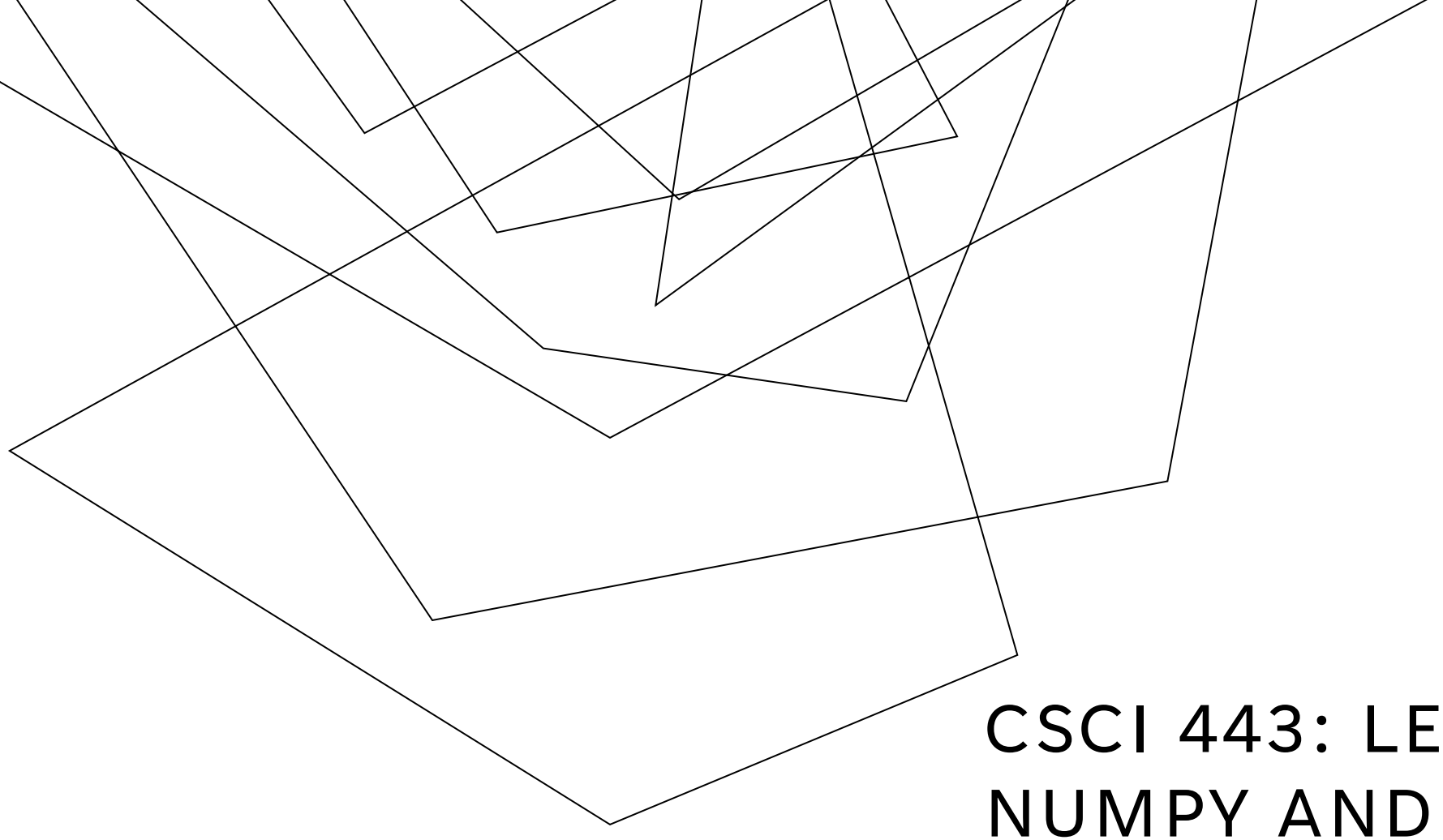
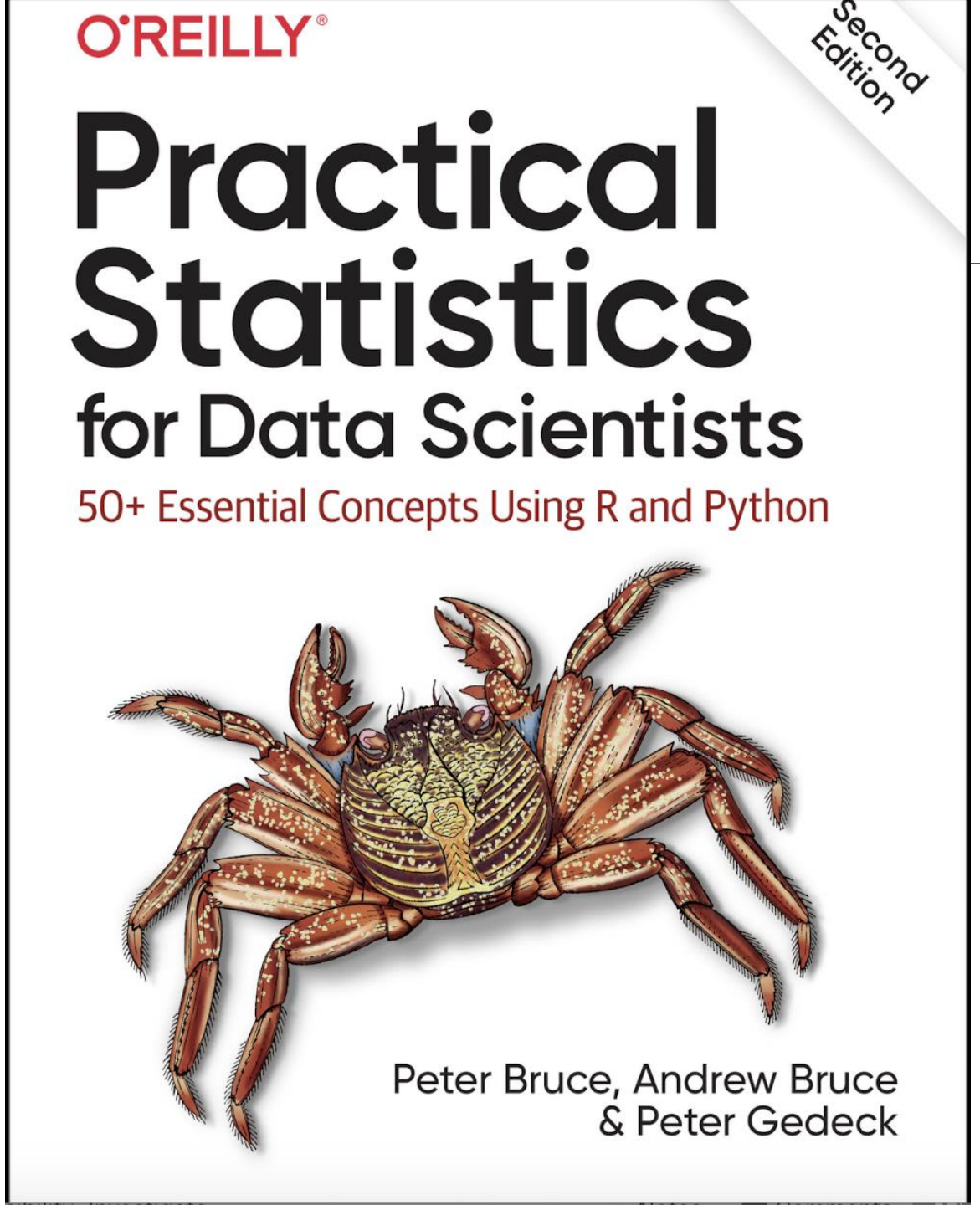


CSCI 443: LECTURE 2 NUMPY AND DATA FRAMES

Professor David Harrison

TODAY

- Remainder of Chapter 1
- Why Python is slow
- Why Python at all?
- Numpy
- Data Frames



HOMEWORK 1

Due Thursday, January 30 at 11 pm.

Focuses on

- setting up accounts,
- using github and Databricks
- Notebooks.

Submission:

- Submit archived Databricks Notebook to Blackboard.

