CS 260: Foundations of Data Science

Prof. Thao Nguyen

Fall 2025

HAVERFORD
COLLEGE

Materials by Sara Mathieson

Admin

- **Roster** should hopefully be finalized by end of week
- **Lab 1** due Tuesday night
- **TA hours** begin tonight (8-10pm in H204)

Linux Boot Camp for CS Courses

New to Linux?
Get the basics under your belt!

MONDAY, 09/08/2025, 6 – 7:30
WEDNESDAY, 09/10/2025, 6 – 7:30
FRIDAY, 09/12/2025, 6 – 7:30 PM

All in H110

Note-cards from Tuesday

- **Practice problems and group work**: many people mentioned these – will try to have every class
- **Visualizations and analogies:** several people mentioned these – I will try!
- **Access to myself and TAs**: some people mentioned this – hours are on the webpage
  - Can schedule meeting with me outside office hours

Introductions

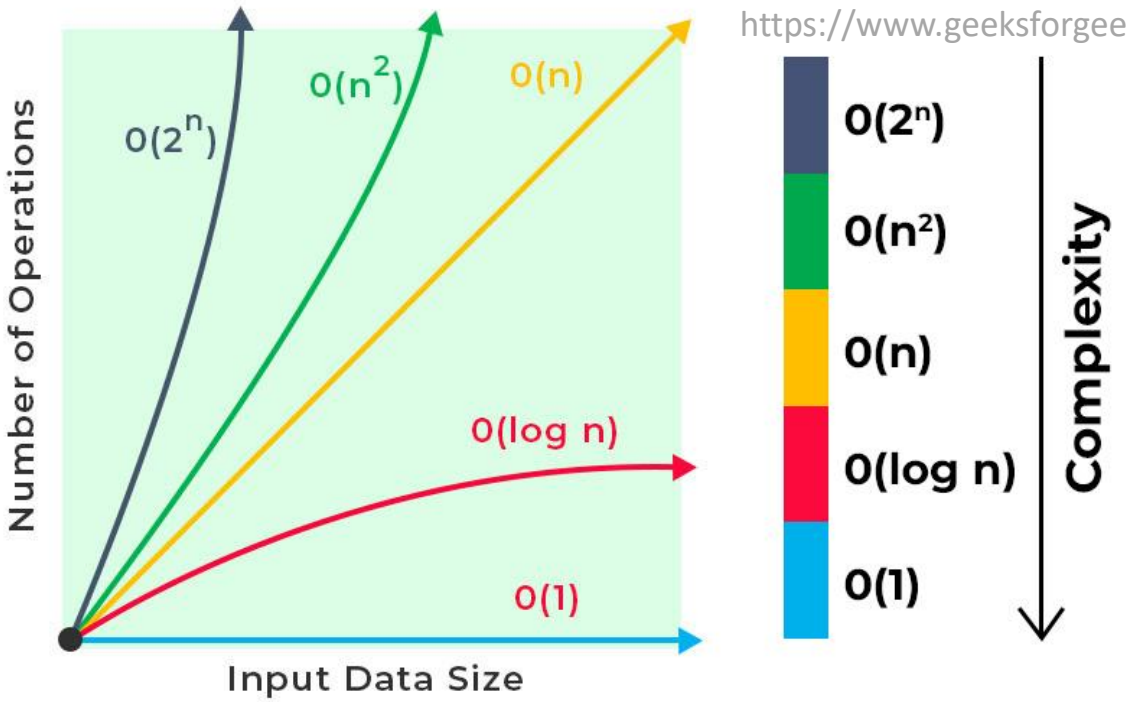
(if you could be a data scientist for any type of data, what would it be?)

Algorithm Runtime/Big-O notation Review

- Largely dependent on the number of data points and data structures in use
- Constant time operations (**O(1)**): accessing values in an array, dictionary, etc.
- Iterating through n items: **O(n)**
- Sequential steps: **add** their runtime
- Nested operations: **multiply** their runtime
- Big-O notation: ignore scalars and small terms, assume worst case

Big-O notation Practice

- What is the big-O runtime of:
  - Dividing a number n by 10 until we get 1
  - Guessing an n-digit password



Outline for today

- Object-oriented programming (OOP) in Python
- Reading in data in Python
- Numerical Python (numpy)
- If time: begin data representation

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Classes in Python represent the same idea as classes in Java

- Classes allow us to encapsulate common data structures and actions so we don’t have to define them over and over again
- Example: say we have two classes: **Point** and **Circle**

