Week 3: HOFs
Announcements

• Watch Ed for announcements
  – One form all assignment extensions
  – *Please don’t fill this out for slip days.*
  – If you need up to 3 days, just submit late. 😊

• CSM sections are out tomorrow
  – Totally optional, but lots of good prep.
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.

[ <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> ]
Demo!
Computational Structures in Data Science

Higher Order Functions
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`

```python
from math import pi, sqrt
from operator import mul
```
An Interesting Example

\[
\begin{align*}
\sum_{k=1}^{5} k &= 1 + 2 + 3 + 4 + 5 = 15 \\
\sum_{k=1}^{5} k^3 &= 1^3 + 2^3 + 3^3 + 4^3 + 5^3 = 225 \\
\sum_{k=1}^{5} \frac{8}{(4k-3)(4k-1)} &= \frac{8}{3} + \frac{8}{35} + \frac{8}{99} + \frac{8}{195} + \frac{8}{323} = 3.04
\end{align*}
\]
Computational Structures in Data Science

Higher Order Functions
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
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

```python
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]
```
Environments & Higher Order Functions
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
Example: compose

- Python Tutor:
  http://pythontutor.com/composingprograms.html#code=def%20square%28x%29: return%20x*x
def%20make_adder%28n%29: def%20adder%28k%29: return%20adder%28k%29%20%2B%20adder%28k%20%2B%201%29

UC Berkeley | Computer Science 88 | Michael Ball | http://cs88.org
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://albertwu.org/cs61a/notes/environments.html