

Introduction to Python (for neuroscience)

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

Plan for 1-2

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

2ish-4ish

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

4ish -

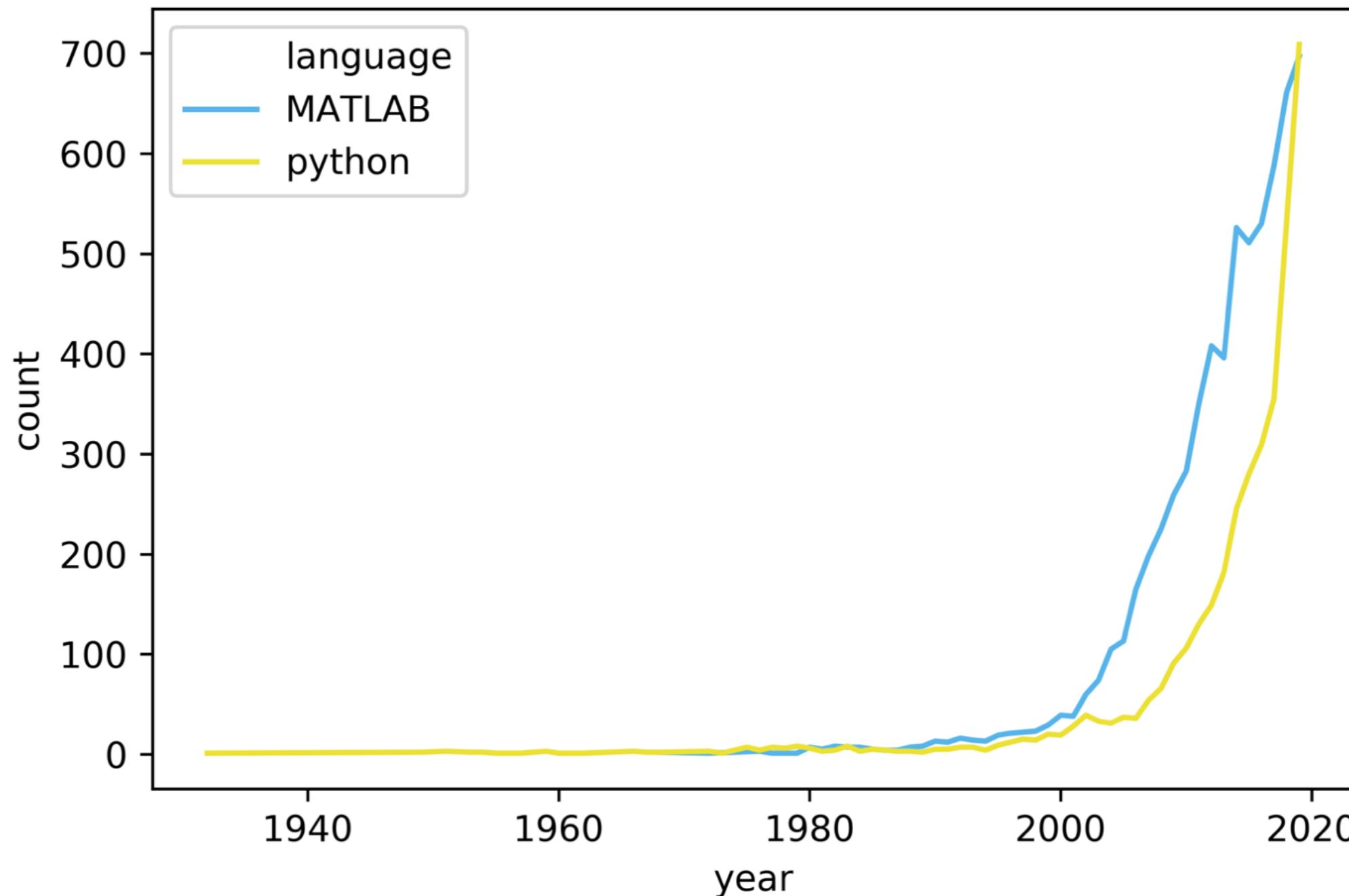
- Small group data analysis notebooks - practice your new skills!!

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 [✉](#)

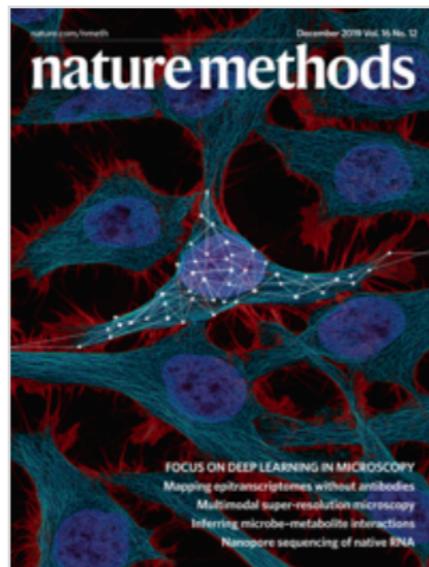
Nature Methods **16**, 1247–1253(2019) | Cite this article

3257 Accesses | 1 Citations | 41 Altmetric | Metrics

2 out top 3 entries used python

history: languages used for neuroscience

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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**

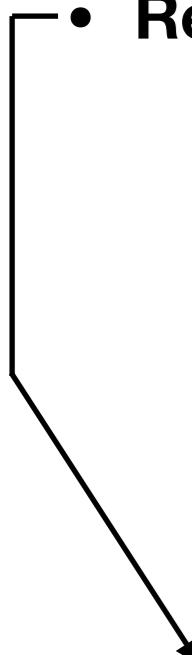
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- **Huge community**
- **Used across science *and* outside of science**

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Some minuses

- **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
“garbage” - memory pointers etc. More stability, fewer resources.

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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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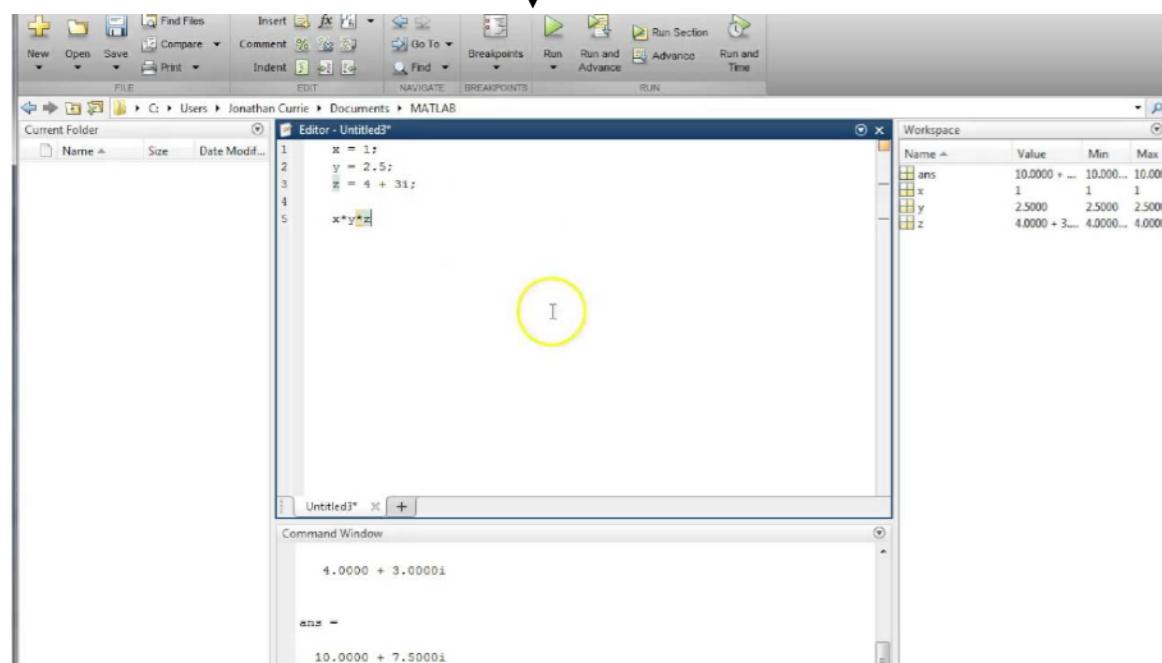
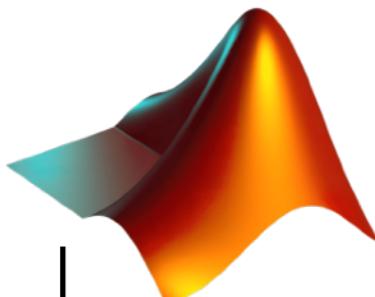
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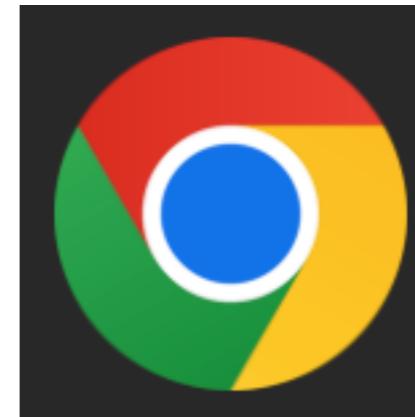
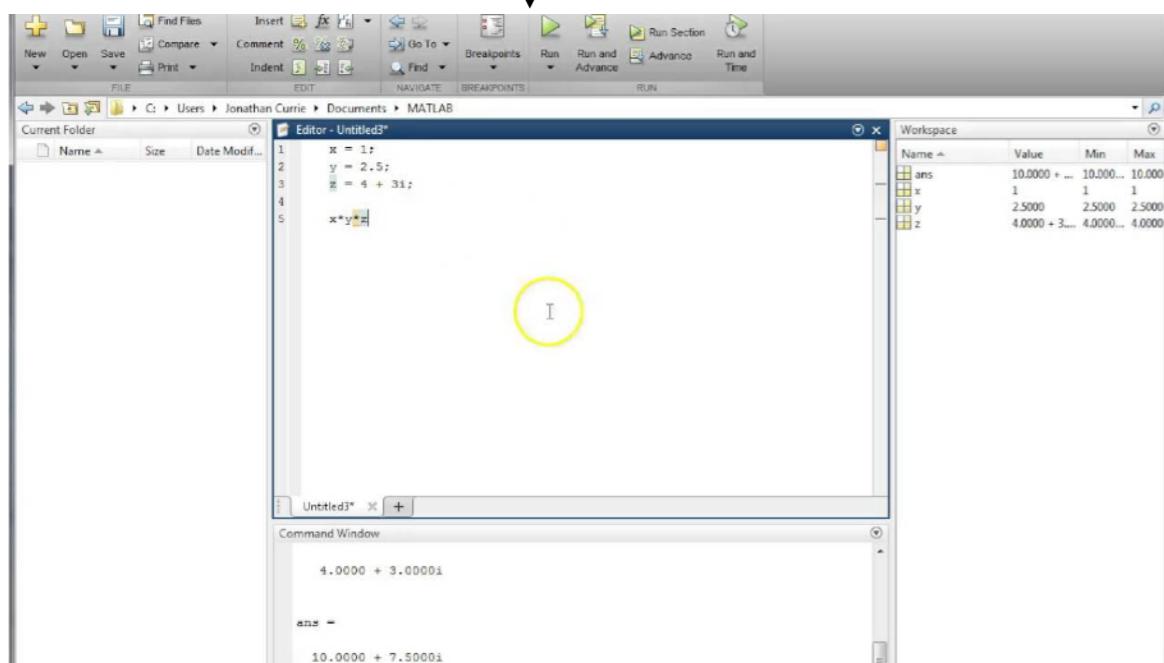
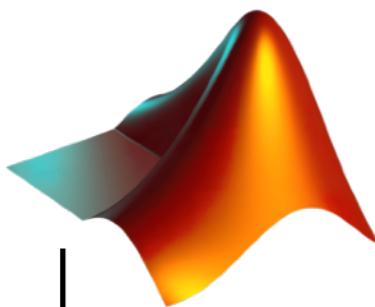
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overview: but, like, what _is_ it?