OFFICE HOURS

Due to scheduling conflict, office hours updated

Tuesday	4:00-5:00 PM
Wednesday	12:30-2:30 PM

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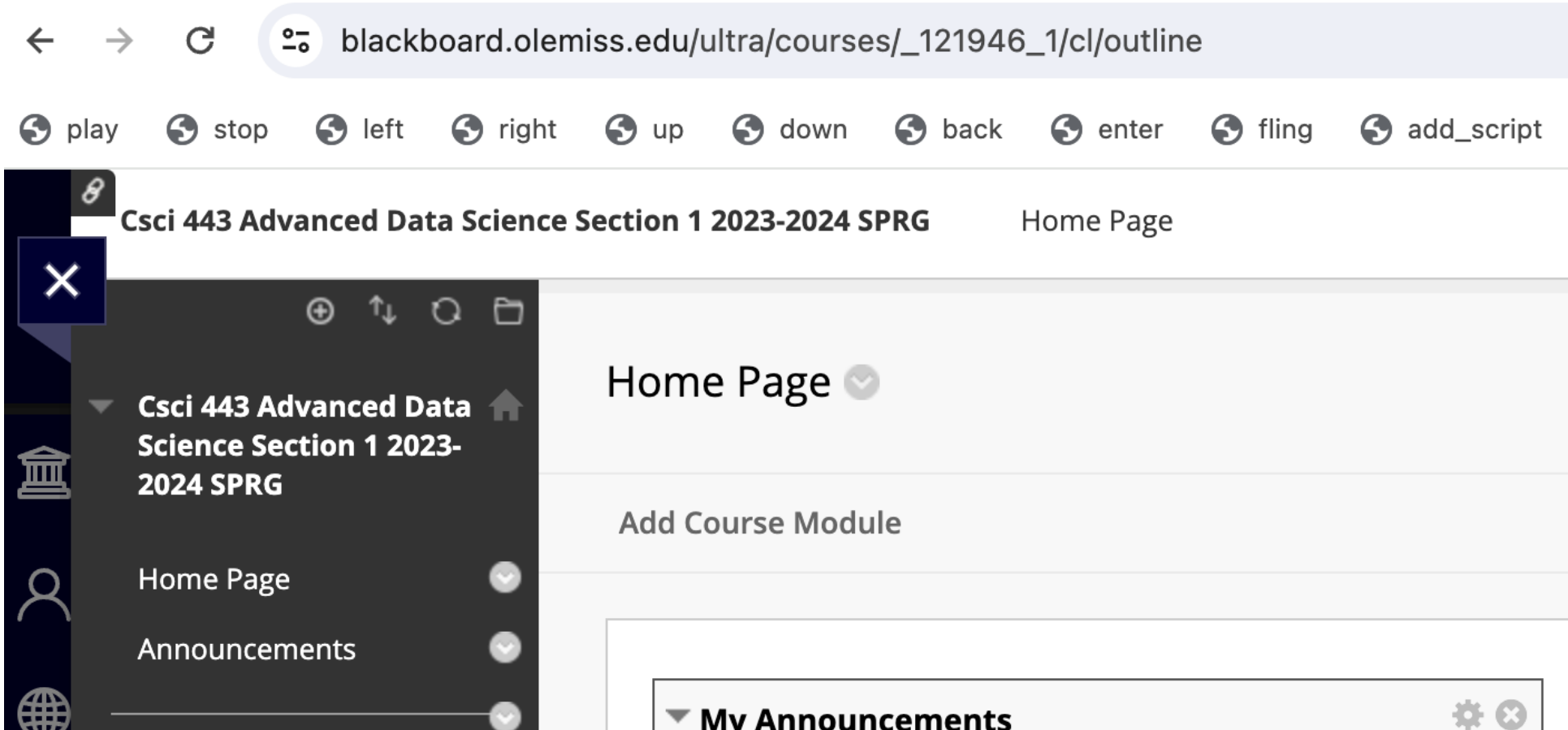
BLACKBOARD

All lecture slides, homeworks, and solutions will appear on blackboard.



GITHUB

Example files I create during class will be put on github.

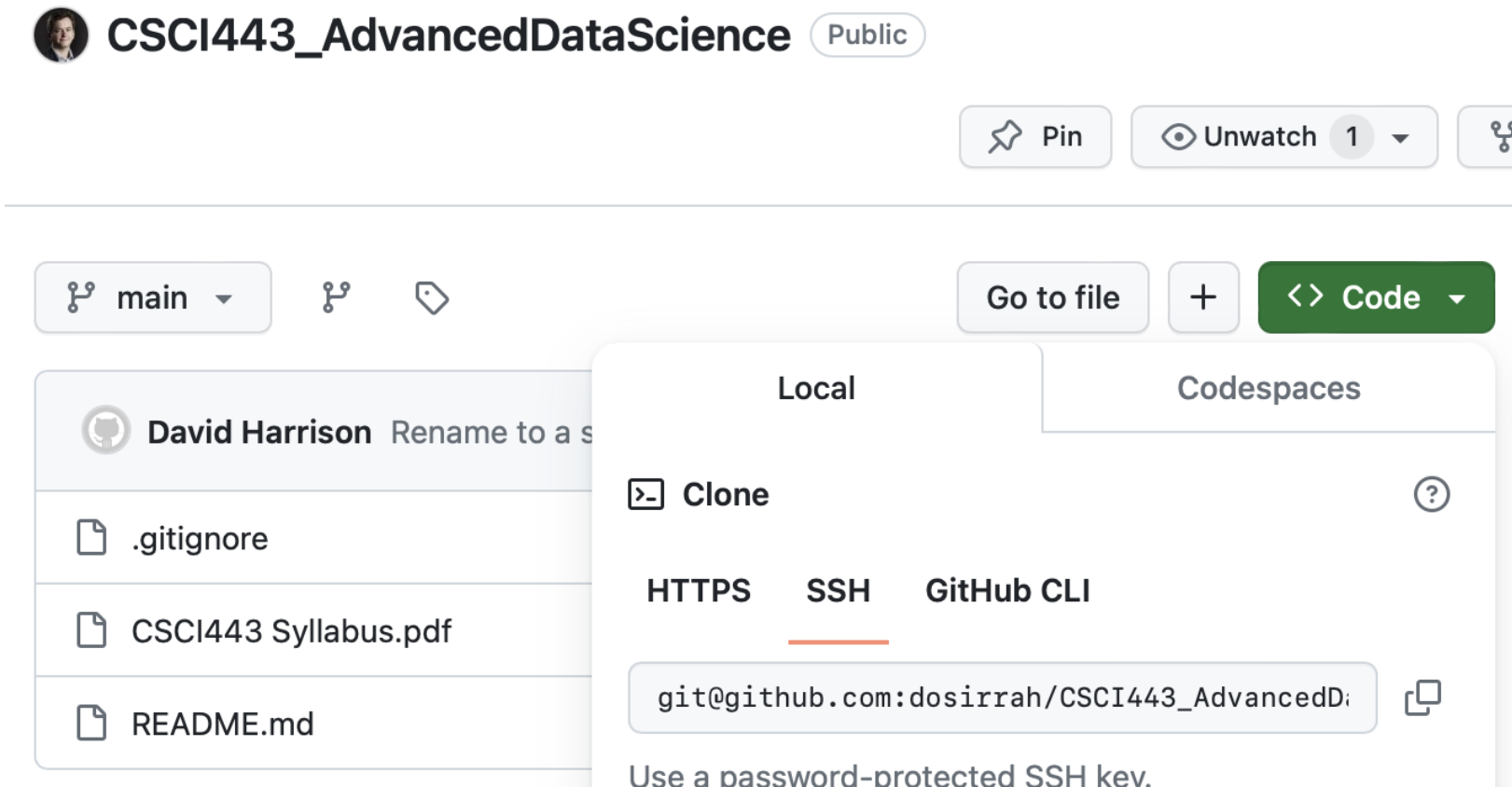
The project is at

https://github.com/dosirrah/CSCI443_AdvancedDataScience

You will need to create a Github account independent of your olemiss accounts.

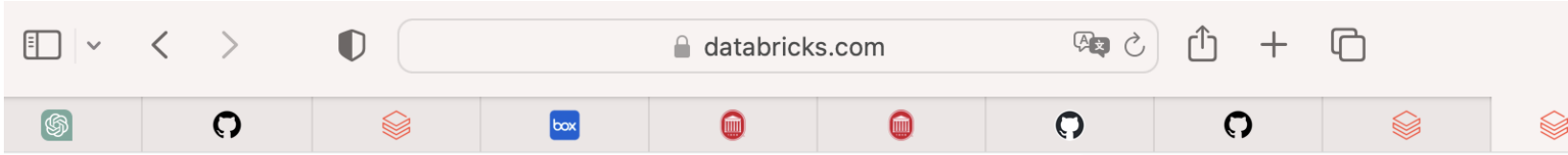
GitHub is free for our purposes.

I highly recommend committing any code you create to GitHub.



DATABRICKS

We will use the databricks community edition.
https://community.cloud.databricks.com/login.html



databricks

Try Databricks free

Test-drive the full Databricks platform free for 14 days on your choice of AWS, Microsoft Azure or Google Cloud. Sign-up with your work email to elevate your trial experience.

