CSCI 141

Lecture 16

How to approach A4, or:
Managing Complexity with Functions

Tuples
Announcements
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• Midterm grades should be out by the end of the weekend.
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• I'm working my way through the mid-quarter eval feedback. I'll discuss findings on Monday.
Goals

• Understand the task assigned in A4 and how to approach it.

• Understand how to use function composition to express complicated computations as clearly and simply as possible.

• Understand the basic usage of tuples:
  • using tuples to return multiple values from a function
  • packing and unpacking via the assignment operator
First: An Apology

Last lecture, I told you a lie.
First: An Apology

[Image: A woman wearing a headscarf with the text "SHAME, SHAME, SHAME" superimposed.]
How to Execute Function Calls

If multiple variables exist with the same name, use the **innermost** one available.

1. Evaluate all arguments
2. Draw a local "box" **inside** the current "box"
3. Assign argument values to parameter variables in the local box
4. Execute the function body
5. When done, erase the local box
How to Execute Function Calls

1. Evaluate all arguments
2. Draw a local "box" inside the global one*
3. Assign argument values to parameter variables in the local box
4. Execute the function body
5. When done, erase the local box

If multiple variables exist with the same name, use* the innermost one available.
How to Execute Function Calls

If multiple variables exist with the same name, use* the innermost one available.

*Global variables can be read but not modified unless you mark them as such using global var_name at the top of the function definition.

In this course, we will never modify global variables from inside a function and will only rarely read them.

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How to Execute Function Calls

1. Evaluate all arguments
2. Draw a local "box" inside the global one*
3. Assign argument values to parameter variables in the local box
4. Execute the function body
5. When done, erase the local box

*Unless the function is defined inside another function or class. This won't happen in this course.

If multiple variables exist with the same name, use* the innermost one available.

*Global variables can be read but not modified unless you mark them as such using global var_name at the top of the function definition.

In this course, we will never modify global variables from inside a function and will only rarely read them.
How did Scott get this wrong?
How did Scott get this wrong?

No excuses! Shame!

SHAME, SHAME, SHAME
How did Scott get this wrong?
How did Scott get this wrong?

“Your scientists were so preoccupied with whether they could that they didn't stop to think if they should.”

-Dr. Ian Malcom (Jurassic Park)
How did Scott get this wrong?

Your professor was so accustomed to doing what you **should** that he lost track of the details of what you **could**.

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How did Scott get this wrong?

Your professor was so accustomed to doing what you should that he lost track of the details of what you could.
How did Scott get this wrong?

The specification of the Python language says:
• You **can** access variables that are not local to the function.

Conventional software engineering wisdom says:
• You **should not** access variables that are not local to the function.

Your professor was so accustomed to doing what you **should** that he lost track of the details of what you **could**.
How did Scott get this wrong?

The specification of the Python language says:
• You can access variables that are not local to the function.

Conventional software engineering wisdom says:
• You should not access variables that are not local to the function.

**Bottom line:** If your function needs a piece of data, that data should be passed in as an argument.
Why is accessing globals bad?

- The function's behavior becomes unpredictable, because it depends on global state.
- "Pure" functions are ideal: the output is fully determined by the inputs.

**Bottom line:** If your function needs a piece of data, that data should be passed in as an argument.
Which of the following belongs in a function's docstring? Select all that apply.

- Preconditions
- Postconditions
- The steps that the function takes to accomplish its task
- Information about any side-effects the function has
- Information about what arguments the function takes
One more modification

To execute a function call:

1. Evaluate all arguments
2. Draw a local "box" inside the global one
3. Assign argument values to parameter variables in the local box
4. Execute the function body
5. When done, erase the local box

We now know how to return a value - what does Python do with it?
One more modification

To execute a function call:

1. Evaluate all arguments
2. Draw a local "box" inside the global one
3. Assign argument values to parameter variables in the local box
4. Execute the function body
5. When done, erase the local box
6. Replace the function call with its return value

We now know how to return a value - what does Python do with it?
To execute a function call:

1. Evaluate all arguments
2. Draw a local "box" inside the global one
3. Assign argument values to parameter variables in the local box
4. Execute the function body
5. When done, erase the local box
6. Replace the function call with its return value

What does this program print?

```
x = 4

def f(x):
    return 3 * x
def g(x):
    return x + 2

print(f(g(x)))
print(g(f(x)))
```
Your task: Draw this.
# Let p be a random point in the window
# loop 10000 times:
#     c = a random corner of the triangle
#     m = the midpoint between p and c
#     choose a color for m
#     color the pixel at m
#     p=m
A4: Pseudocode

# Let p be a random point in the window
# loop 10000 times:
#   c = a random corner of the triangle
#   m = the midpoint between p and c
#   choose a color for m
#   color the pixel at m
#   p=m

Demo: break this down into manageable pieces by inventing functions that solve pieces of the problem!
# Let p be a random point in the window
# loop 10000 times:
#   c = a random corner of the triangle
#   m = the midpoint between p and c
#   choose a color for m
#   color the pixel at m
#   p=m
def midpoint(p1x, p1y, p2x, p2y):
    """ Return the midpoint between (p1x, p1y) and (p2x, p2y) """
    # code here
def midpoint(p1x, p1y, p2x, p2y):
    """ Return the midpoint between (p1x, p1y) and (p2x, p2y) """

    # code here
def midpoint(p1x, p1y, p2x, p2y):
    """ Return the midpoint between (p1x, p1y) and (p2x, p2y) """
    # code here
    (mid_x, mid_y)
def midpoint(p1x, p1y, p2x, p2y):
    """Return the midpoint between (p1x, p1y) and (p2x, p2y)"
    """
    # code here

(mid_x, mid_y)

This is two things!? Can we return two things?
def midpoint(p1x, p1y, p2x, p2y):
    """ Return the midpoint between (p1x, p1y) and (p2x, p2y) """
    # code here

(mid_x, mid_y)

This is **two** things!?
Can we return two things?
def midpoint(p1x, p1y, p2x, p2y):
    """ Return the midpoint between (p1x, p1y) and (p2x, p2y) """
    # code here
    # mid_x = . . .
    # mid_y = . . .
    return mid_x, mid_y
Returning Multiple Values

• You can return multiple values from a function by grouping them into a comma-separated sequence:
  
  ```
  return mid_x, mid_y
  ```

• You can assign each to a variable when calling the function:
  
  ```
  mx, my = midpoint(p1x, p1y, p2x, p2y)
  ```
These are actually **tuples**

- A tuple is a sequence of values, optionally enclosed in parens.
  
  \[(1, 4, "Mufasa")\]

- You can “pack” and “unpack” them using assignment statements:

  \[v = (1, 4, "Mufasa") \# \text{packing}\]
  
  \[(a, b, c) = v \# \text{"unpacking"}\]
These are actually **tuples**

- Tuples can also be passed *into* functions as arguments:

```python
def midpoint(p1, p2):
    """Compute the midpoint between p1 and p2"""
    p1x, p1y = p1
    p2x, p2y = p2

    # . . .
    # return mx, my
```
Tuples: Demo
Tuples: Demo

• assignment, packing, unpacking

• with and without parens (printing)

• swapping

• equality

• mismatched # values to unpack
Tuples - 1

```python
a = 1
b = 2
c = 3

v = (a, a, c)

print(v, sep=" ")
```

# What does this print?
# A: 1 2 3
# B: 1 1 3
# C: (1, 2, 3)
# D: (1, 1, 3)
Tuples - 2

a = 1
b = 2
c = 3

a, b, c = (a, a, c)

print(a, b, c, sep=" ")

# What does this print?
# A: 1 2 3
# B: 1 1 3
# C: (1, 2, 3)
# D: (1, 1, 3)
def midpoint(p1x, p1y, p2x, p2y):
    """ Return the midpoint between (p1x, p1y) and (p2x, p2y) """
    # code here
    # mid_x = . . .
    # mid_y = . . .

    return mid_x, mid_y
Midpoint Function

# mid_x = . . .
# mid_y = . . .

Okay, but how do you actually calculate this?