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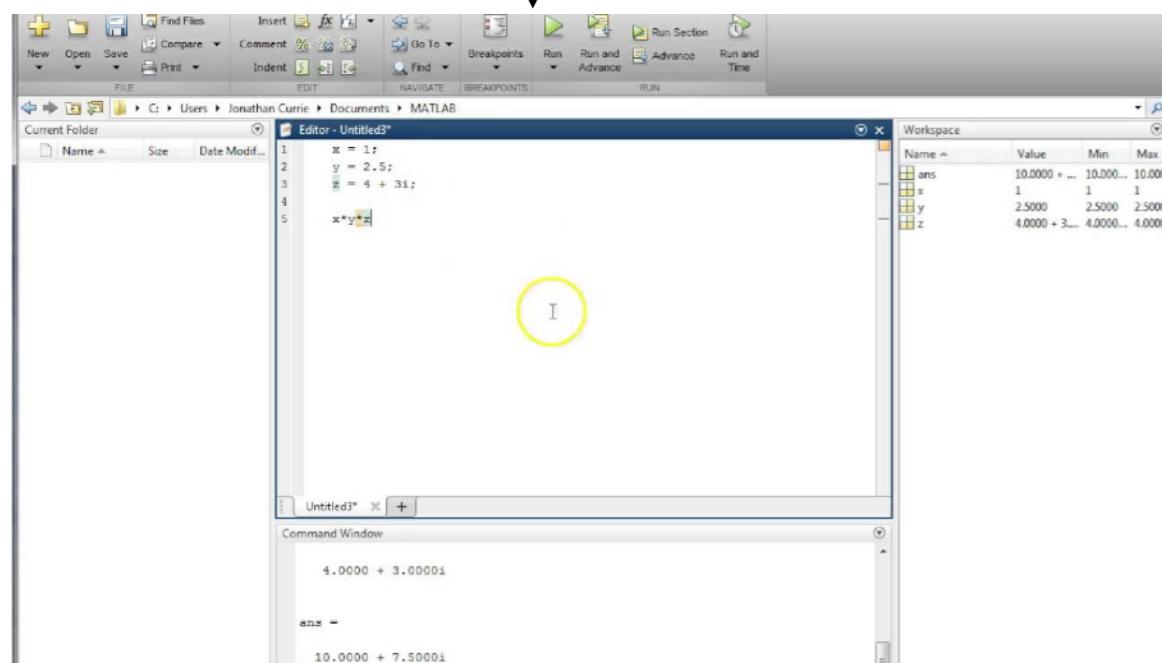
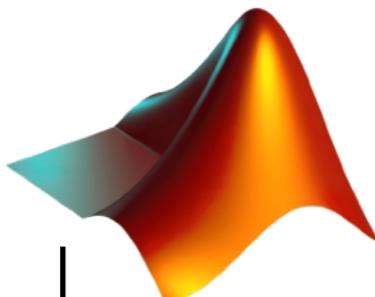
The Neuron journal website features a large "Neuron" logo and the tagline "A Cell Press journal that supports open access". It includes links for "This journal", "Journals", "Publish", "News & events", and "About Cell Press". The "Current issue" section shows the cover of Volume 113, Issue 16, August 20, 2025, with a "Download full issue" button. The "Explore" section lists "About Neuron", "Subscribe", "Collections", "NeuroViews", and "Q&A". The "Publish" section has links for "Submit article", "Aims and scope", "For authors", and "Supports open access". The "Connect" section includes "Alerts", "X (formerly Twitter)", and "Kim et al.". A search bar at the top right allows users to "Search for..." or use "Advanced search".

Featured content

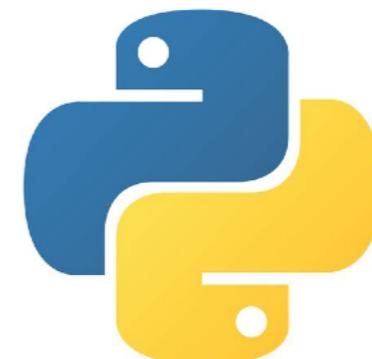
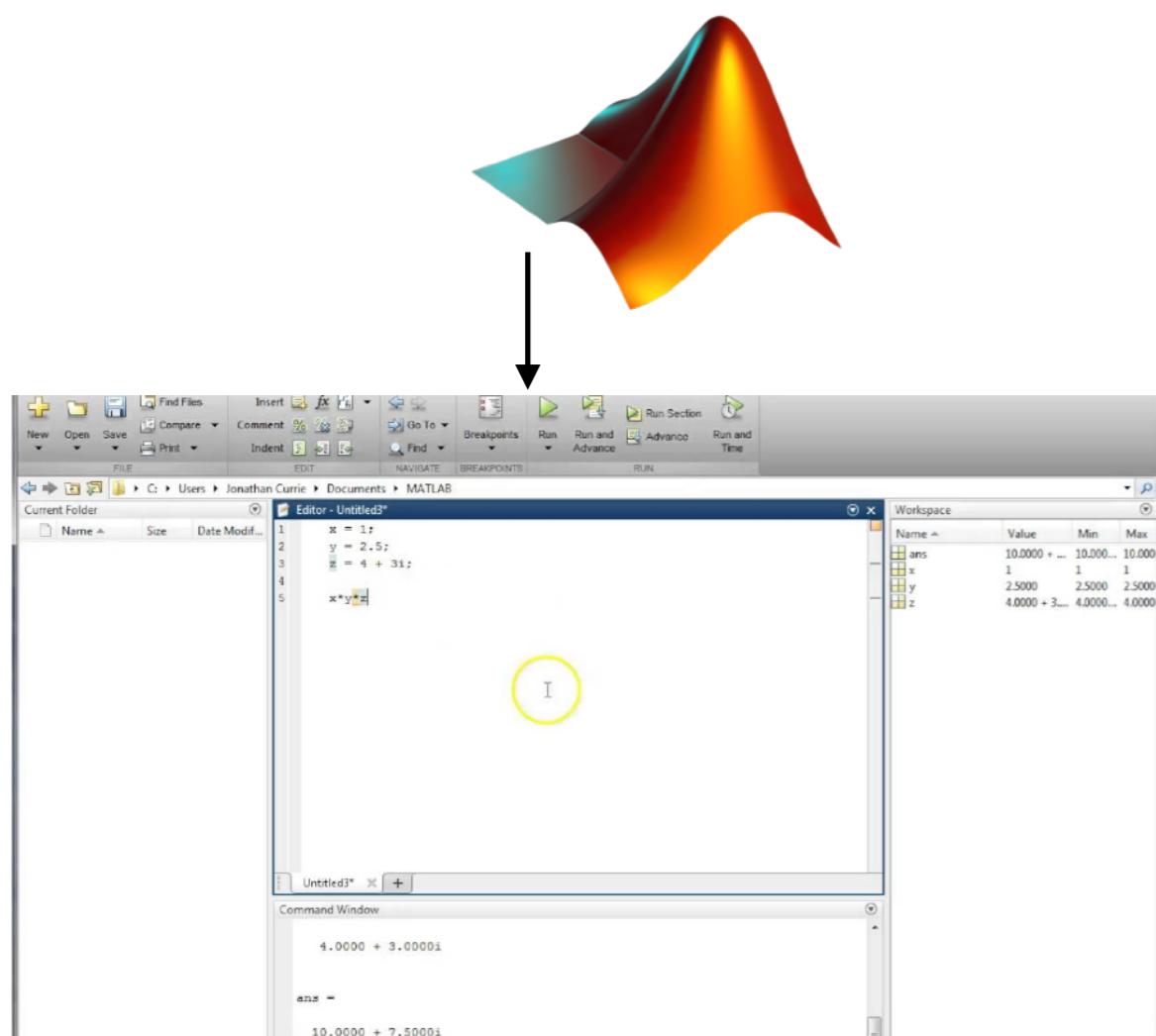
The grid of cards includes:

- Review** FREE **Lipid metabolism alterations in peripheral neuropathies** Silva et al. Published online: April 30, 2025
- NeuroResource** FREE **In vivo 7 Tesla MRI of non-human primate intracortical microvascular architecture** Wang et al. Published online: July 24, 2025
- Article** Open Access **Neurodevelopmental origins of structural and psychomotor defects in CXCR4-linked primary immunodeficiency** Demenego et al. Published online: June 6, 2025
- Article** FREE **Encoding the glucose identity by discrete hypothalamic neurons via the gut-brain axis** Kim et al. Published online: June 20, 2025

overview: but, like, what _is_ it?



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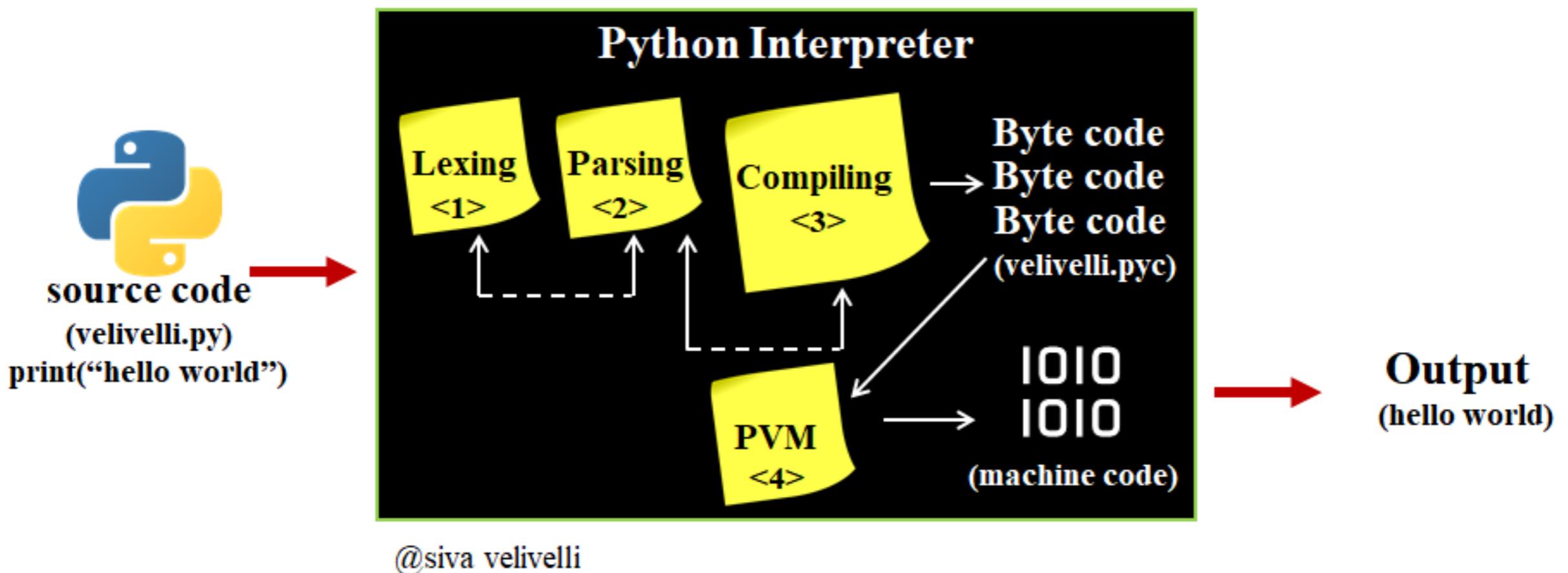


Uh, this isn't anywhere

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

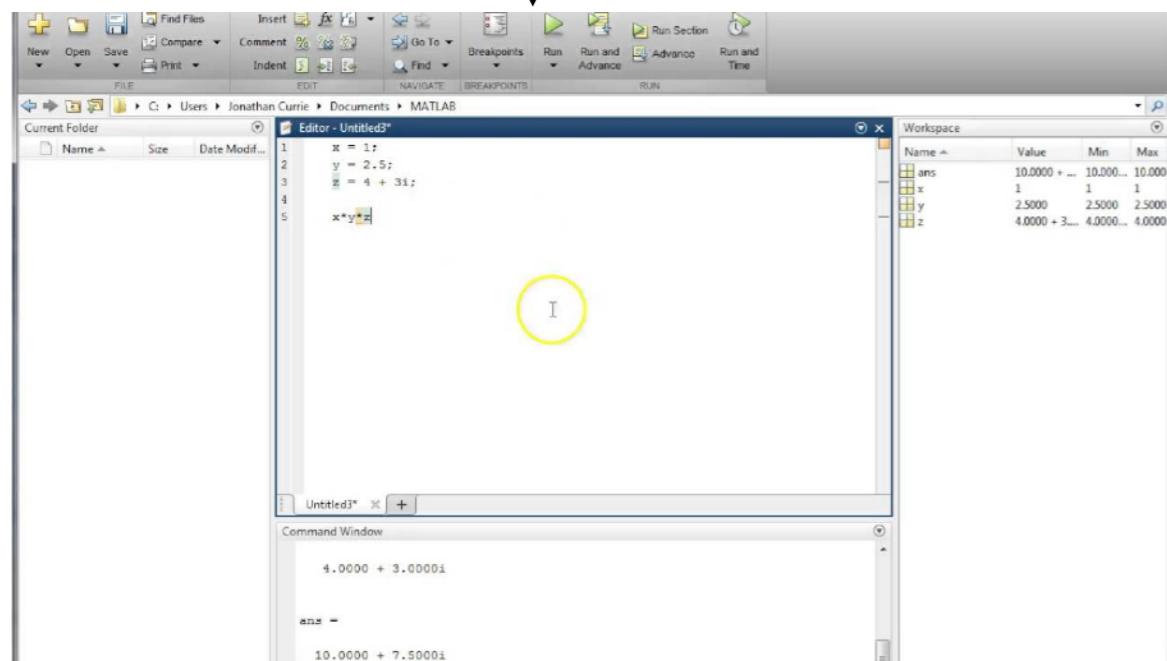
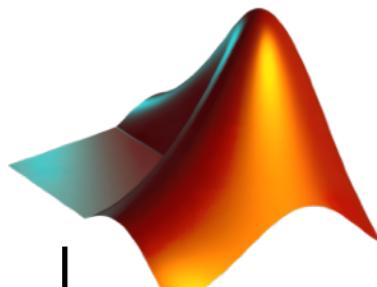
I do want to install it, and multiple times?
Except if I use it in the cloud? What?