Create your Databricks account 1/2

Sign up with your work email to elevate your trial with expert assistance and more.

First name

Last name

Email

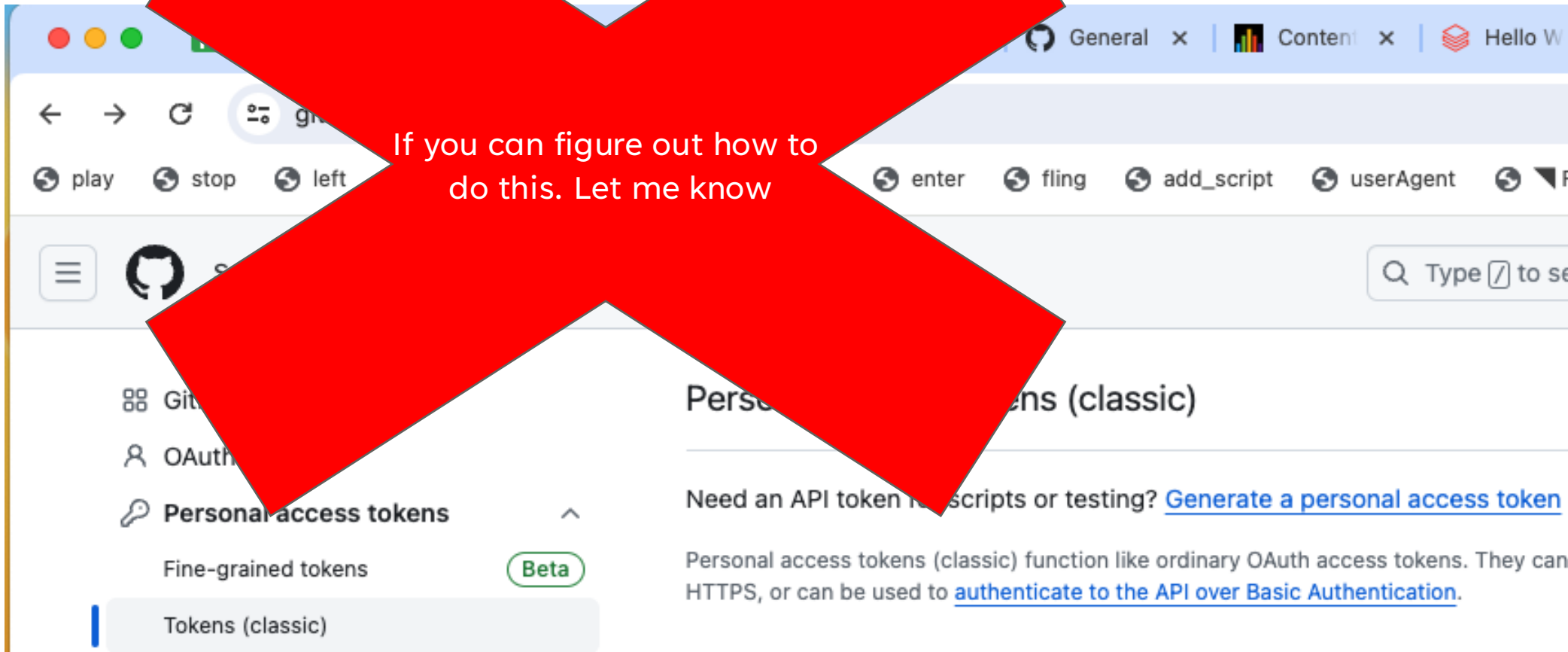
COMMIT NOTEBOOKS TO GITHUB

Please connect your notebooks to github.

Checkpoint your w regularly.

Ask chatgpt how

1. On github g Access T

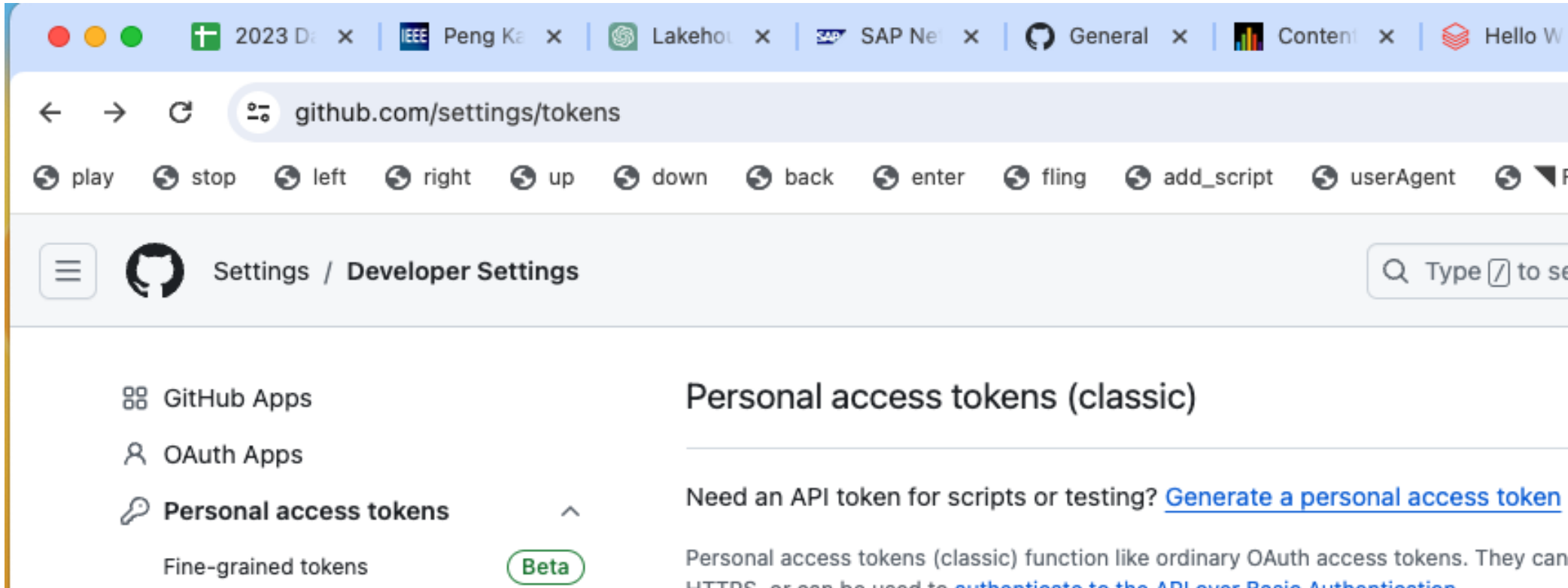


If you can figure out how to do this. Let me know

CLARIFICATION GITHUB

You can still commit notebooks to Github, but you have to download it first.

The direct connection between Github and Databricks is not available in the community edition of Databricks.



WHY IS PYTHON SLOW?

Everything in Python is a PyObject.

Everything in Python is allocated from dynamic memory

- i.e., from the memory heap.

Python uses duck-typing:

- makes inlining often impossible

Python command-line is interpreted

- .py files are just-in-time compiled (faster, but still slow)

Python is single threaded

- Global Interpreter Lock (GIL)

Python does not natively make use of vector processing.

WHY USE PYTHON FOR DATA SCIENCE?

Python is easy to program.

Python has beautiful, terse syntax.

Python is well supported by tools.