(p2_x, p2_y)

(mid_x, mid_y)

(p1_x, p1_y)
Midpoint Function

# mid_x = . . .
# mid_y = . . .

Okay, but how do you actually calculate this?

\[(p_{2x}, p_{2y})\]

\[(p_{1x}, p_{1y})\]

\[(\text{mid}_x, \text{mid}_y)\]

\[\text{mid}_y\]
Midpoint Function

# mid_x = . . .
# mid_y = . . .

Okay, but how do you actually calculate this?

(p1_x, p1_y)

(mid_x, mid_y)

(p2_x, p2_y)

mid_x

mid_y
Midpoint Function

# mid_x = . . .
# mid_y = . . .
Okay, but how do you actually calculate this?

(on the board)
Midpoint Function

# mid_x = . . .
# mid_y = . . .

Okay, but how do you actually calculate this?

(mid_x, mid_y)

(p1_x, p1_y)            (p2_x, p2_y)

(mid_x, mid_y)        mid_y

mid_x = (p1_x + p2_x) / 2
mid_y = (p1_y + p2_y) / 2

(on the board)
Demo: writing the midpoint function

- With tuple as return value
- Switch to tuples as parameters for points
# Let p be a random point in the window
# loop 10000 times:
#     c = a random corner of the triangle
#     m = the midpoint between p and c
#     choose a color for m
#     color the pixel at m
#     p=m

Color is chosen based on distance from each corner.
(details on the handout)

Subproblem: compute the distance between two points.
Exercise: Implement This

on paper!

def distance(p1x, p1y, p2x, p2y):
    """ Return the distance between p1 and p2, which are points with coordinates (p1x, p1y) and (p2x, p2y)"""

Exercise: Implement This

on paper!

```python
def distance(p1x, p1y, p2x, p2y):
    """ Return the distance between p1 and p2, which are points with coordinates (p1x, p1y) and (p2x, p2y)"
```

Math reminder:

\[ c = \sqrt{a^2 + b^2} \]

\[ a = p2_x - p1_x \]

\[ b = p2_y - p1_y \]
def distance(p1x, p1y, p2x, p2y):
    """ Return the distance between p1 and p2, which are points with coordinates (p1x, p1y) and (p2x, p2y)"""

Math reminder:

(a, b) = (p2x - p1x, p2y - p1y)

c = \sqrt{a^2 + b^2}

b = p2y - p1y

(a, b) = (p2x - p1x, p2y - p1y)
Reminder: Docstrings, Preconditions and Postconditions

Example. Suppose you wrote this function:

```python
def split_bill(bill_amt, tip_pct, num_diners):
    """ Return the total owed by each diner for a
    restaurant bill of bill_amt, assuming a tip
    percent of tip_pct and splitting the bill
    evenly among num_diners people.
    """

    total = bill_amt + (bill_amt * tip_pct/100)
    return total / num_diners
```
Reminder: Docstrings, Preconditions and Postconditions

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```

```python
>>> split_bill(34.78, 18.0, 0)
```
Reminder: Docstrings, Preconditions and Postconditions

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    total = bill_amt + (bill_amt * tip_pct/100)
    return total / num_diners

>>> split_bill(34.78, 18.0, 0)
ZeroDivisionError: float division by zero
```
Reminder: Docstrings, Preconditions and Postconditions

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Bad news:
Reminder: Docstrings, Preconditions and Postconditions

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    total = bill_amt + (bill_amt * tip_pct/100)
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```

```python
>>> split_bill(34.78, 18.0, 0)
ZeroDivisionError: float division by zero
```

Bad news: This is your fault.
Docstrings, Preconditions and Postconditions

Example. Suppose you wrote this function:

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def split_bill(bill_amt, tip_pct, num_diners):
    """ Return the total owed by each diner for a restaurant bill of bill_amt, assuming a tip percent of tip_pct and splitting the bill evenly among num_diners people.
    """  
    # Precondition: num_diners > 0

    total = bill_amt + (bill_amt * tip_pct/100)
    return total / num_diners
```
Docstrings, Preconditions and Postconditions

