Computational Structures in Data Science

Lecture 5
Higher Order Functions

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Announcements

- Do watch Ed for announcements
  - Please remember to pick the best category when asking questions
  - Use the Python code option
- CSM Sections
  - https://edstem.org/us/courses/44119/discussion/3397312
- Alternate Midterm/Final Exams
  - https://edstem.org/us/courses/44119/discussion/3416965
-

More OH and Staff Coming Soon!

- **Welcome, Christy, Liliana, Ananyaa – Tutors starting soon. ☺**

Reminders:

https://go.c88c.org/chat - use for fun / retail time discussion

https://go.c88c.org/qa5/ - Use during lecture!

https://go.c88c.org/5 - self check (after lecture)

Computing In the News

iPhone Users Update Your iPhones

https://apnews.com/article/apple-iphone-security-update-0964e8bd5264e5b66c3908d49fdf404a

- More warning than news, but software can be vulnerable!
- Attacks like these known as "zero-click" as particularly dangerous because they require no action on your part. Someone can simply send you a malicious image over iMessage.
- In other news, it's new iPhone day tomorrow. Yay for rampant consumerism!
- If stories like this are interesting, consider CS161 (Security), or CS195 (Social Implications)

Computational Structures in Data Science

List Comprehensions

Learning Objectives

- List comprehensions let us build lists "inline".
- List comprehensions are an *expression that returns a list.*
- We can easily “filter” the list using a conditional expression, i.e. `if`

Data-driven iteration

- describe an expression to perform on each item in a sequence
- let the data dictate the control
- In some ways, nothing more than a concise for loop.
- Always returns a list!

```
[ <expr with loop var> for <loop var> in <sequence expr > ]
```

```
[ <expr with loop var> for <loop var> in <sequence expr >
if <conditional expression with loop var> ]
```

List Comprehensions vs for Loops

- List comprehensions always return a list!
- For loops do not return anything.

```
my_data = []
for item in range(10):
    my_data.append(item)
my_data

# or
my_data = [ item for item in range(10) ]
```

Demo!

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Higher Order Functions

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Learning Objectives

- Learn how to use and create higher order functions:
- Functions can be used as data
- **Functions can accept a function as an argument**
- Functions can return a new function

Code is a Form of Data

- Numbers, Strings: All kinds of data
- Code is its own kind of data, too!
- Why?
    - More expressive programs, a new kind of abstraction.
    - "Encapsulate" logic and data into neat packages.
- This will be one of the trickier concepts in CS88.

What is a Higher Order Function?

- A function that takes in another function as an argument

OR

- A function that returns a function as a result.

Brief Aside: `import`

- Python organizes code in modules
  - These functions come with Python, but you need to "import" them.
- `import module_name`
  - gives us access to `module_name` and `module_name.x`
- `import module_name as my_module`
  - can access `my_module` and `my_module.x` (same code, just a different name)
- `from module_name import x, y, z`
  - can only access the functions we import. `x` is `my_module.x`

```
from math import pi, sqrt
from operator import mul
```

An Interesting Example

$$\sum_{k=1}^{5} k = 1 + 2 + 3 + 4 + 5 \qquad = 15$$

$$\sum_{k=1}^{5} k^3 = 1^3 + 2^3 + 3^3 + 4^3 + 5^3 \qquad = 225$$

$$\sum_{k=1}^{5} \frac{8}{(4k-3)\cdot(4k-1)} = \frac{8}{3} + \frac{8}{35} + \frac{8}{99} + \frac{8}{195} + \frac{8}{323} \qquad = 3.04$$

Why Higher Order Functions?

- We can sum 1 to N easily enough.
- We can sum 1 to N^2 easily enough too.
- Or we can sum, 1 to N^3…
- But why write so many functions?

Why not write *one function(!)* which allows us flexibility in solving many problems?

A Generic Sum Function

```
def summation(n, term):
    """Sum the first N terms of a sequence.
    >>> summation(5, cube)
    225
    >>> summation(5, identity)
    15
    >>> summation(10, identity)
    55
    """
    total = 0
    for i in range(n + 1):
        total = total + term(i)
    return total
```

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Higher Order Functions

Learning Objectives

- Learn how to use and create higher order functions:
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- **Functions can return a new function**

Review: What is a Higher Order Function?

- A function that takes in another function as an argument

OR

- **A function that returns a function as a result.**

Higher Order Functions

- **A function that returns (makes) a function**

```
def leq_maker(c):
    def leq(val):
        return val <= c
    return leq
```

```
>>> leq_maker(3)
<function leq_maker.<locals>.leq at 0x1019d8c80>


>>> leq_maker(3)(4)
False

>>> [x for x in range(7) if leq_maker(3)(x)]
[0, 1, 2, 3]
```

Demo

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Environments & Higher Order Functions

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Example: compose

- Python Tutor: http://pythontutor.com/composingprograms.html#code=def%20square%28x%29%3A%0A%20%20%20%20return%20x%20*%20x%0A%20%20%20%20%0As%20%3D%20square%0Ax%20%3D%20s%283%29%0A%0Adef%20make_adder%28n%29%3A%0A%20%20%20%20def%20adder%28k%29%3A%0A%20%20%20%20%20%20%20%20%20%2

Environment Diagrams

- Organizational tools that help you understand code
- **Terminology:**
  - **Frame:** keeps track of variable-to-value bindings, each function call has a frame
  - **Global Frame:** global for short, the starting frame of all python programs, doesn’t correspond to a specific function
  - **Parent Frame:** The frame of where a function is defined (default parent frame is global)
  - **Frame number:** What we use to keep track of frames, f1, f2, f3, etc
  - **Variable** vs **Value**: x = 1. x is the **variable**, 1 is the **value**

Environment Diagrams Steps

1. Draw the global frame
2. When evaluating assignments (lines with single equal), always evaluate right side first
3. When you call a function MAKE A NEW FRAME!
4. When assigning a primitive expression (number, boolean, string) write the value in the box
5. When assigning anything else, draw an arrow to the value
6. When calling a function, name the frame with the intrinsic name – the name of the function that variable points to
7. The parent frame of a function is the frame in which it was defined in (default parent frame is global)
8. If the value isn’t in the current frame, search in the parent frame

Environment Diagram Tips / Links

- NEVER EVER draw an arrow from one variable to another.
- Useful Resources:
  - http://markmiyashita.com/cs61a/environment_diagrams/rules_of_environment_diagrams/
  - http://albertwu.org/cs61a/notes/environments.html