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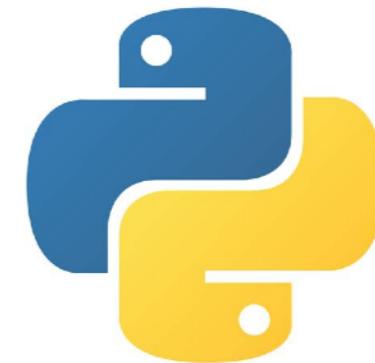
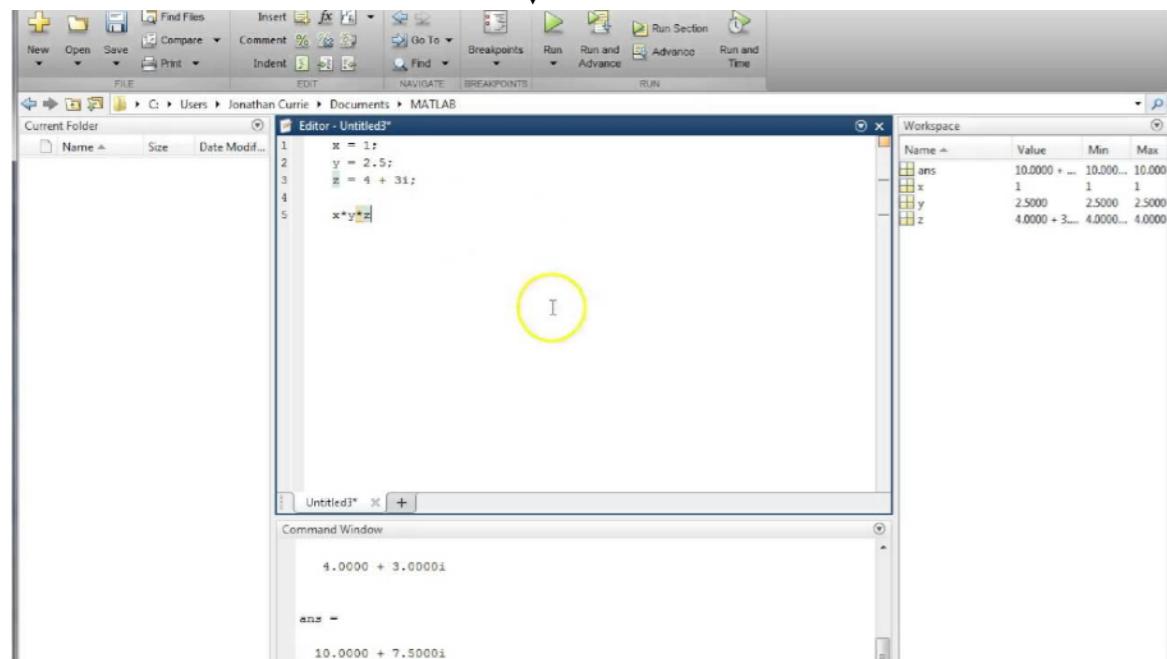
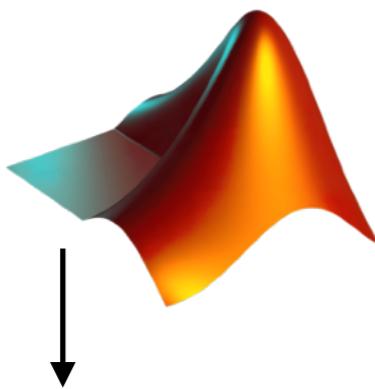


@siva velivelli

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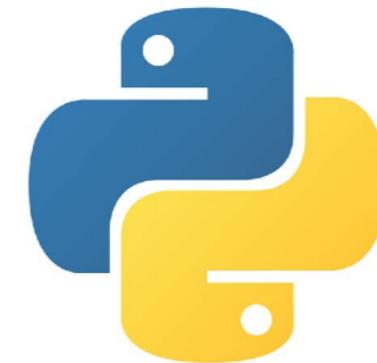
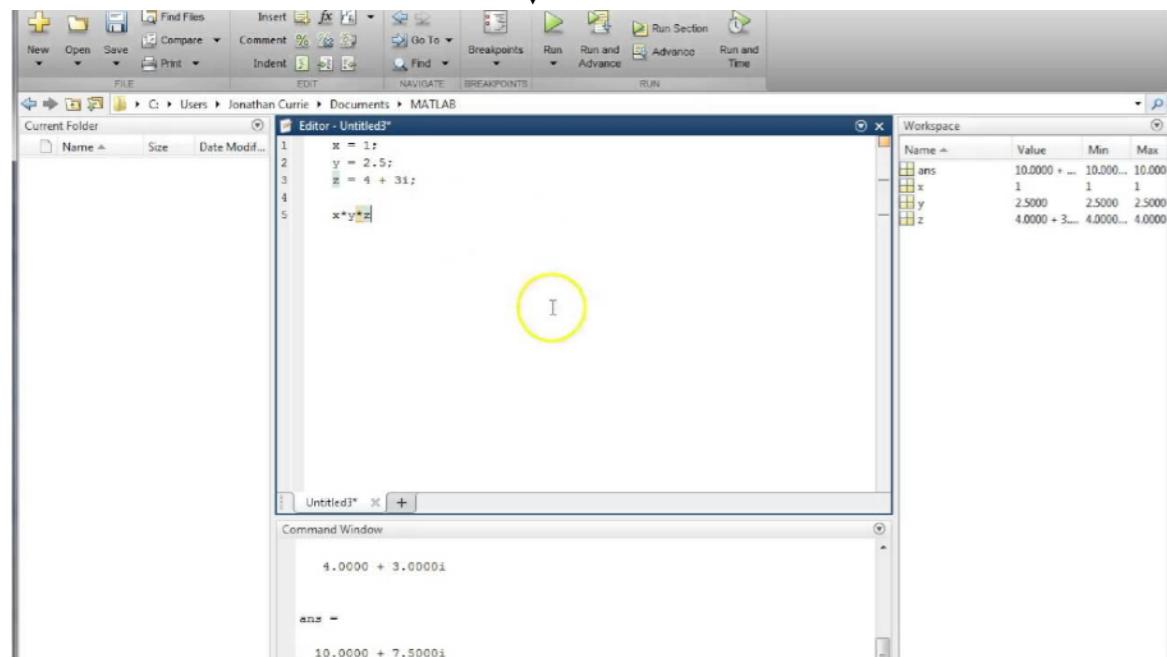
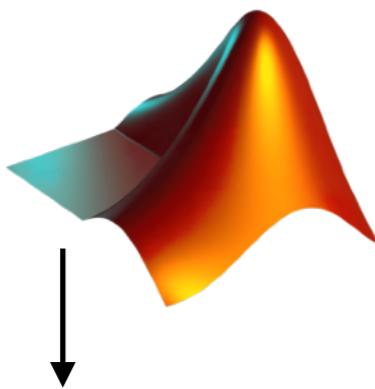


Your computer comes with a default Python interpreter.