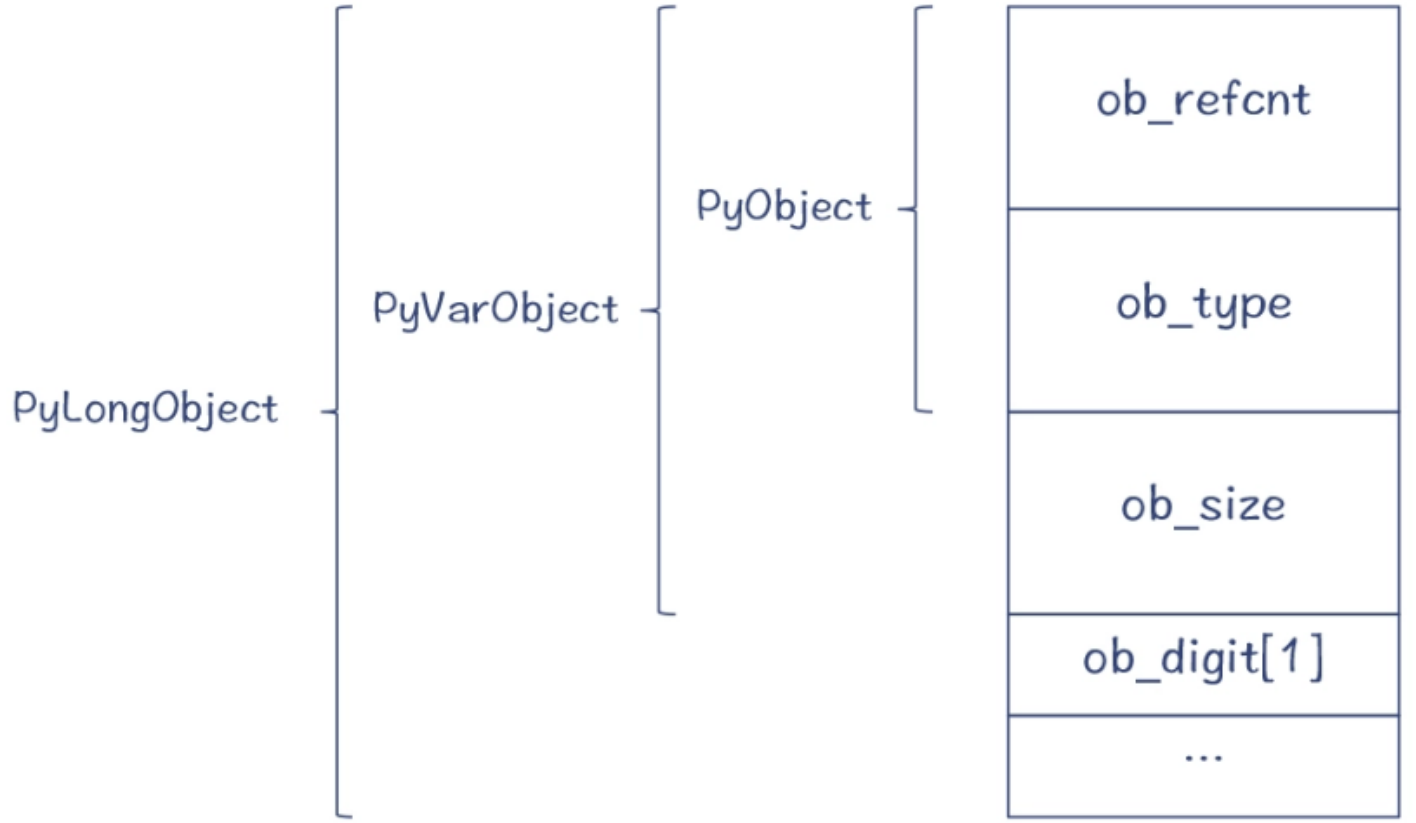
The big stuff is usually not done in Python, so slow doesn't matter (usually):

- Apache Spark
- PyTorch
- TensorFlow

The medium-sized stuff and postprocessing is usually not done in Python either

- NumPy
- DataFrames
- SciPy

PYTHON INTEGERS ARE OBJECTS



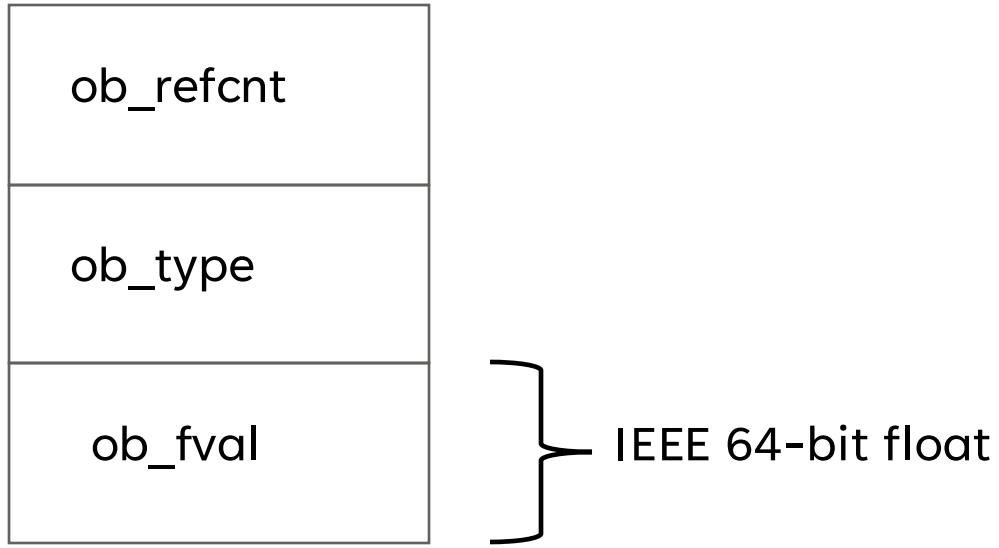
Reference count

Dynamic array of digits

PYTHON FLOATS ARE ALSO OBJECTS

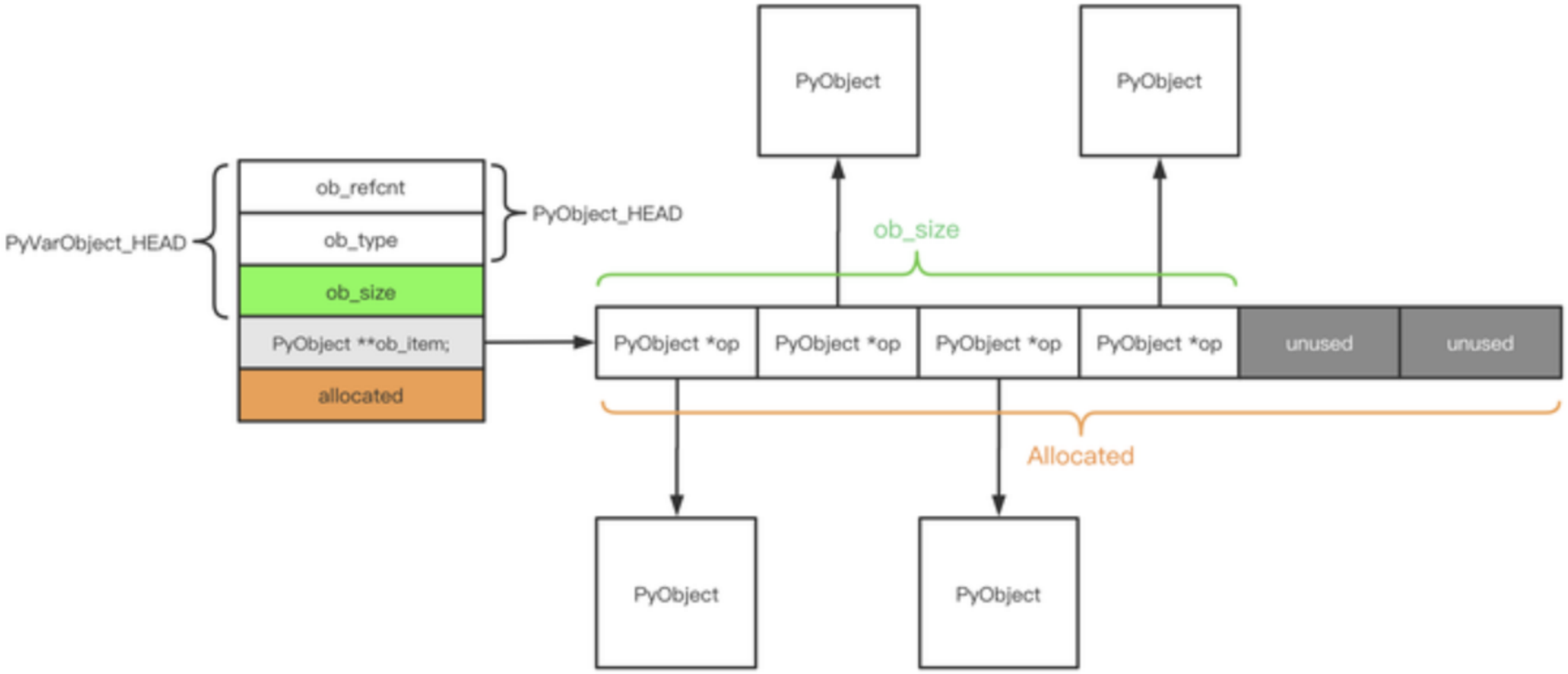
A float in python is an IEEE 64-bit floating point value wrapped in a PyObject.

- Compared to floating point arithmetic:
  - **Integer math is faster for small integers,**
  - **but slower for large integers.**



PYTHON LISTS ARE DYNAMIC ARRAYS

A list is a dynamic array of pointers to PyObjects.



