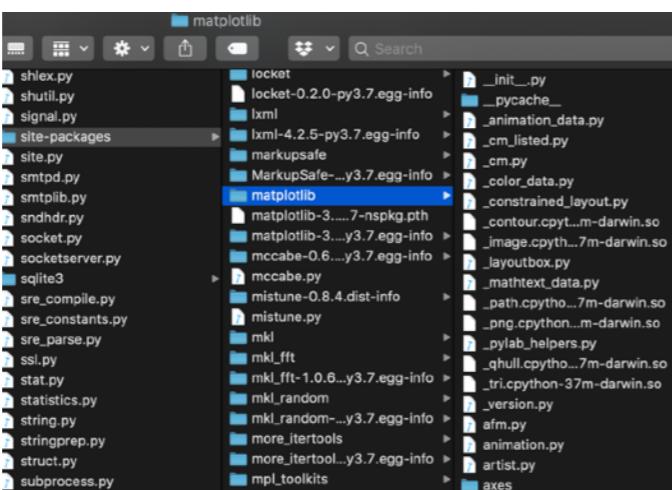


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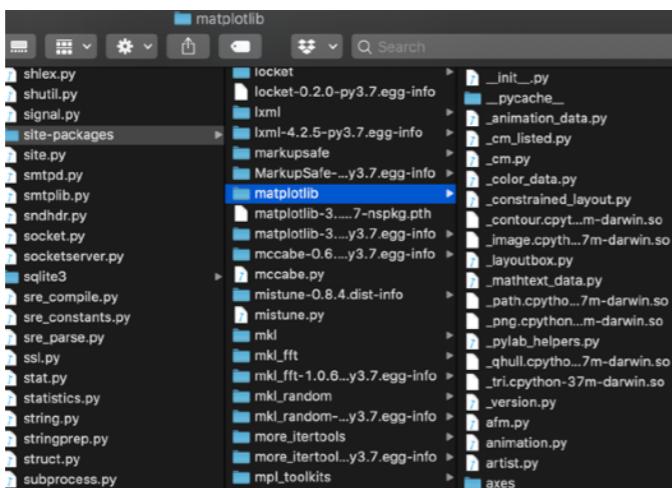
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 7  from direct.interval.FunctionInterval import Func
 8  from panda3d.core import Mat4, WindowProperties, CardMaker, NodePath, TextureStage, MovieTexture, MovieVideo
 9
10 import sys,glob,time,datetime,os
11 from math import pi, sin, cos
12 from numpy.random import randint, exponential
13 from numpy import arange, concatenate
14 import numpy as np
15 from pyglet.window import key
16
17 try:
18     from toolbox.toolbox.IO.nidaq import DigitalInput,DigitalOutput, AnalogInput, AnalogOutput
19     have_nidaq=True
20 except:# Exception, e:
21     print("could not import iodaq.")
22     have_nidaq=False
23
24
25 MOUSE_ID = 'test'
26
27 #this is used to change whether the mouse's running and licking control the rewards.
```

Packages



overview: levels

Package Managers Environments



Containerized



Notebooks (IPython, Jupyter, Jupyter Lab)

Introduction to Python (for Neuroscientists)
a guided tour of data analysis with python
10 Jan 2019
NRSC 7601 Systems Neuroscience
Daniel J Denman
University of Colorado Anschutz

Important: this is not meant to be a comprehensive guide. Use the internet! [Python documentation](#), [Stack Overflow](#), [Google](#), [Markdown cheatsheets](#) (e.g. [this one](#)) all are your friends.

Here, we are using a Jupyter notebook environment to run a Python 3.7 kernel
First, let's get our bearings in a Jupyter notebook
In a Jupyter notebook, we can iteratively explore data, do computations, make plots, and define functions and objects.
The notebook will contain a mix of code, markdown (a simple way to make formatted text) that might explain what is going on in the code, and outputs. The outputs will be in the form of printed statements and plots.
The fundamental unit of the Jupyter notebook is the cell. Here is an empty code cell:

- You can see the empty brackets on the left; this bracket is empty until the cell is executed
- Cells can be "code", "markdown", or "raw". This cell, for example, is a "markdown cell". When I execute it (by pressing Shift + Enter), it renders the text I have entered.
- In the cell below, a code cell, we will enter some code. To execute it, enter that cell and press Shift + Enter.

```
[1]: message = 'hello world! time to do some science' #define a variable. this variable is a string, because we put the value in ''
print(message)
hello world! time to do some science
```

The empty brackets on the left has now been filled with a number, which is the order in which the cell was executed. This will forever increment until the this bracket is empty until the kernel (or Jupyter) quits.

why is it good for doing neuroscience?

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- Do analyses that would be a whole PhD to implement yourself (i.e., ML) **packages!**

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Stack Overflow <– not cheating!

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in this realm, cloud resources (data, compute) also open science to a wider group that aren't collecting their own data and running their own super computers

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Hardware control

RaspberryPi

Arduino

PyDAQMX

PsychoPy

...many APIs...

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Pandas

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Specialized Tools

Image analysis: PIL / OpenCV

Ca2+ analysis: Suite2P, AQUA

Movement Tracking: DeepLabCut

Expression Analysis: scanpy

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Sharing
Docker
Google Colab
Jupyter
[it is free!]

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Guided example:

- Variables: definitions, types
- Some important packages
- Making plots
- Functions

git

...and GitHub, are **version control**

- This is important. And not intuitive. It will likely make you frustrated and/or confused at some point.
- Version control is not optional; if you don't use git for version control, you are going to use something else (e.g.,: analysis_script_v1.py, analysis_script_v2.py, analysis_script_v2_20210622.py, analysis_script_v3_07142021.py, analysis_script_final.py, analysis_script_final2.py, ..., analysis_script_final2_for.py)
- Making git a part of your workflow can simplify and provide redundancy and flexibility; more advanced features also makes sharing simpler. Evaluation.
- git has to be installed, which we will use Anaconda to do so
- GitHub Desktop <https://desktop.github.com/> is by far the easiest way; git bash (command line) is another option
- We're going to go over some git interactively to get course materials today.