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

They are in folders on your computer

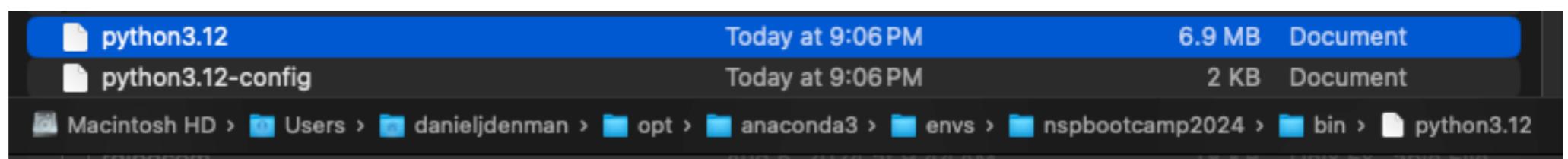
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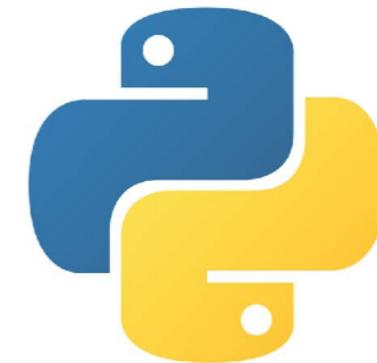
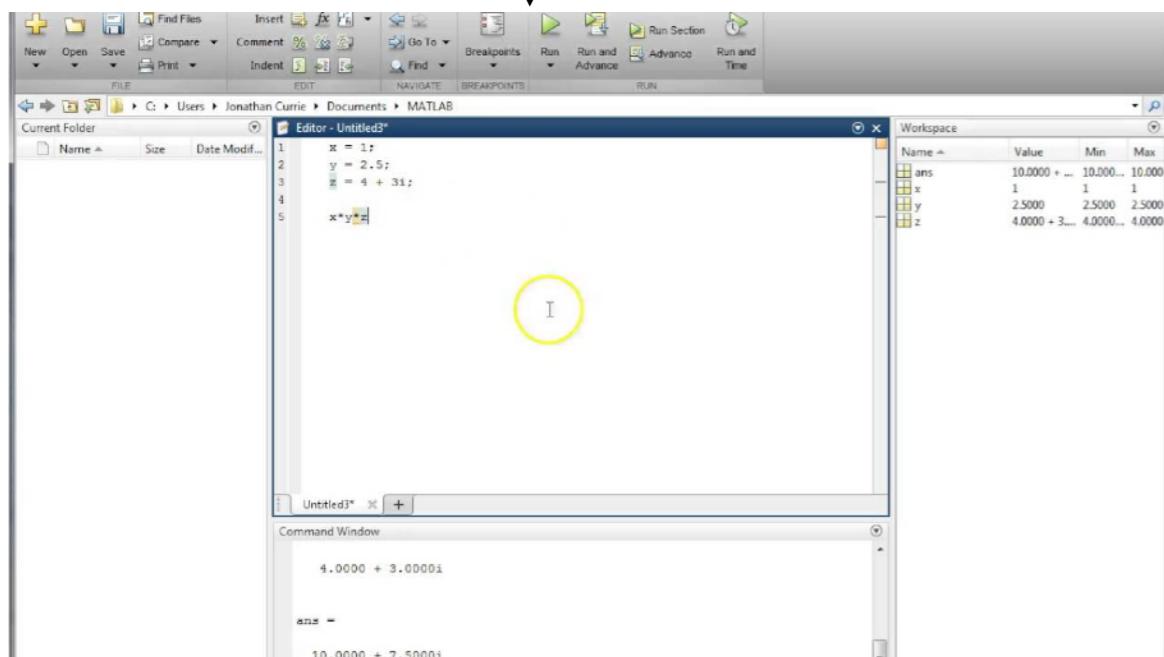
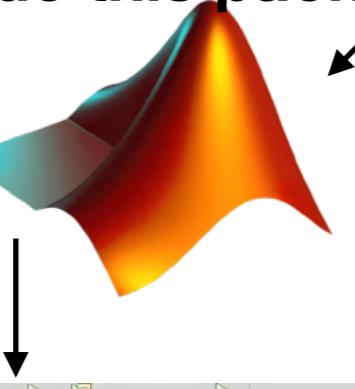
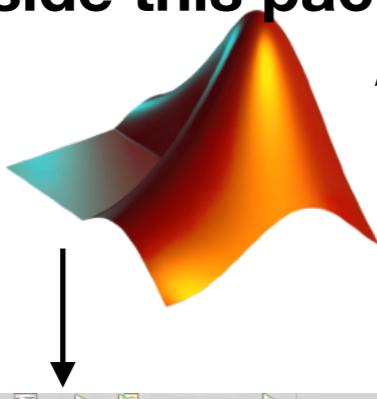
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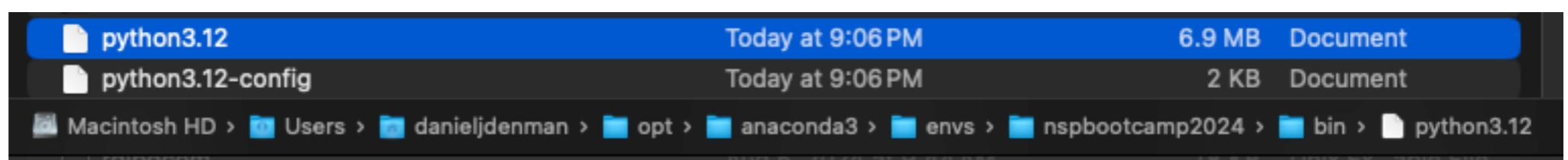
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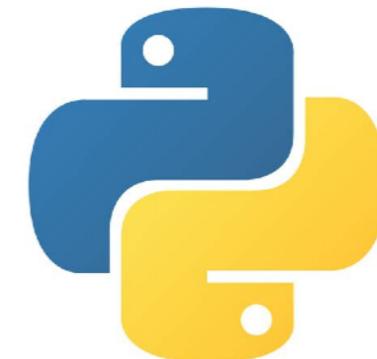
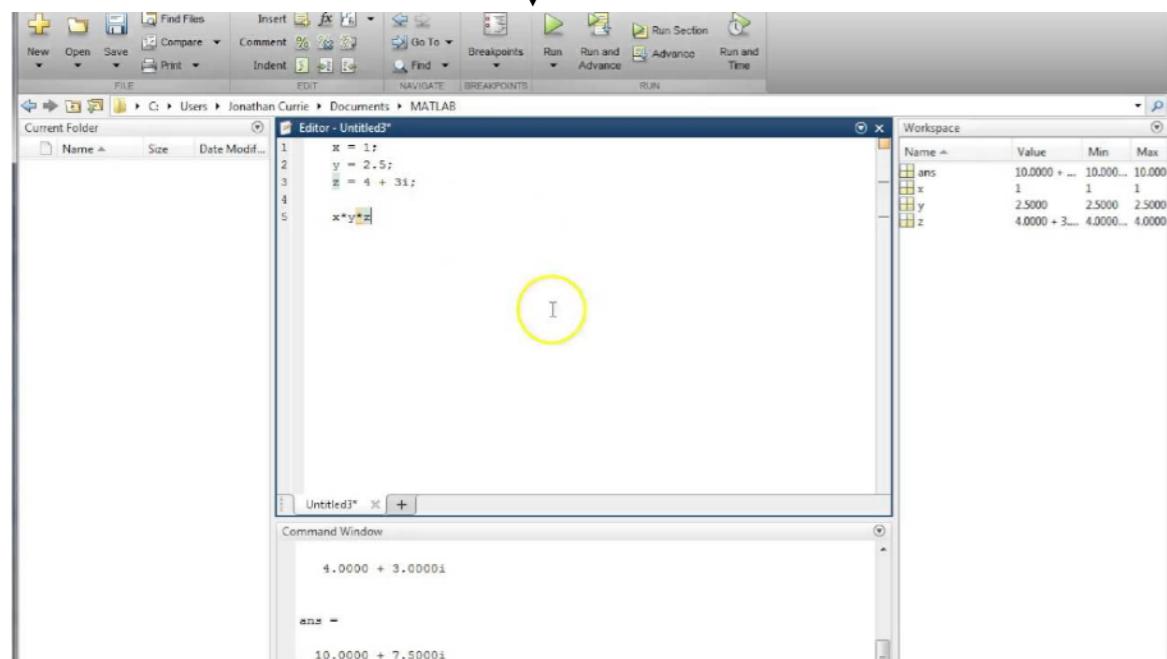
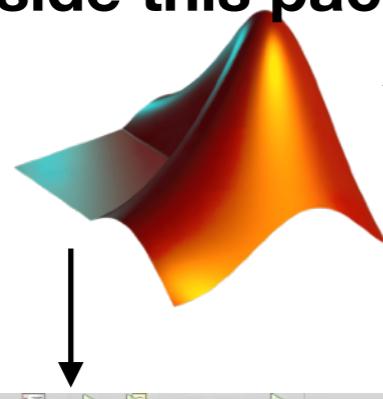
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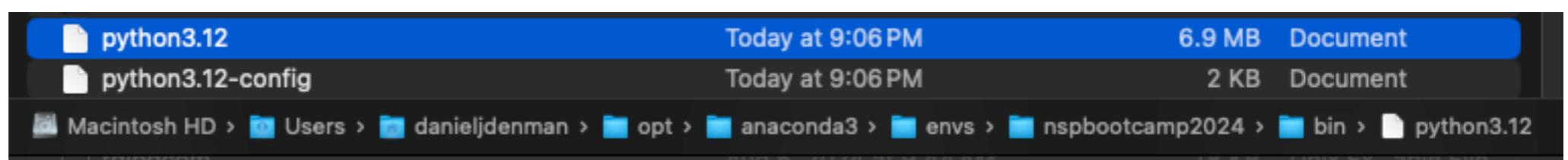
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All platforms for data analysis are going to work this way, with varying levels of packaging/abstraction/convenience (Excel, jmp, R, MATLAB, python on your computer, something running on a cloud server...) that translate what you write to a machine 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)
[Clang 4.0.1 (tags/RELEASE_401/final)] :: Anaconda, Inc. on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> 
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Native in Mac OS X, Linux; in Windows store (free)



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Package Managers Environments



Containerized





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Scripts

```
Users > danieljdenman > github > mouse_tunnel > mouse_tunnel_auto_CUtest.py
 1  from direct.showbase.ShowBase import ShowBase
 2  from direct.task import Task
 3  # from direct.gui.OnscreenText import OnscreenText
 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.")
22     have_nidaq=False
23
24 MOUSE_ID = 'test'
25
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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Native in Mac OS X, Linux; in Windows store (free)

Package Managers Environments



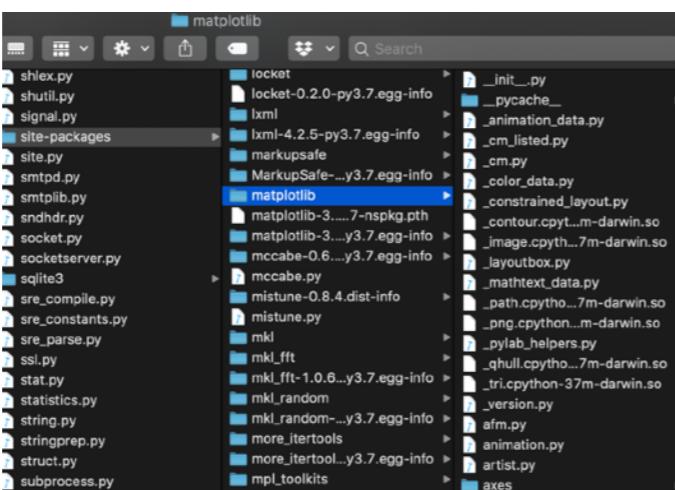
Containerized



Scripts

```
Users > danieljdenman > github > mouse_tunnel > mouse_tunnel_auto_CUtest.py
 1  from direct.showbase.ShowBase import ShowBase
 2  from direct.task import Task
 3  # from direct.gui.OnscreenText import OnscreenText
 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.")
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





System

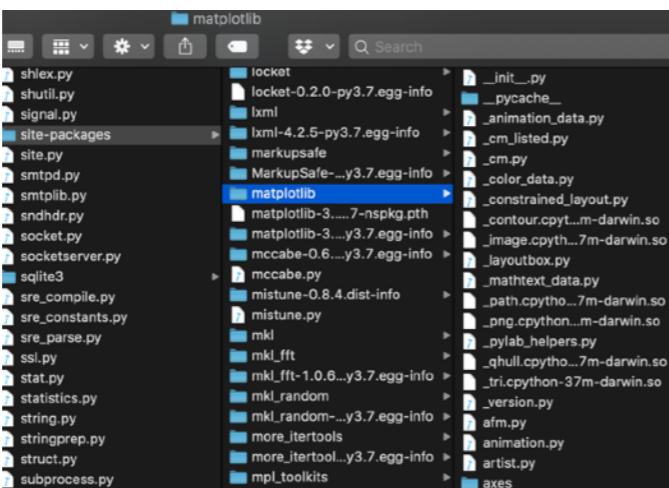
```
danieljdenman — python — 80x24
Last login: Wed Dec 18 16:26:32 on ttys002
The default interactive shell is now zsh.
To update your account to use zsh, please run `chsh -s /bin/zsh`.
For more details, please visit https://support.apple.com/kb/HT208050.
(base) djd-mbpro:~ danieljdenman$ python
Python 3.7.4 (default, Aug 13 2019, 15:17:50)
[Clang 4.0.1 (tags/RELEASE_401/final)] :: Anaconda, Inc. on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> 
```

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Packages



overview: levels

Package Managers Environments



Containerized



Notebooks (IPython, Jupyter, Jupyter Lab)

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

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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also it is free —> democratizing science
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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Data science

scikit-learn

Pandas

TensorFlow

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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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...

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[it is free!]



Guided example:

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

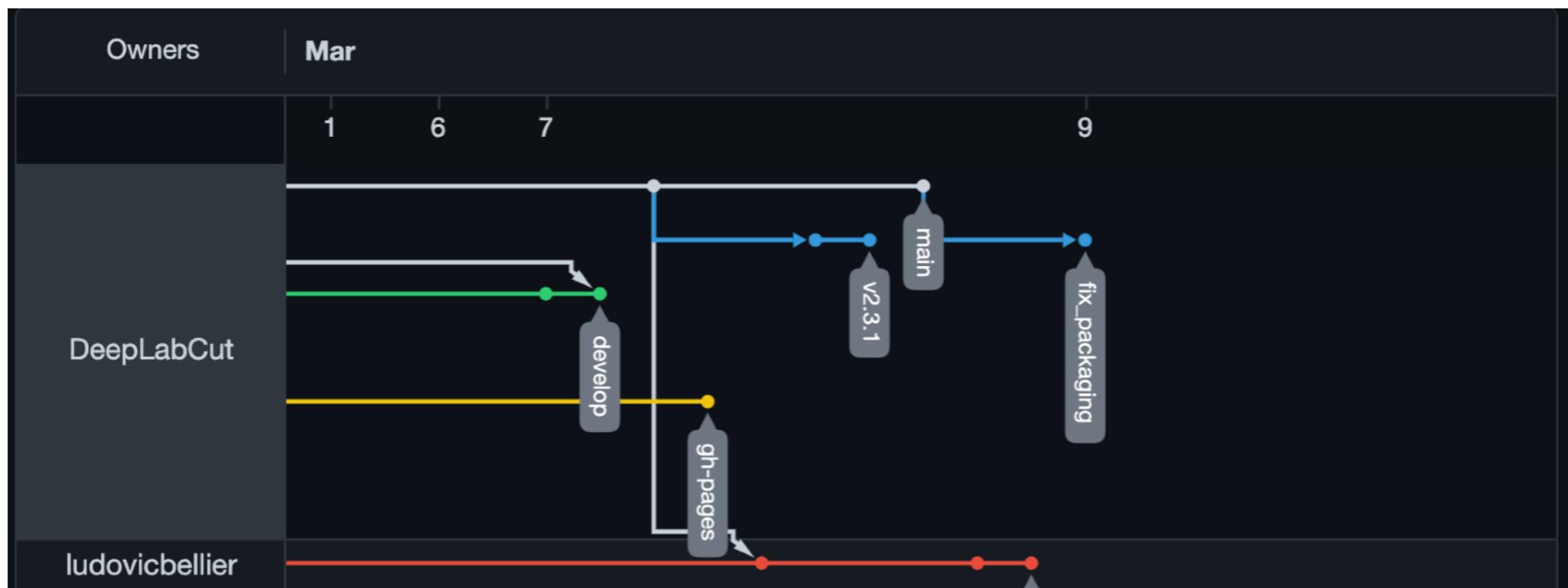
git

...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
- GitHub Desktop <https://desktop.github.com/> or use VS Code; git bash (command line) is another option
- We're going to go over some git (with VS Code) interactively to get course materials today.