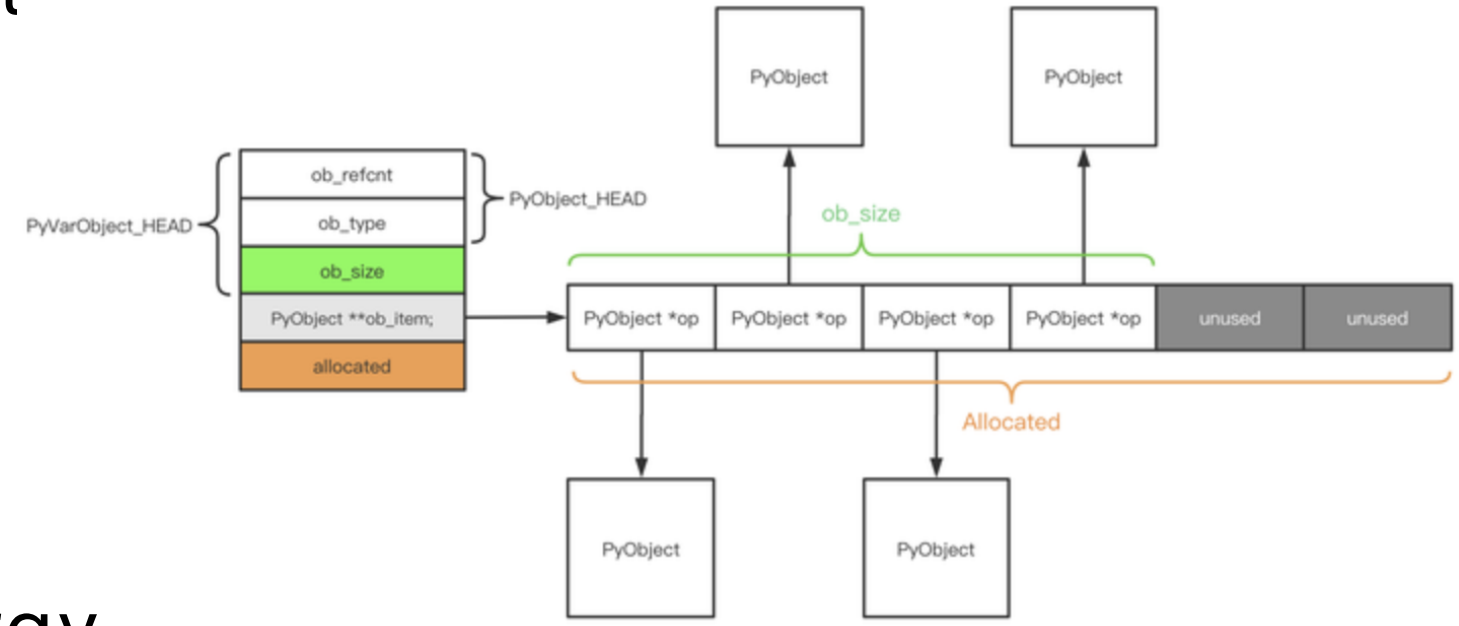
WHY NUMPY?

NumPy provides

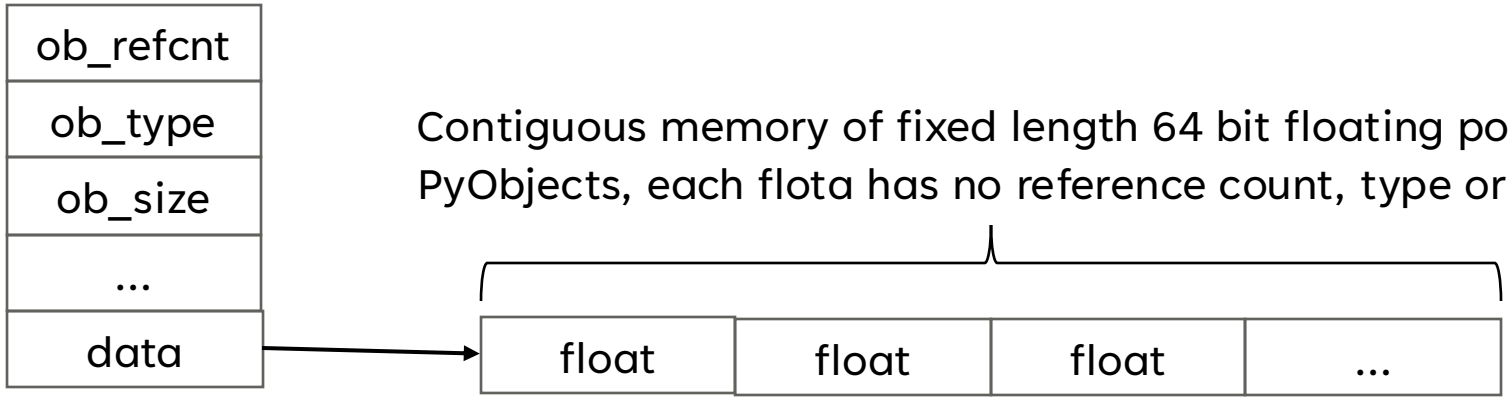
- large, memory-efficient, multi-dimensional arrays
- Fixed size integers and floats without
  - reference count field
  - type field
  - object size field
- Array and matrix operations
  - Utilizes vector operations when supported by the hardware. Thus FAST.

PYTHON LIST VS. NUMPY ARRAY

Python list

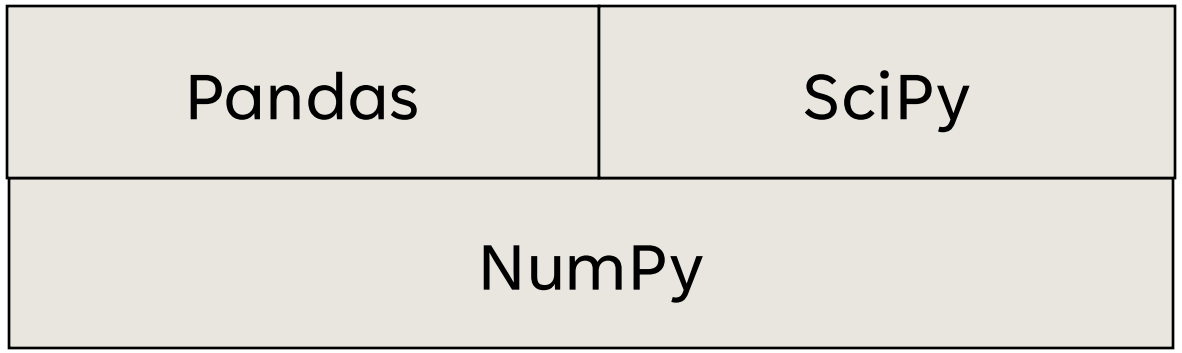


Numpy array



Contiguous memory of fixed length 64 bit floating point numbers. Unlike PyObjects, each flota has no reference count, type or size fields

MANY OTHER LIBRARIES BUILD ON NUMPY



EXAMPLE 1: ADD CONSTANT TO ARRAY

Python version

```
array = [1, 2, 3, 4, 5]
new_array = [0] * len(array)
for i in range(len(array)):
    new_array[i] = array[i] + 5
```

Both Python and NumPy versions can be found in the github class repository at lecture02/example1/example_1_array_add.py

