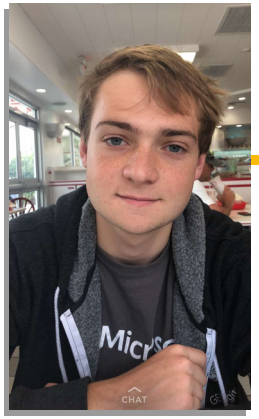
Computational Structures in Data Science



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Subbing for Michael while he's in Germany⏪

Lecture #3: Higher Order Functions & Environment Diagrams

Announcements!

- Tutoring
  - Sign up for computer science mentor sections – super helpful and a great way to get EPA!
  - Prep for midterm – chance to practice writing code by hand
  - Link: https://scheduler.csmentors.org/
  - More Info: https://piazza.com/class/jzknkt427nz3oz?cid=131
  - Sign up for one on one tutoring through cs370:
  - More Info: https://piazza.com/class/jzknkt427nz3oz?cid=180
- Midterm:
  - October 7th 7-9pm
  - Thats two weeks away!
  - More info will be emailed out – might be a good time to start prepping!
- First project after midterm!

Computational Concepts Toolbox

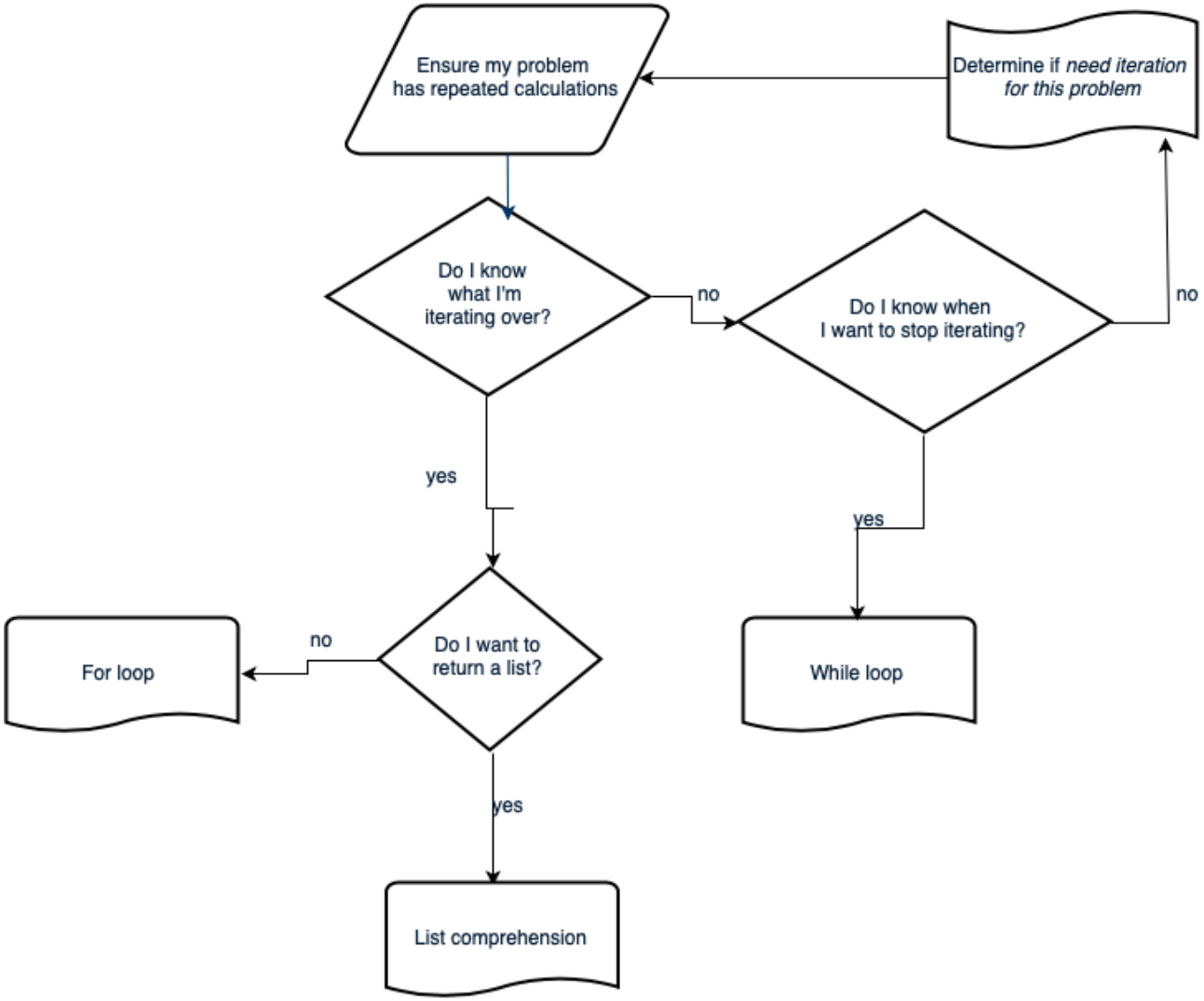
- Data type: values, literals, operations,
  - e.g., int, float, string
- Expressions, Call expression
- Variables
- Assignment Statement
- Sequences: list
- Data structures
- Call Expressions
- Function Definition Statement
- Conditional Statement
- Iteration:
  - data-driven (list comprehension)
  - control-driven (for statement)
  - while statement