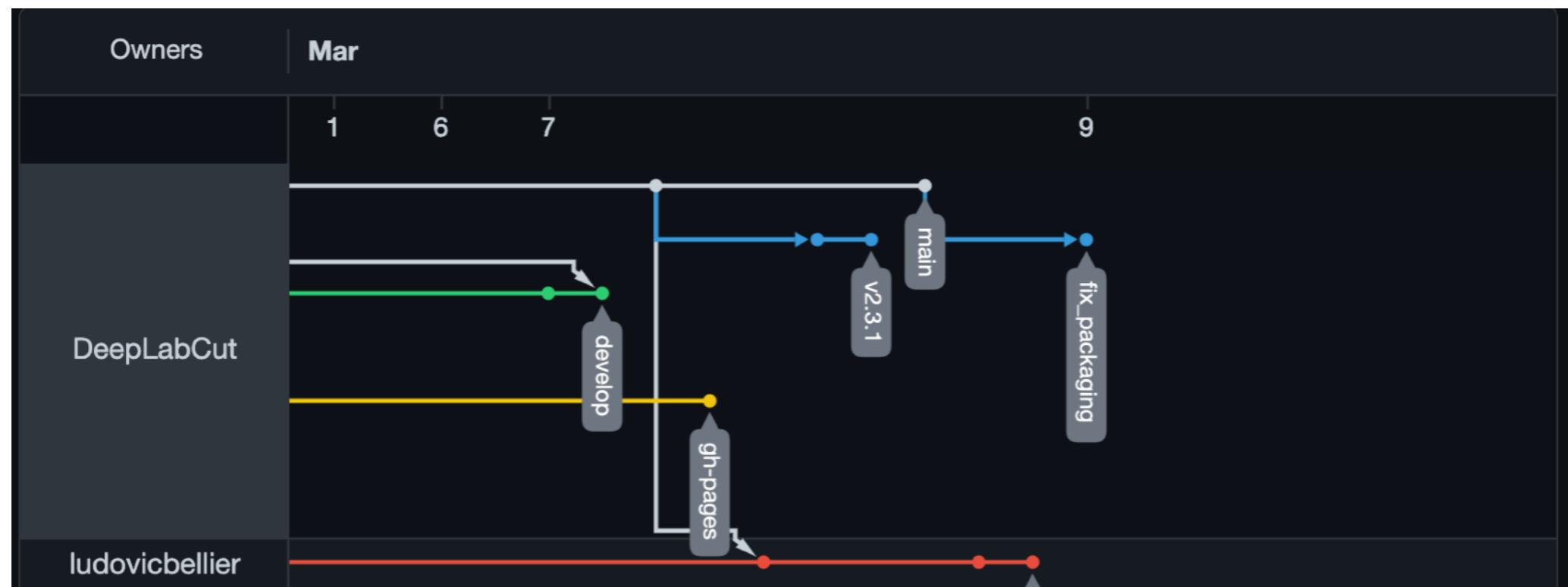
git

Conceptually



git

Conceptually



A little like a super powered Dropbox for code management

- cloud backup
- full history
- Summaries that let you skip reading the content...and automatic content reading
- Multiple “histories” or branches that can be automatically merged *if its OK*

GitHub

Conceptually



Remote



The screenshot shows a terminal window with the following content:

```
squirrel_2AFC_gratings.py

# This file is part of the Python Game Development book by Daniel J. Denman.
# See http://danielsdenman.com/python-game-development/
# It is released under the MIT License, available at http://opensource.org/licenses/MIT

# Import required modules
import glob, time
from numpy import random
from pyfimata import ArduinoMega, util

# Set up image and gameplay resources=====
# Import pyglet
pyglet.resource.path = ['../models']
pyglet.resource.reindex()
game_window = pyglet.window.Window(800, 600)
grating_image = pyglet.resource.image('grating.jpg')
grating_image.anchor_x = grating_image.width // 2 #center image
sprite = pyglet.sprite.Sprite(grating_image, x = 100, y = 300)
#=====

# set up simple class that does nothing but hold parameter states
class Params():
    params = Params()
#=====

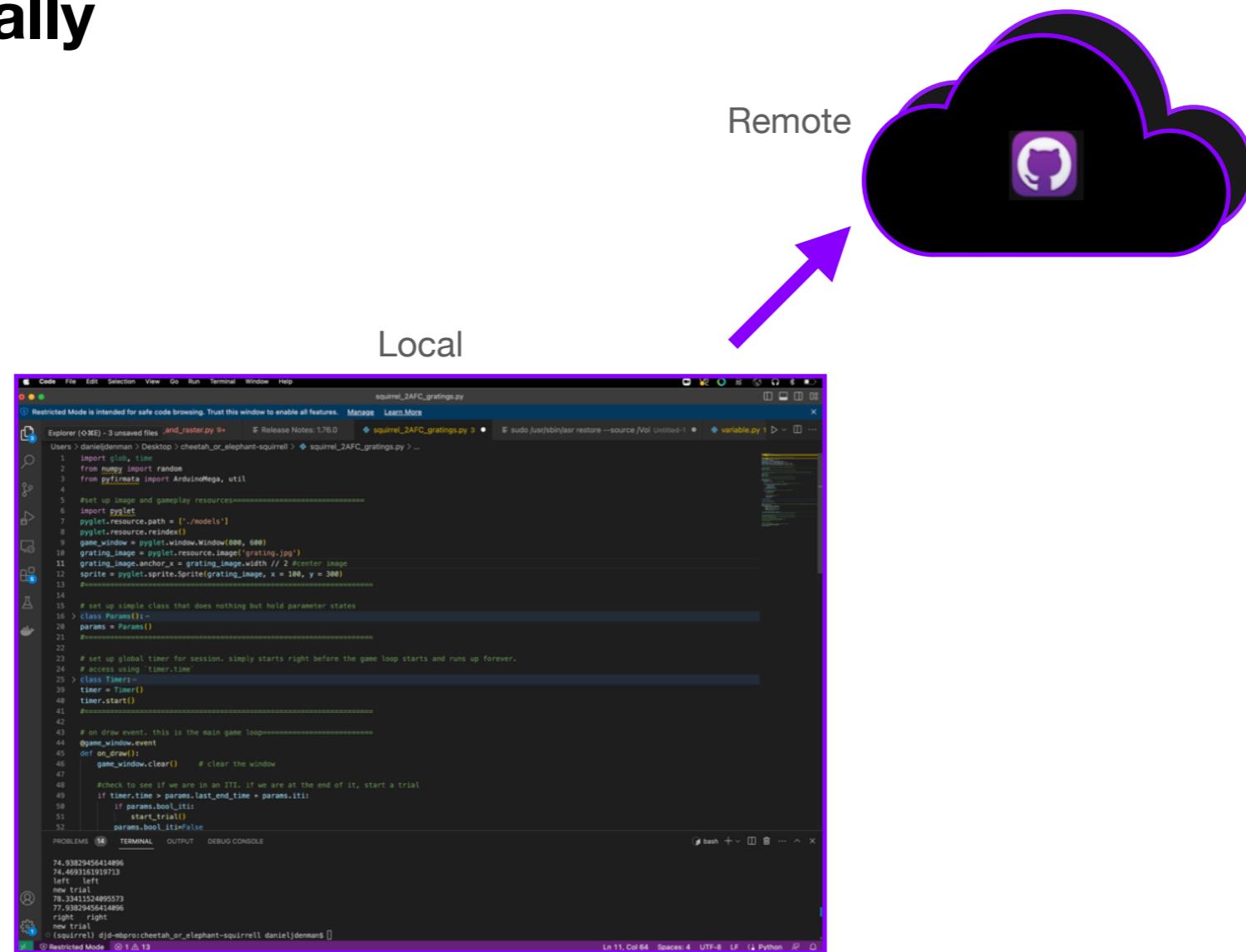
# set up global timer for session, simply starts right before the game loop starts and runs up forever.
# access using `timer.time`.
class Timer:
    timer = Timer()
    timer.start()
#=====

# on draw event, this is the main game loop=====
@game_window.event
def on_draw():
    game_window.clear()      # clear the window

    #check to see if we are in an ITI. If we are at the end of it, start a trial
    if timer.time > params.last_end_time + params.itii:
        if params.bool_itii:
            start_trial()
        params.bool_itii=False

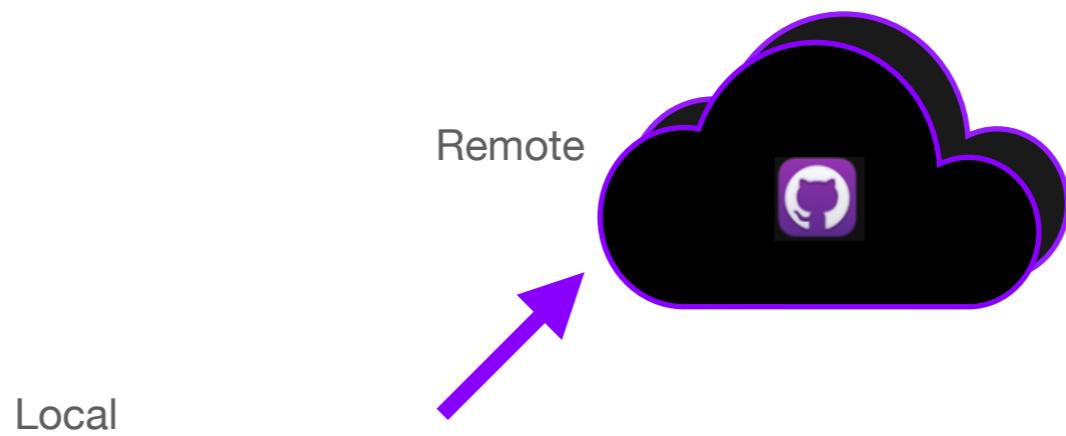
PROBLEMS (0) TERMINAL OUTPUT DEBUG CONSOLE
```