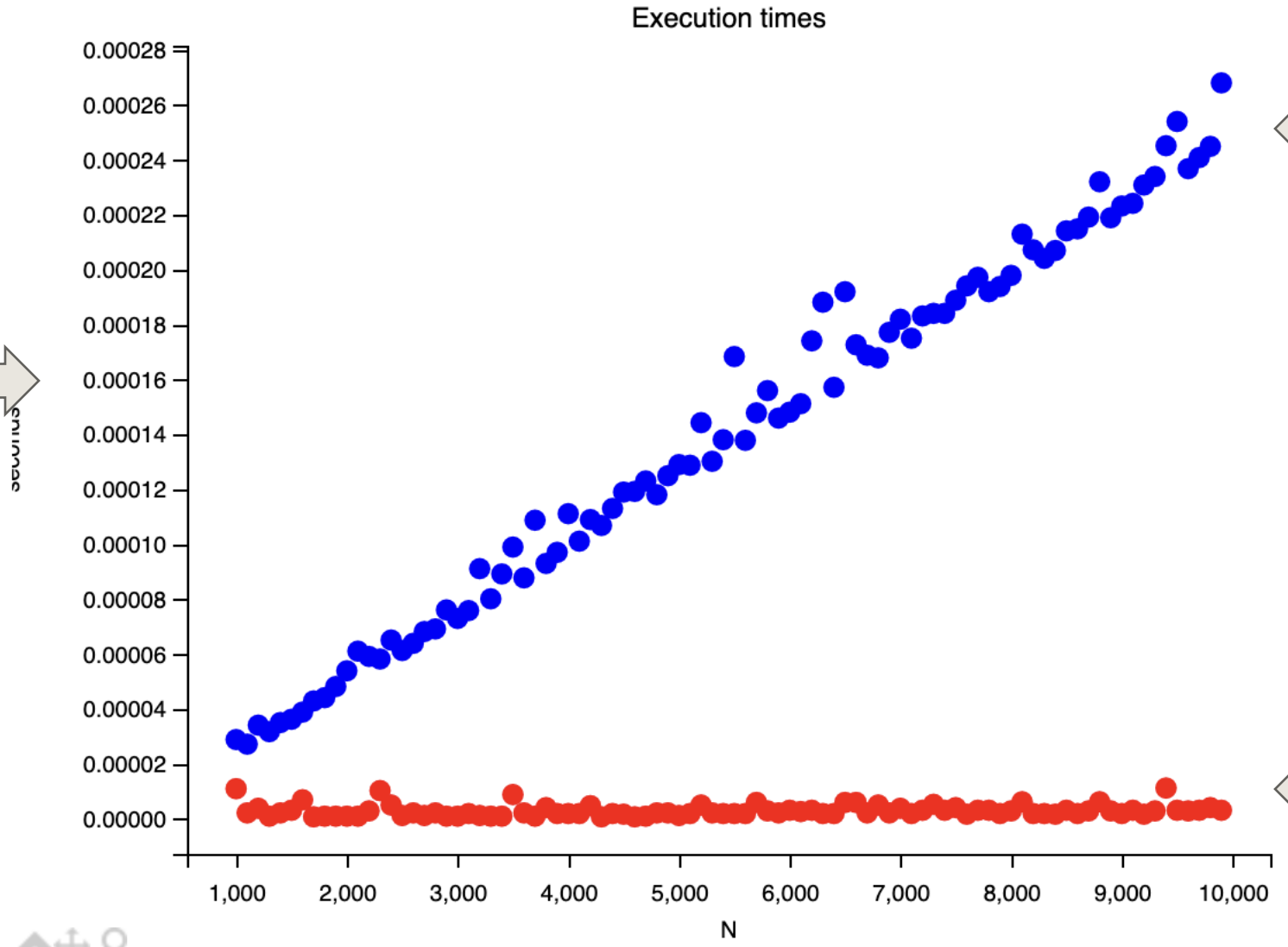
Python with NumPy version

```
# Create a one-dimensional NumPy array
array = np.array([1, 2, 3, 4, 5])

# Add constant to all elements of the array
new_array = array + 5
```