Computational Concepts today

- Higher Order Functions
- Functions as Values
- Functions with functions as argument
- Functions with functions as return values
- Environment Diagrams

Big Idea: Software Design Patterns

Iteration flow chart



Control Structures Review

- **The result of** *list(range(0,10))* **is…**

  A) *[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]*
  B) *[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10]*
  C) *[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]*
  D) *[1, 2, 3, 4, 5, 6, 7, 8, 9]*
  E) an error

  http://bit.ly/88Lec3Q1

Solution:
A) *list(range(m,n))* **creates a list with elements from m to n-1.**

Control Structures Review

- **The result of** *[i for i in range(3,9) if i % 2 == 1]* **is…**

  A) *[3, 4, 5, 6, 7, 8, 9]*
  B) *[3, 4, 5, 6, 7, 8]*
  C) *[1, 3, 5, 7, 9]*
  D) *[3, 5, 7, 9]*
  E) *[3, 5, 7]*

  http://bit.ly/88Lec3Q2

Solution:
E) *[3, 5, 7]*

Control Structures Review

The result of *len([i for i in range(1,10) if i % 2 == 0)])* **is…**

A) 5
B) 4
C) 3
D) 2
E) 1

http://bit.ly/88Lec3Q3

Solution:
B) *len([2, 4, 6, 8])=4*

An Interesting Example

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

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

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

Environment Diagrams aka what python tutor makes

Environment Diagrams are 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**

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) right 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

NEVER EVER EVER draw an arrow from one variable to another.

Source:
http://markmiyashita.com/cs61a/environment_diagrams/rules_of_environment_diagrams/
http://albertwu.org/cs61a/notes/environments.html

Another example

- **Higher Order Functions**

```
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%20return%20k%20%2B%20n%0A
%20%20%20%20return%20adder%0A%20%20%20%20%0Aadd_2%20%3D
%20make_adder%282%29%0Aadd_3%20%3D%20make_adder%283%29%0Ax
%20%3D%20add_2%28x%29%0A%0Adef%20compose%28f,%20g%29%3A%0A
%20%20%20%20def%20h%28x%29%3A%0A%20%20%20%20%20%20%20%20return
%20f%28g%28x%29%29%0A%20%20%20%20return%20h%0A%0Aadd_5%20%3D
%20compose%28add_2,%20add_3%29%0Ay%20%3D%20add_5%28x%29%0A%0Az
%20%3D%20compose%28square,%20make_adder
%282%29%29%283%29&cumulative=true&mode=edit&origin=composingpr
ograms.js&py=3&rawInputLstJSON=%5B%5D
```

Higher Order Functions

- **Functions that operate on functions**
- **A function**

```
def odd(x):
    return x%2==1

odd(3)
True
```

- **A function that takes a function arg**

```
def filter(fun, s):
    return [x for x in s if fun(x)]

filter(odd, [0,1,2,3,4,5,6,7])
[1, 3, 5, 7]
```

Why is this not 'odd' ?

Higher Order Functions (cont)

- **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

>>> filter(leq_maker(3), [0,1,2,3,4,5,6,7])
[0, 1, 2, 3]
```

Three super important HOFS (Wait for lab)

* For the builtin filter/map, you need to then call list on it to get a list. If we define our own, we do not need to call list

```
list(map(function_to_apply,
list_of_inputs))
```

Applies function to each element of the list

```
list(filter(condition,
list_of_inputs))
```

Returns a list of elements for which the condition is true

```
reduce(function, list_of_inputs)
```

Reduces the list to a result, given the function

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