Computational Structures in Data Science

UC Berkeley EECS
Lecturer
Michael Ball

Lecture #6: Higher Order Functions

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Computing in the News

- Lots of discussion about facial recognition
- "The End of Privacy as We Know It?"
  - https://www.nytimes.com/2020/02/10/podcasts/the-daily/facial-recognition-surveillance.html
  - " A secretive start-up promising the next generation of facial recognition software has compiled a database of images far bigger than anything ever constructed by the United States government: over three billion, it says. Is this technology a breakthrough for law enforcement — or the end of privacy as we know it?"
- " **Facial Recognition Moves Into a New Front: Schools** "
  - https://www.nytimes.com/2020/02/06/business/facial-recognition-schools.html
  - " Lockport's Aegis software studies images of faces captured by 300 newly installed cameras and calculates whether those faces match a "persons of interest" database compiled by school administrators; if the system finds a match, it alerts security staff who vet the image for confirmation."

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iClicker Check-In

- How are you feeling about CS88 so far?

- A) It's going very well! ☺
- B) It's going good…
- C) So, so…
- D) Not so great…
- E) Terribly. ☹

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Announcements!

- **Bonus Questions in Labs**
  - **Extra practice, not just coding.**
  - **Goal is to focus on the concepts.**
    - **Different styles of questions promote different ways of thinking and synthesizing information.**
  - **Half point extra for each lab you complete, ~5 points throughout the semester. (Labs are 40 points total.)**
  - **https://codestyle.herokuapp.com/cs88-lab02**

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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**

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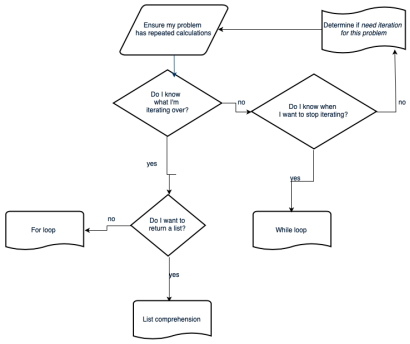
Iteration flow chart



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Computational Concepts today

- **Higher Order Functions**
  - **Functions as Values**
  - **Functions with functions as argument**
  - **Functions that *return* a function**

- In Python, we use () to *call* a function.
- We don't need to do this!

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Functions: A New Kind of Data!

Lists, Numbers, Strings: All kinds of data

Code *is its own* kind of data, too!

Why?
More expressive programs, a new kind of abstraction.

This will be one of the trickier concepts in CS88.

Big Idea: Software Design Patterns

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iClicker Question

Question: What's the result of the following?

```
def greet(name):
      print('Hello, ' + name)

hello = greet

def greet(name):
     print('Hi, ' + name)

hello('CS88')
```

A) Error
B) prints "Hello, CS88"
C) prints "Hi, CS88"
D) "I'm lost…."

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Three super important HOFS

* 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)`

Applies the function, combining items of the list into a "single" value.

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Today's Task: Acronym

```
Input: "The University of California at
Berkeley"

Output: "UCB"

def acronym(sentence):
     """YOUR CODE HERE"""
```

P.S. Pedantry alert: This is really an *initialism* but that's rather annoying to say and type. ☺ (However, the code we write is the same, the difference is in how you pronounce the result.) The more you know!

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MAP

`list(map(function_to_apply, list_of_inputs))`

Transform each of items by a function.
e.g. square()
Inputs (Domain):
- Function
- Sequence

Output (Range):
- A sequence

```
def map(function, sequence):
    return [ function(item) for item in sequence ]
```


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What does this do?

```
list(map(capitalize,
    ['michael', 'Alex', 'Srinath', 'julia']
))

Assume capitalize('michael') == 'Michael'
```

A) `['michael', 'Alex', 'Srinath', 'julia']`
B) `['Michael', 'Alex', 'Srinath', 'Julia']`
C) []
D) Error
E) I'm lost.

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FILTER

`list(filter(function, list_of_inputs))`

Keeps each of item where the function is true.

Inputs (Domain):
- Function
- Sequence

Output (Range):
- A sequence

```
def filter(function, sequence):
    return [ item for item in sequence if function(item) ]
```


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What does this do?

```
list(filter(return_false,
    range(100)
))

Assume return_false(42) == False
```

A) `range(0, 100) # A standard range object`
B) `[0, 1, 2, … 96, 97, 98, 99]`
C) []
D) Error
E) I'm lost.

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REDUCE

`reduce(function, list_of_inputs)`

Successively **combine** items of our sequence
- function: add(), takes 2 inputs gives us 1 value.

Inputs (Domain):
- Function, with 2 inputs
- Sequence

Output (Range):
- An item, specifically, the output of our function.

```
def reduce(function, sequence):
    result = function(sequence[0], sequence[1])
    for index in range(2, len(sequence)):
        result = function(result, sequence[index])
    return result
```


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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' ?

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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]
```


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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