NUMPY DESTROYS PYTHON ARRAY ADD

Execution time
In seconds

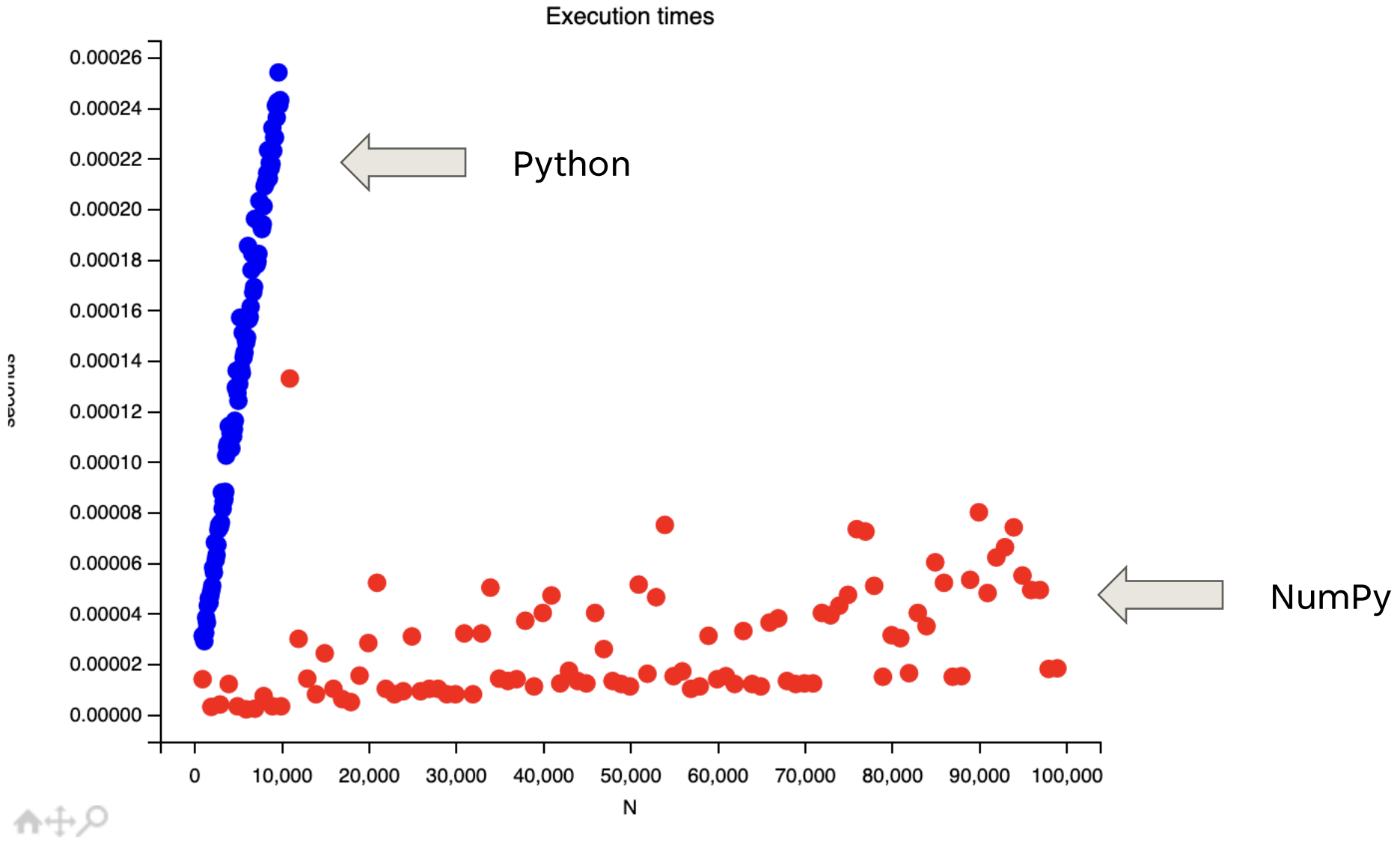


Python

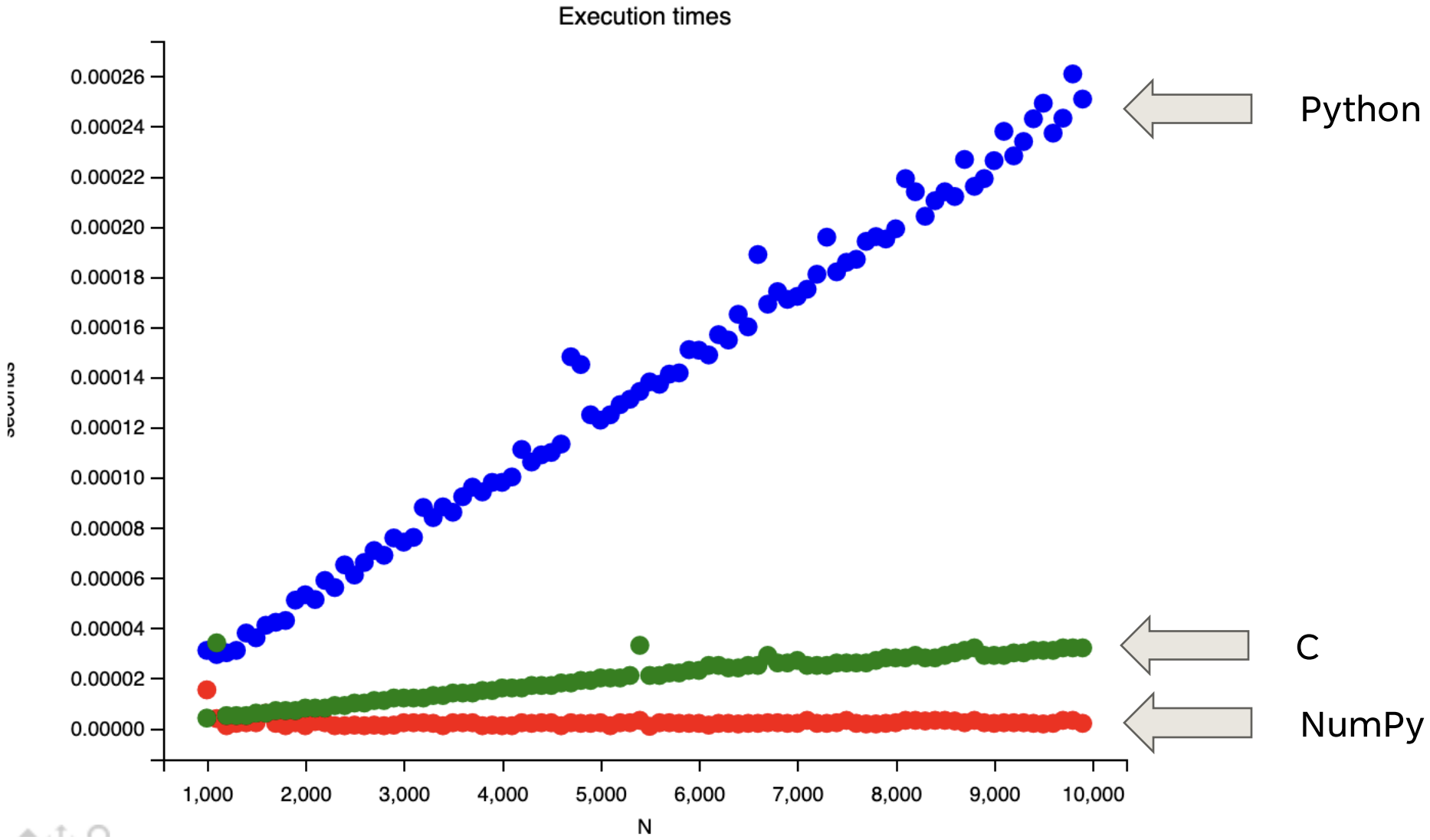
NumPy

N elements in the array

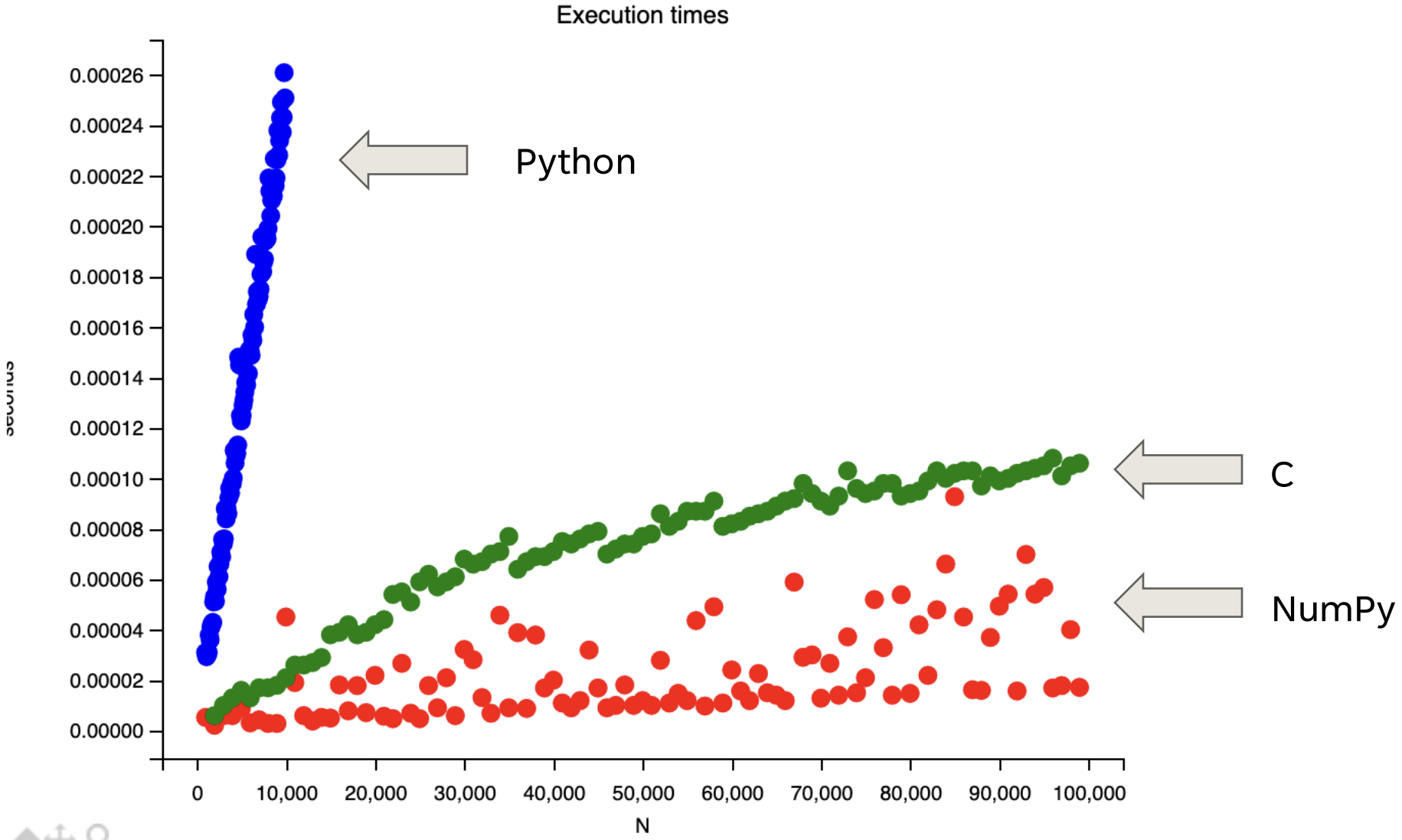
NUMPY DESTROYS PYTHON ARRAY ADD



FOR KICKS COMPARE TO C WITHOUT VECTOR OPERATIONS



FOR KICKS COMPARE TO C WITHOUT VECTOR OPERATIONS



EXAMPLE 2: MATRIX MULTIPLICATION

Python version

```
A = [[random.rand() for _ in range(n)] for _ in range(n)]
B = [[random.rand() for _ in range(n)] for _ in range(n)]
```

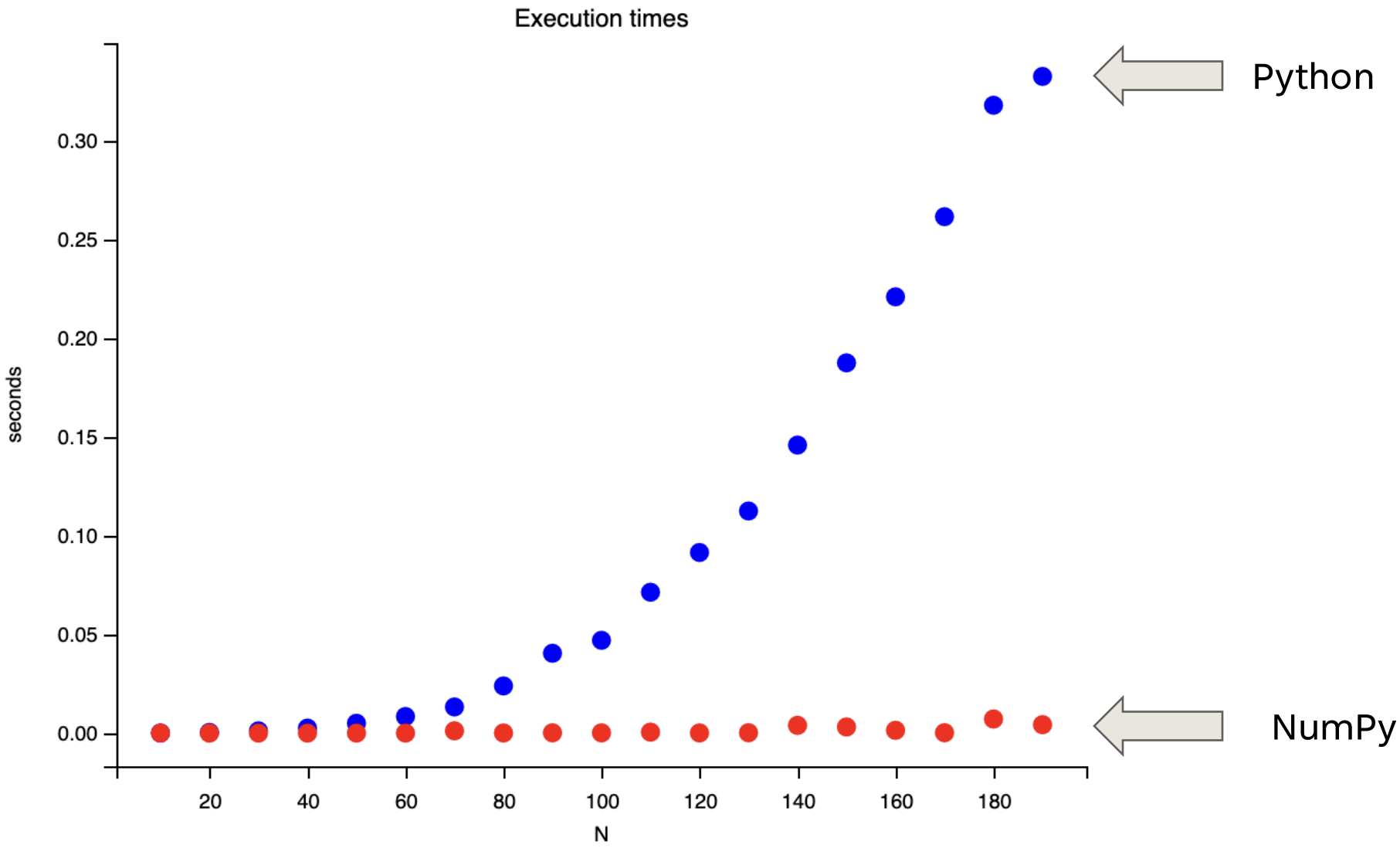
```
for i in range(n):
    for j in range(n):
        C = sum(A[i][k] * B[k][j] for k in range(n))
```