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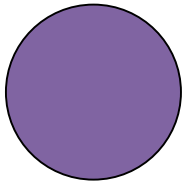
dot = Circle(Point(x,y), r)



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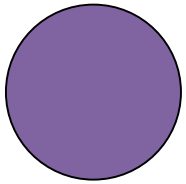

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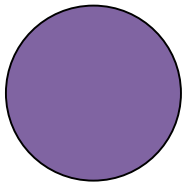
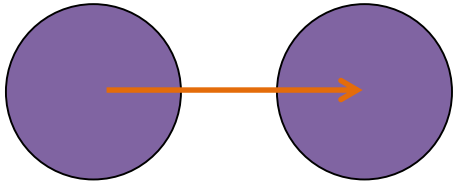


- We can access the instance's data using *methods*

```
r = dot.get_radius()
```

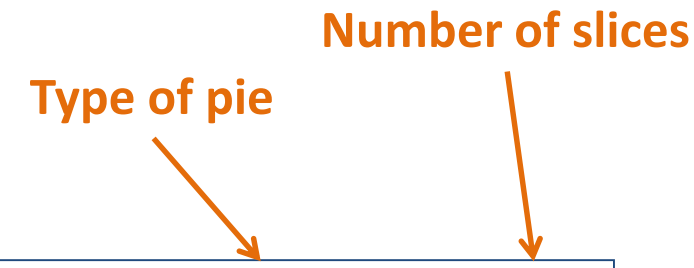
- We can use/modify class instances using *methods*

```
dot.move(dx,dy)
```



Motivation for classes: LOLs

- List-of-lists let us keep track of things that should be "together", but they get cumbersome to modify:




```
>>> pie_lst = [["apple",8], ["cherry",8], ["chocolate",8]]
>>>
>>> pie_lst[2][1] -= 1
>>>
>>> pie_lst
[['apple', 8], ['cherry', 8], ['chocolate', 7]]
```

Motivation for classes: encapsulation and abstraction

- Neither encapsulated (data for one student is spread over multiple objects), nor abstract

```
name_lst = ["Kendre", "Rohan", "Ayaka", "Maleyah"]
year_lst = [2020, 2021, 2020, 2021]
name = name_lst[0]
year = year_lst[0]
```

Motivation for classes: encapsulation and abstraction

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- Encapsulated (student is represented as one thing, a list), but not abstract

```
kendre = ["Kendre", 2020, ["cs35","act1","relg43","span1"]]
name = kendre[0]
year = kendre[1]
```

Motivation for classes: encapsulation and abstraction

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name_lst = ["Kendre", "Rohan", "Ayaka", "Maleyah"]
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- Encapsulated (student is represented as one thing, a list), but not abstract

```
kendre = ["Kendre", 2020, ["cs35","act1","relg43","span1"]]
name = kendre[0]
year = kendre[1]
```

- Both abstract and encapsulated

Should be:
get_name()
get_year()

```
kendre = Student("Kendre", 2020)
name = kendre.getName()
year = kendre.getYear()
```

Advantages of encapsulation/abstraction

- Interface (how you interact with something) is consistent even if the internal details change.

  1) If you change the engine in your car, you still drive it the same way – don't need to know how the engine works.

  2) In online shopping you have a "Cart", which is an abstract concept and is roughly the same across sites. Probably represented as a list underneath but user doesn't need to know.

“Pie” class example

```
class Pie: # class names should be capitalized

    # must use init for the constructor
    def __init__(self, flavor):
        """Constructor for the Pie class."""
        # in the constructor, define the data (i.e. self.data)
        # data are called: attributes or instance variables
        self.flavor = flavor
        self.slices = 8

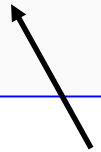
    def get_slices(self):
        """Return the number of slices left (int)."""
        return self.slices

    def get_flavor(self):
        """Return the flavor of the pie (str)."""
        return self.flavor
```

“Pie” class example

```
def serve(self):
    """If there is at least one slice left, reduce the number of slices."""
    if self.slices > 0:
        print("Here is a slice of %s pie!" % self.flavor)
        self.slices -= 1
    else:
        print("Sorry, there is no more %s pie!" % self.flavor)

def __str__(self):
    """Return a string representation of a pie."""
    s = "%s pie has %i slices left!" % (self.flavor, self.slices)
    return s
```



better to use: f“{self.flavor} pie has {self.slices} left!”

