UC Berkeley EECS
Lecturer
Michael Ball

Computational Structures in Data Science

Week 3: HOFs

Announcements

- Guest Lecture from Head TA Shreya on Wednesday!
  - It's going to be great.

"AI Can Now Write Its Own Computer Code. That's Good News for Humans."

The New York Times Cade Metz September 9, 2021

Experts suggest new artificial intelligence (AI) technology that can write its own programs poses no threat to coders' jobs, and may enhance human productivity. Research laboratory OpenAI trained its Codex system on a massive dataset of prose and code so users can ask the system in plain English to write programs that perform specific functions; it can write programs in 12 computer languages and translate between them, although it is highly error-prone and cannot think on its own. According to OpenAI, Codex generates correct code 37% of the time, which makes it useful only to seasoned coders. Tom Smith of AI startup Gado Images said Codex could help train a new generation of programmers, as well as helping accelerate everyday tasks by directing them to basic coding elements or toward new concepts.

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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!

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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.

An Interesting Example

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

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

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

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
```

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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

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%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%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