Python with NumPy version

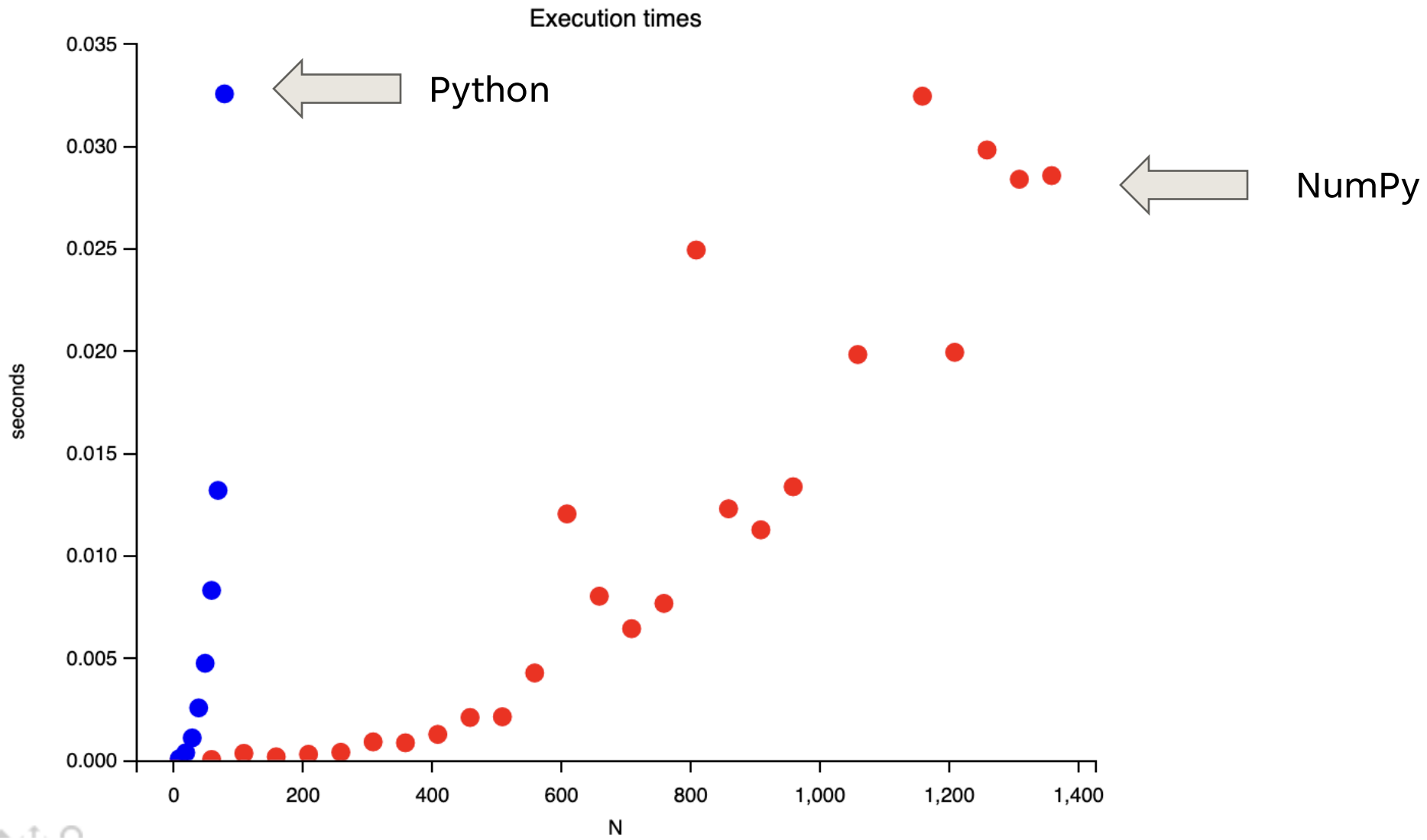
```
A_np = np.random.rand(n, n)
B_np = np.random.rand(n, n)
```

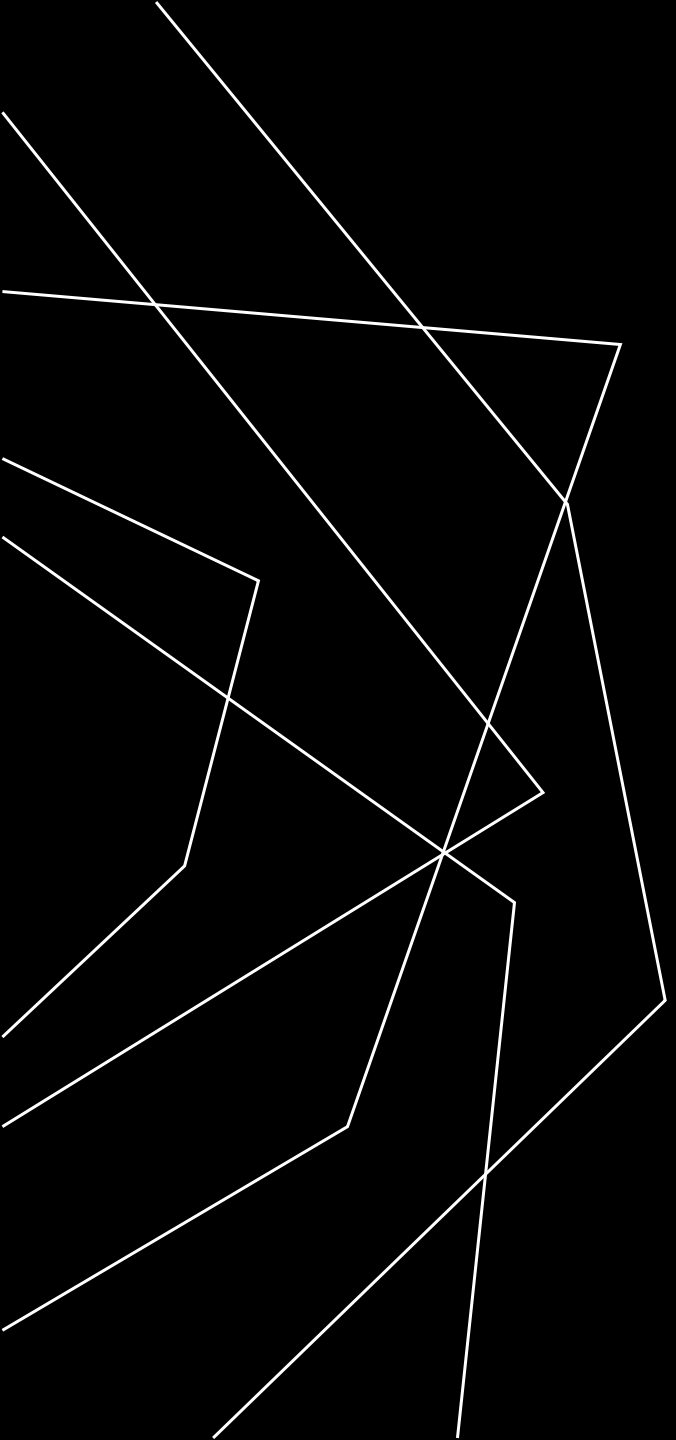
```
C_np = np.dot(A_np, B_np)
```

NUMPY DESTROYS PYTHON MATRIX MULT



NUMPY DESTROYS PYTHON MATRIX MULT





THANK YOU

David Harrison

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