“Pie” class example

```
def main():
    pie1 = Pie("apple")
    print(pie1) # __str__ is automatically called when we call print(..)
    for i in range(12):
        pie1.serve()
    print(pie1.get_slices())
    print(pie1.get_flavor())
    print(pie1)

    pie2 = Pie("pumpkin")
    print(pie2)
    pie2.serve()
    print(pie2)
```

```
apple pie has 8 slices left!
Here is a slice of apple pie!
Here is a slice of apple pie!
Here is a slice of apple pie!
Here is a slice of apple pie!
Here is a slice of apple pie!
Here is a slice of apple pie!
Here is a slice of apple pie!
Here is a slice of apple pie!
Sorry, there is no more apple pie!
Sorry, there is no more apple pie!
Sorry, there is no more apple pie!
Sorry, there is no more apple pie!
0
apple
apple pie has 0 slices left!
pumpkin pie has 8 slices left!
Here is a slice of pumpkin pie!
pumpkin pie has 7 slices left!
```

TwitterUser class

```
class TwitterUser: # only time camel case is okay!

    # constructor
    def __init__(self, name, curr_following, curr_followers):
        self.name = name
        self.following = curr_following
        self.followers = curr_followers

    def add_follower(self): # always have to use self!
        self.followers += 1
        # TODO we could make this better by creating a list of followers who
        # are themselves instances of TwitterUser

    def follow(self):
        self.following += 1

    def __str__(self):
        # must return a string, not print a string!
        return "name: %s\nnum following: %i\nnum followers: %i" % (self.name, \
            self.following, self.followers)
```

Handout 2

- Find and work with a partner

Recap Die class

- Defining the Constructor: builds an instance of the class (self), and initializes all instance variables (self.xxx)

```
class Die:

    def __init__(self, num_sides):
        """Construct a new die with the given number of sides."""
        self.sides = num_sides
        self.value = 1 # default starting value
```

Recap Die class

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class Die:

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```

- Using the Constructor: assign the new object to a variable, making the "self" placeholder a concrete instance

```
def main():
    # create 8-sided dice
    die1 = Die(8)
    die2 = Die(8)
```

Recap Die class

- Defining Methods: always use “self” as the first argument (placeholder for the instance). Getters are a type of method that return instance variables or their derivatives.

```
def getValue(self):
    """Getter for the die's current value."""
    return self.value

def roll(self):
    """Choose a new random value for the die, i.e. roll it."""
    self.value = random.randrange(1,self.sides+1)
```

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```

- Using Methods: instance.method(…), don't use self

```
# roll both until we get the same value
same = False
while not same:
    die1.roll()
    die2.roll()
    print(die1)
    print(die2)
    print()
    # check if the values are the same
    same = (die1.getValue() == die2.getValue())
```

Recap Die class

- Defining the __str__ method: no print(..) statements! Build and return a single string. (no arguments besides self)

```
def __str__(self):
    """String representation of the die (with current value)."""
    return "%d-sided die, current value: %d" % (self.sides, self.value)
```

Recap Die class

- Defining the __str__ method: no print(..) statements! Build and return a single string. (no arguments besides self)

```
def __str__(self):
    """String representation of the die (with current value)."""
    return "%d-sided die, current value: %d" % (self.sides, self.value)
```

- Using the __str__ method: simply call print(instance)!

```
print(die1)
print(die2)
```

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```
# open(..) returns a file object (called an TextIOWrapper but think: file)
c_file = open("colleges.txt", 'r') # 'r' for read, 'w' for write

enroll_lst = []

# one way to read a file: loop through each line of the file
for line in c_file:
    # split breaks up the line on spaces, it is a method that returns a list
    tokens = line.split()

    # extract information from specific tokens
    name = tokens[0]
    enroll = int(tokens[1])
    enroll_lst.append(enroll)

# always remember to close your files!
c_file.close()
```

colleges.txt

```
Amherst 1792
Bates 1792
Bowdoin 1806
BrynMawr 1709
Colby 1815
Davidson 1950
HarveyMudd 735
Haverford 1290
Middlebury 2526
Pomona 1663
Reed 1411
Smith 2600
Swarthmore 1620
Vassar 2450
Wellesley 2474
Williams 2099
```

Example of reading in data

File reading demo

```
import csv
import numpy as np

# 1) read line by line
fb_file = open("data/facebook_users.csv", 'r') # 'r' for read mode
for line in fb_file:
    tokens = line.split(",") # split on comma
    year = int(tokens[0])
    num_users = int(tokens[1])
    print(year, num_users)
fb_file.close()

# 2) csv reader
with open("data/facebook_users.csv", 'r') as fb_file:
    csv_reader = csv.reader(fb_file)
    for line in csv_reader:
        print(line)