GitHub Conceptually



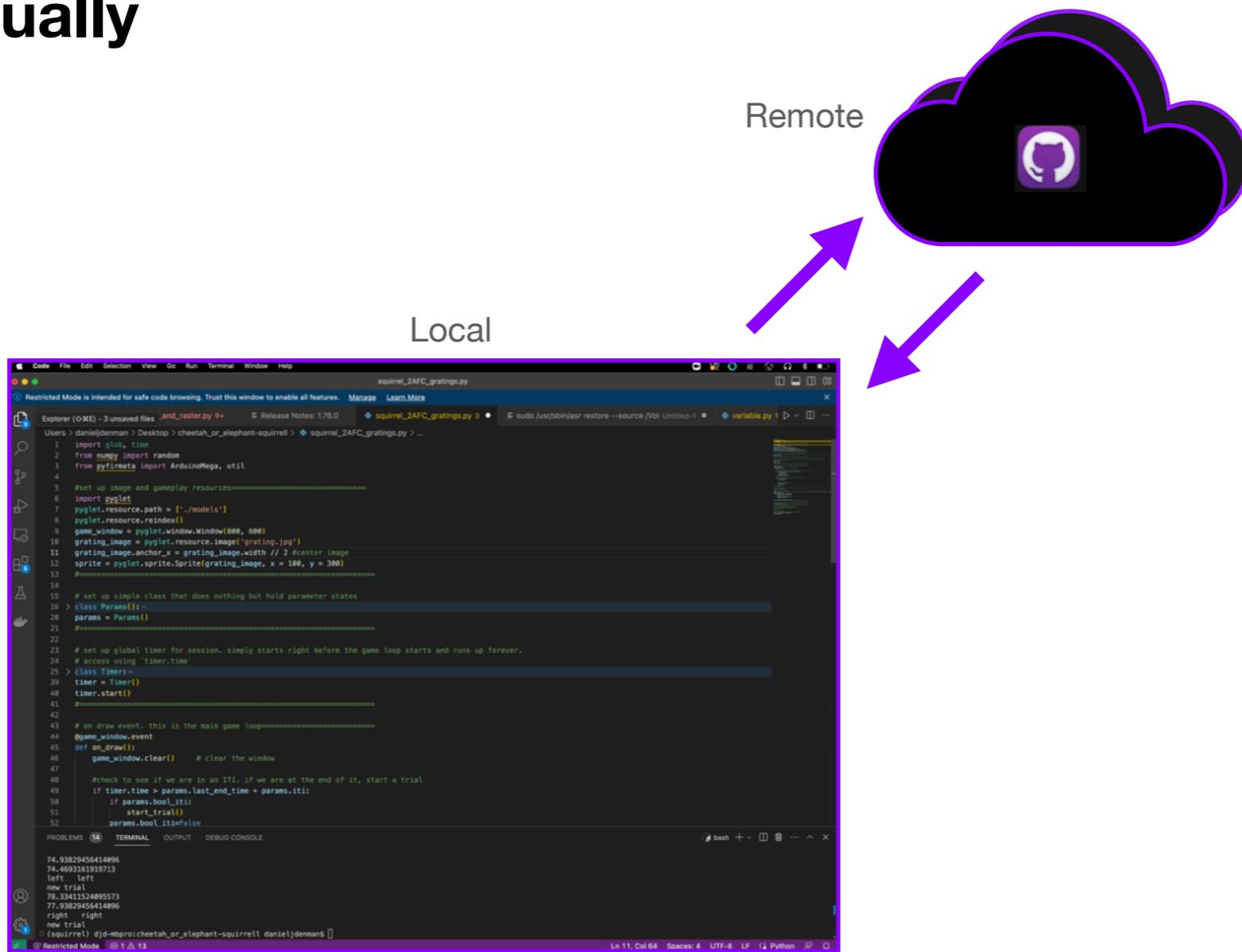
GitHub

Conceptually

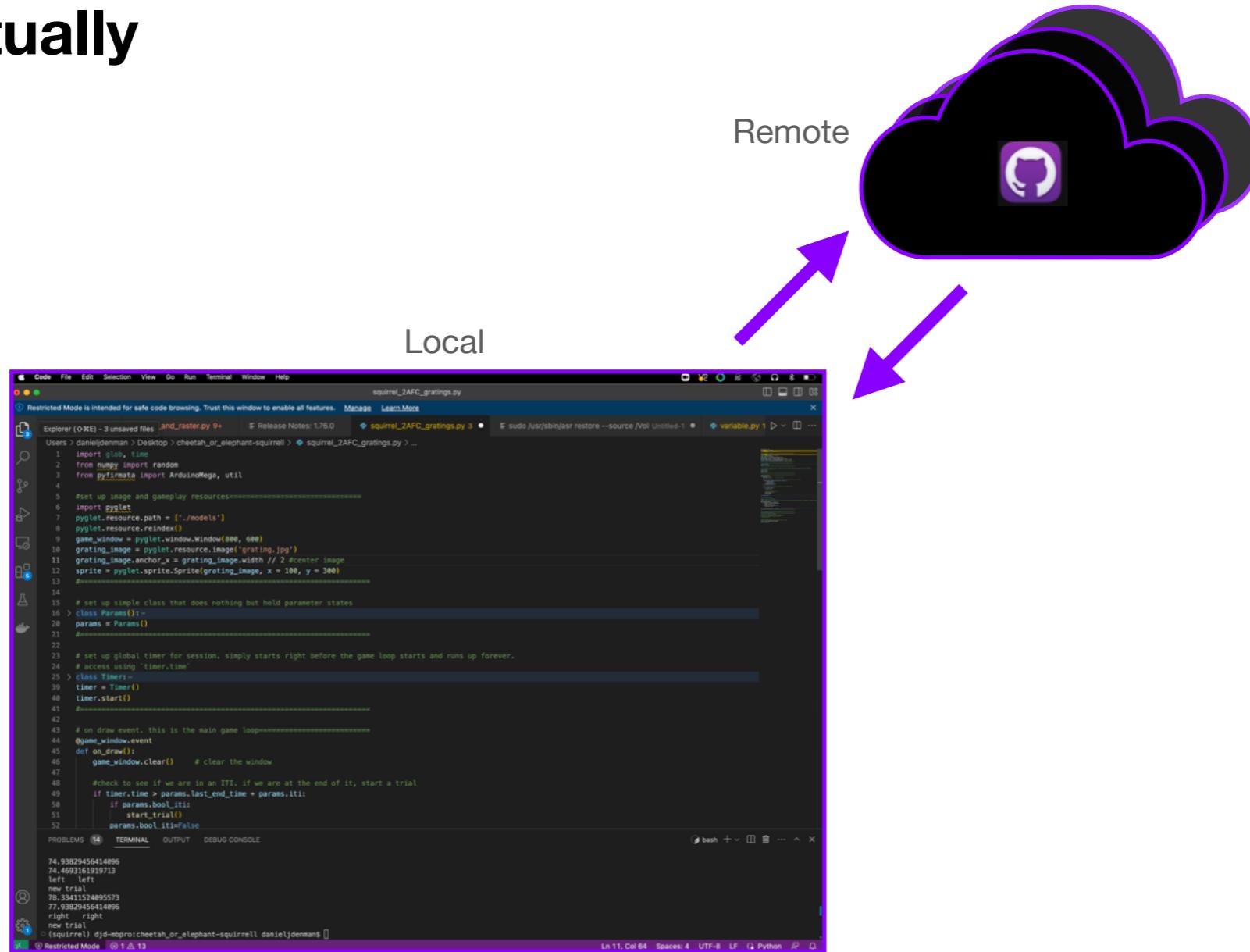


GitHub

Conceptually

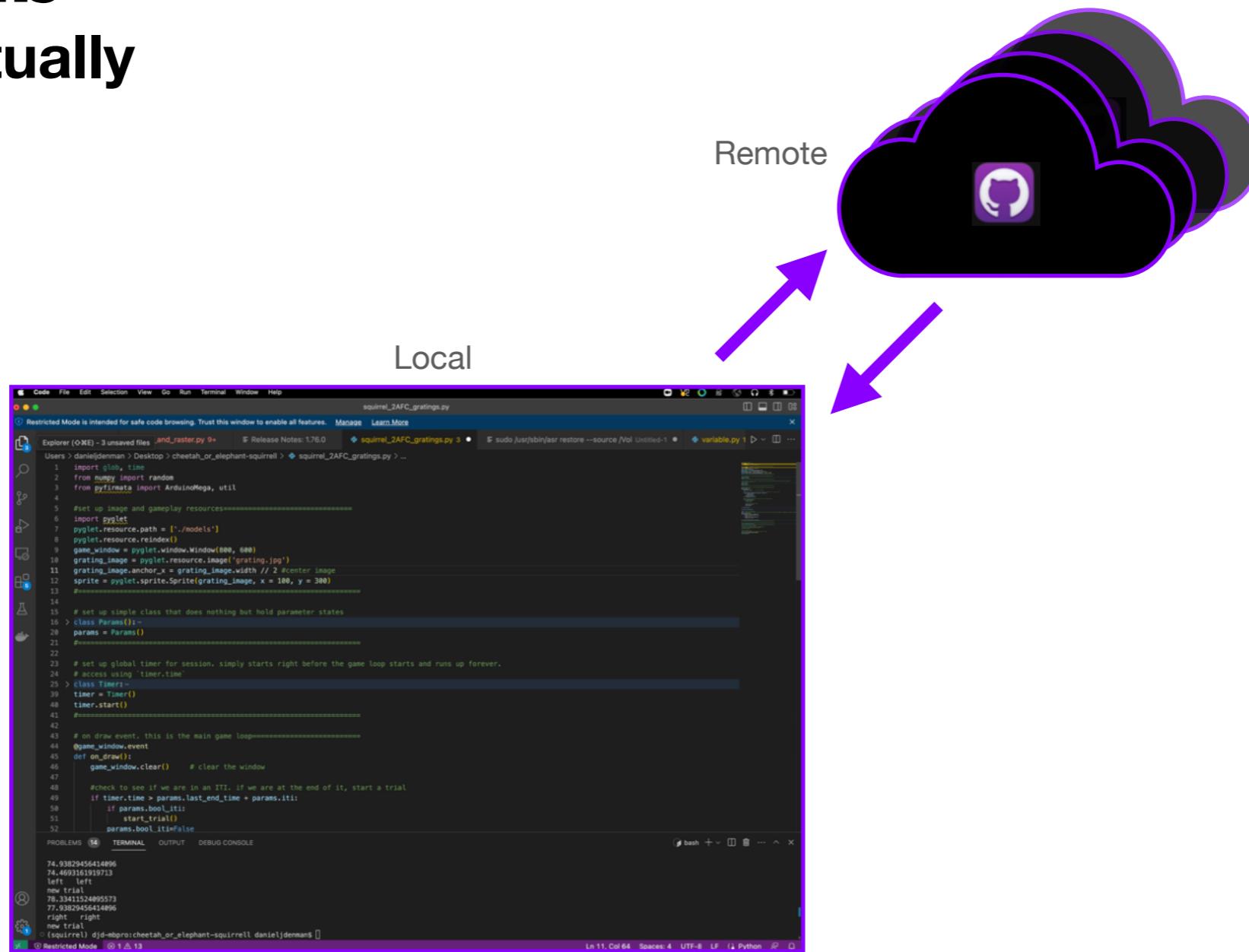


GitHub Conceptually



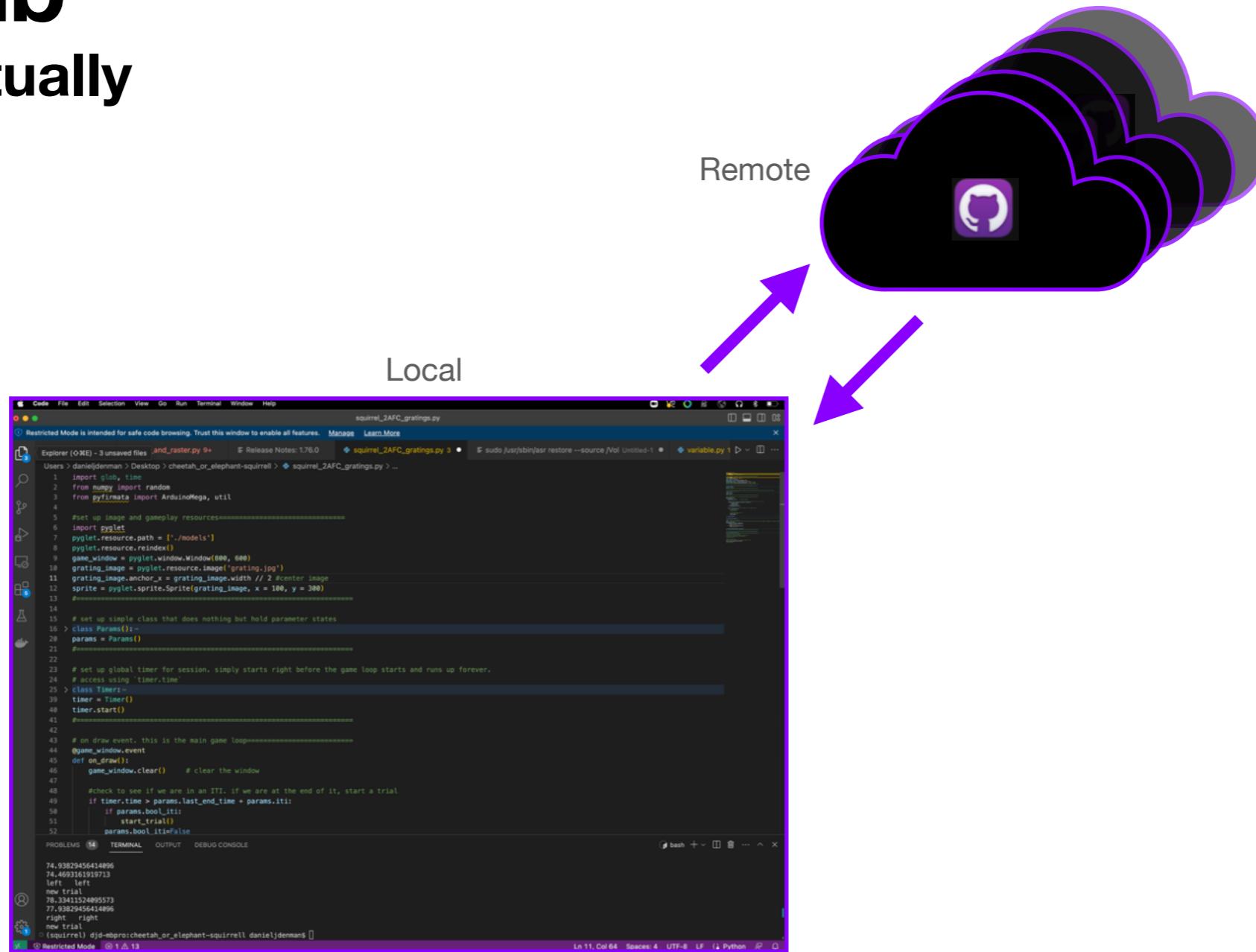
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Conceptually