# 3) load into numpy array
data = np.loadtxt("data/facebook_users.csv", dtype=int, delimiter=",")
print(data)
```

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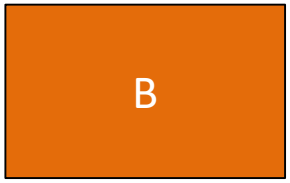
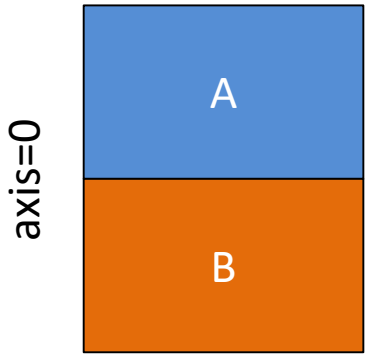
Numpy

- Numerical Python
- Designed for fast computation on arrays
- Implemented in C underneath
- **pip3 install numpy** (on the terminal) OR
  python3 –m pip install numpy

Numpy concatenation

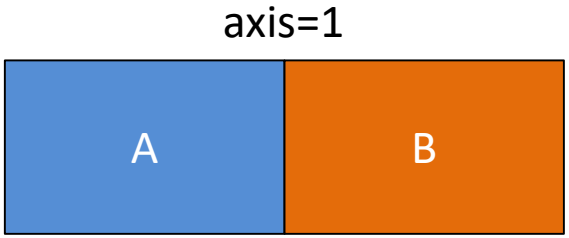


np.concatenate((A,B), axis=0)



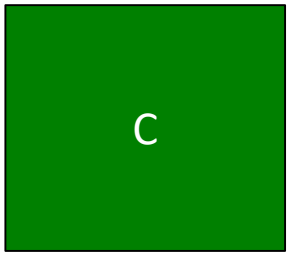
must match along axis 1

np.concatenate((A,B), axis=1)

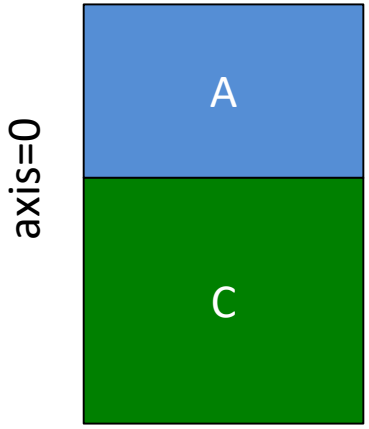


must match along axis 0

Numpy concatenation



np.concatenate((A,C), axis=0)



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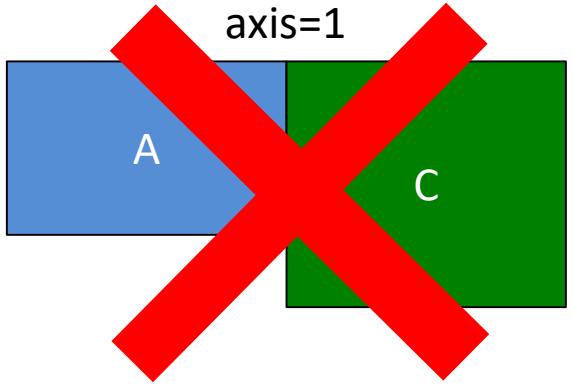

Error: must match along axis 0!

Numpy concatenation example

```
a = [[3,4,2],[7,8,9],[2,1,0]]
b = [[4,9,7],[3,0,1],[3,8,4]]

a_arr = np.array(a)
b_arr = np.array(b)
```

```
>>> a_arr
array([[3, 4, 2],
       [7, 8, 9],
       [2, 1, 0]])
>>> b_arr
array([[4, 9, 7],
       [3, 0, 1],
       [3, 8, 4]])
```

```
>>> many_rows = np.concatenate((a_arr,b_arr), axis=0)
>>>
>>> many_rows
array([[3, 4, 2],
       [7, 8, 9],
       [2, 1, 0],
       [4, 9, 7],
       [3, 0, 1],
       [3, 8, 4]])
```

```
>>> many_rows.shape
(6, 3)
>>> many_cols.shape
(3, 6)
```

```
>>> many_cols = np.concatenate((a_arr,b_arr), axis=1)
>>>
>>> many_cols
array([[3, 4, 2, 4, 9, 7],
       [7, 8, 9, 3, 0, 1],
       [2, 1, 0, 3, 8, 4]])
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Data Representation