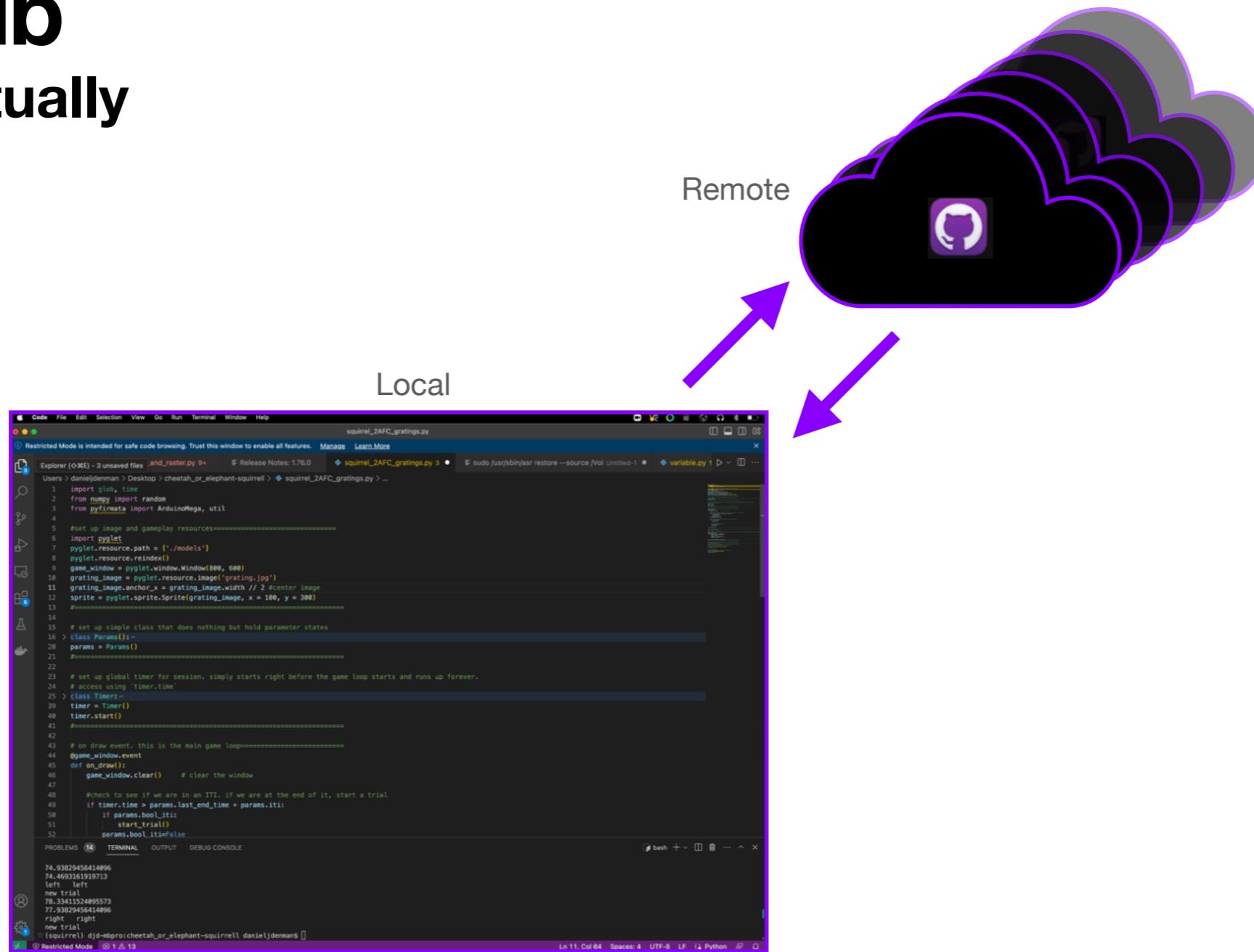


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Conceptually

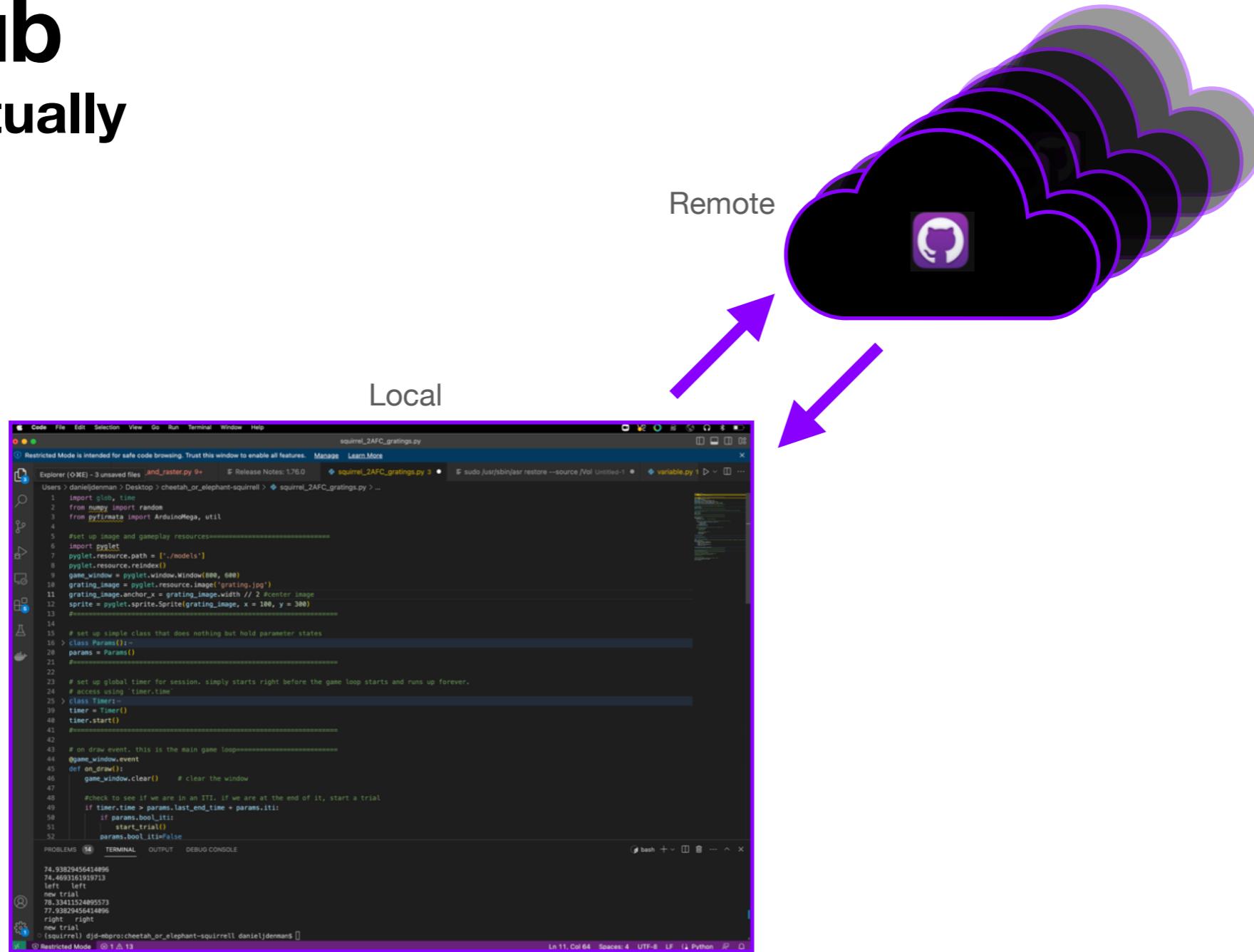


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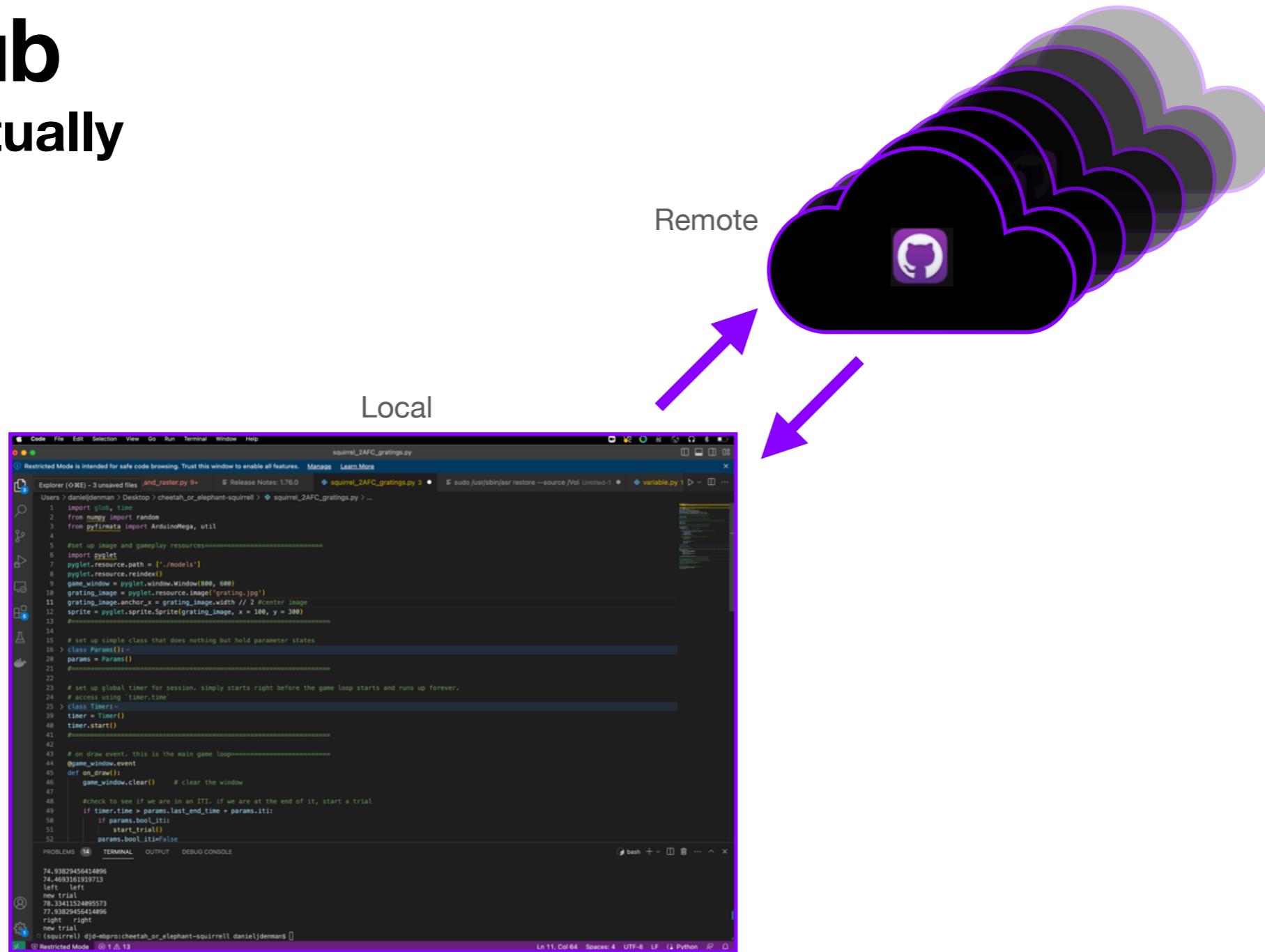
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Conceptually

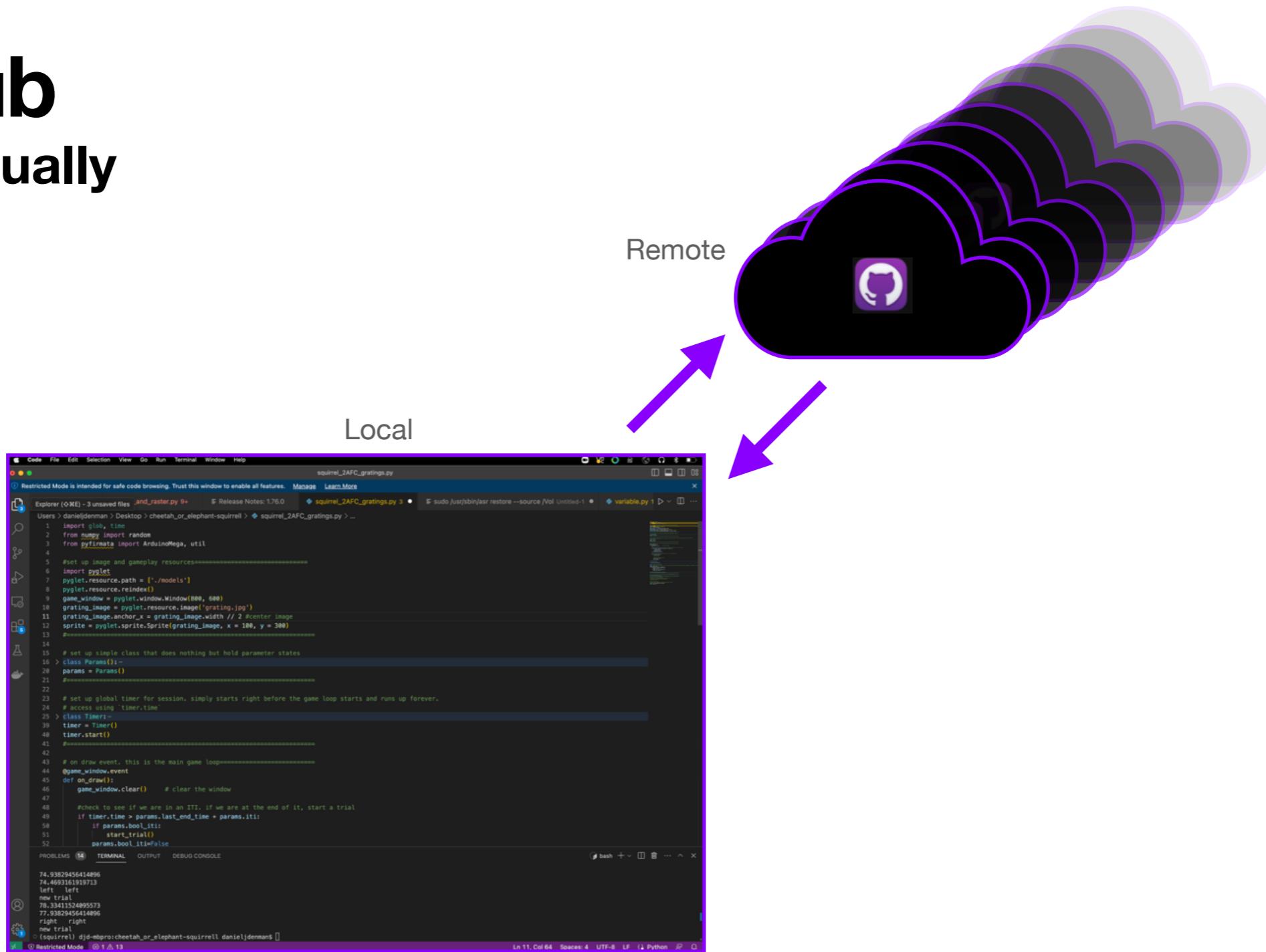


GitHub

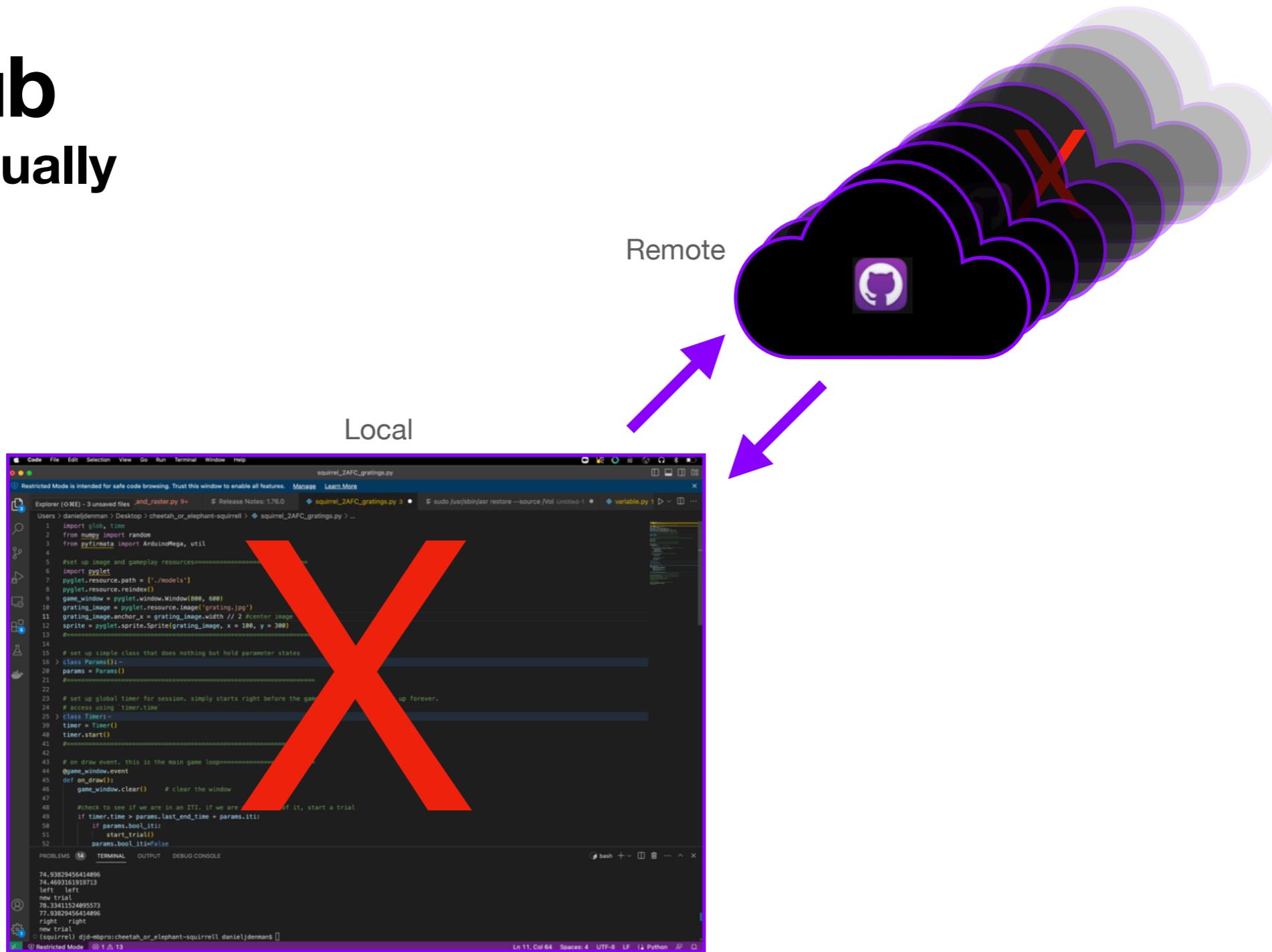
Conceptually



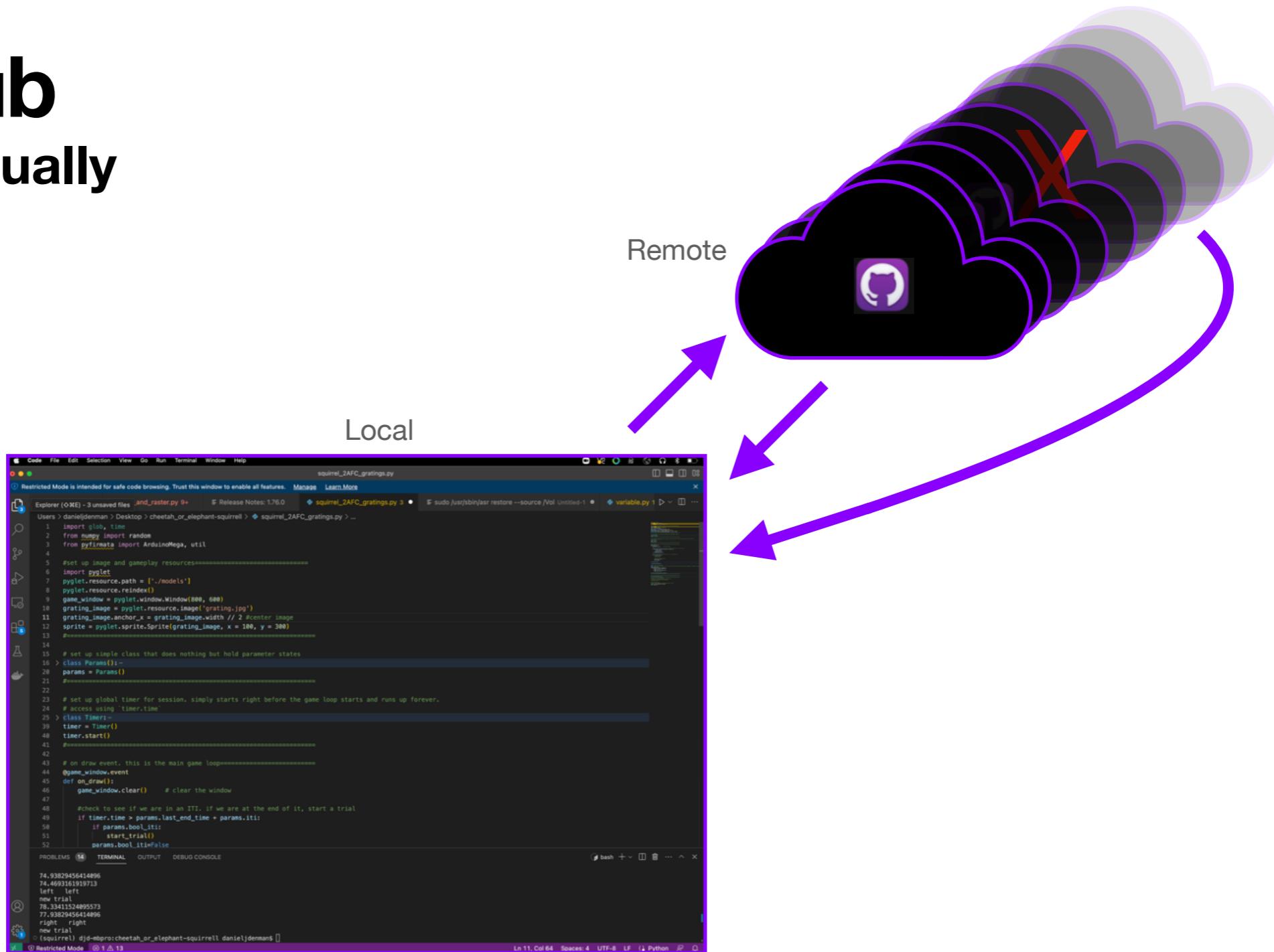
GitHub Conceptually

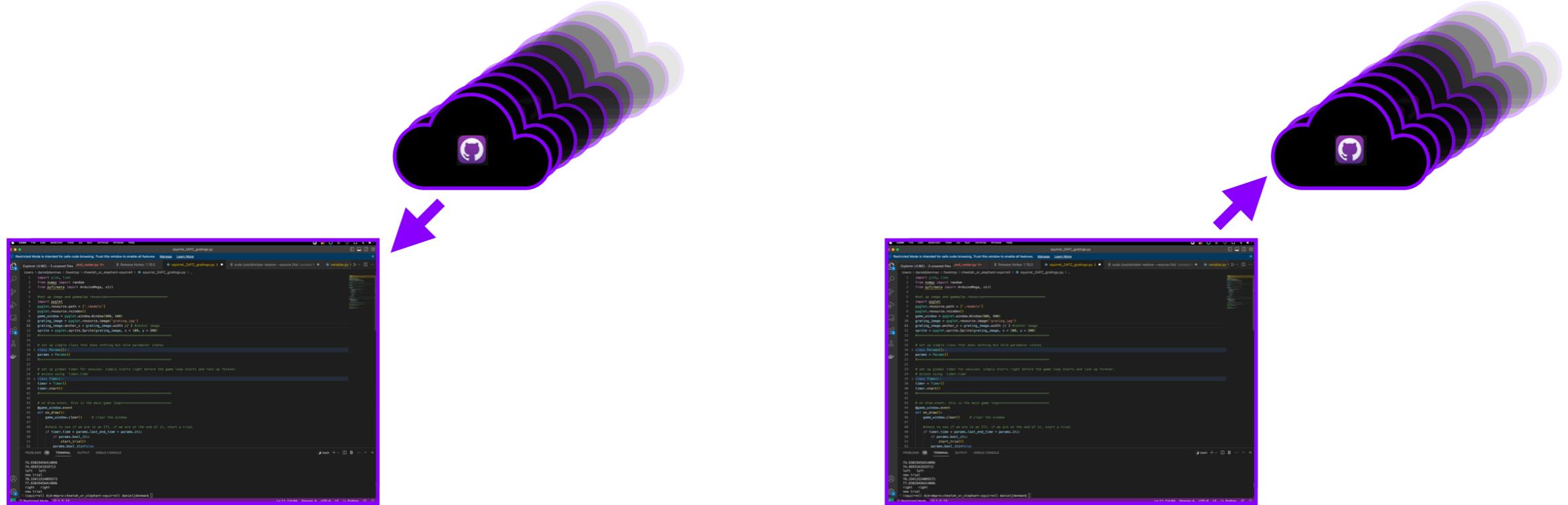


GitHub Conceptually



GitHub Conceptually





```
git fetch origin  
git reset --hard origin/master
```