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def split_bill(bill_amt, tip_pct, num_diners):
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```

"""
Docstrings, Preconditions and Postconditions

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Docstrings, Preconditions and Postconditions

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    '''
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```python
>>> split_bill(34.78, 18.0, 0)
ZeroDivisionError: float division by zero
```

This is my fault.
Function Composition

Here’s a made-up equation:

```
final_result = (a + b)**2 - d // 12 + (a**2 - 0.5*a*c) + alpha * (dx**2 + dy**2)
```
Function Composition

Here’s a made-up equation:

\[
\text{final_result} = (a + b)^2 - d \div 12 + (a^2 - 0.5a c) + \alpha \times (dx^2 + dy^2)
\]

It’s pretty incomprehensible, even if you do know what a, b, d, c, \(\alpha\), dx, and dy mean.
Function Composition

Here’s a made-up equation:

\[
\text{final_result} = (a + b)^2 - \frac{d}{12} + (a^2 - 0.5a^2) + \alpha \cdot (dx^2 + dy^2)
\]

It’s pretty incomprehensible, even if you do know what a, b, d, c, alpha, dx, and dy mean.

Here’s a nicer way to write it:
Function Composition

Here’s a made-up equation:

\[
\text{final\_result} = (a + b)^2 - d // 12 + (a^2 - 0.5 \times a \times c) + \alpha \times (dx^2 + dy^2)
\]

It’s pretty incomprehensible, even if you do know what a, b, d, c, \(\alpha\), dx, and dy mean.

Here’s a nicer way to write it:

\[
\begin{align*}
x &= (a + b)^2 - d // 12 \\
y &= (a^2 - 0.5 \times a \times c) \\
z &= \alpha \times (dx^2 + dy^2)
\end{align*}
\]

\[
\text{final\_result} = x + y + z
\]
Function Composition

Here’s a made-up equation:

$$\text{final\_result} = (a + b)^2 - \frac{d}{12} + (a^2 - 0.5a^2c) + \alpha (dx^2 + dy^2)$$

What if x, y, and z weren’t expressions, but more complicated computation requiring (for example) for loops to compute?
Function Composition

Here's a made-up equation:

\[
\text{final\_result} = (a + b)^2 - \frac{d}{12} + (a^2 - 0.5ac) + \alpha (dx^2 + dy^2)
\]

What if \(x\), \(y\), and \(z\) weren't expressions, but more complicated computation requiring (for example) for loops to compute?

```python
def calc_x(a, b, d):
    # calculation of \(x\)

def calc_y(a, c):
    # calculation of \(y\)

def calc_z(alpha, dx, dy):
    # calculation of \(z\)

x = calc_x(a, b, d)
y = calc_y(a, c)
z = calc_z(alpha, dx, dy)
final_result = x + y + z
```
Function Composition

Here’s a made-up equation:

\[
\text{final\_result} = (a + b)^2 - d \div 12 + (a^2 - 0.5*a*c) + \alpha \cdot (d^2 + dy^2)
\]

What if x, y, and z weren’t expressions, but more complicated computation requiring (for example) for loops to compute?

What if this is just an intermediate result that goes into an even larger calculation?
Function Composition

Here’s a made-up equation:

\[
\text{final\_result} = (a + b)^2 - d \div 12 + (a^2 - 0.5ac) + \alpha (dx^2 + dy^2)
\]

What if \(x\), \(y\), and \(z\) weren’t expressions, but more complicated computation requiring (for example) for loops to compute?

What if this is just an intermediate result that goes into an even larger calculation?

def calc_x(a, b, d):
    # calculation of x

def calc_y(a, c):
    # calculation of y

def calc_z(alpha, dx, dy):
    # calculation of z

x = calc_x(a, b, d)
y = calc_y(a, c)
z = calc_z(alpha, dx, dy)

intermediate\_result = x + y + z
Function Composition

Here’s a made-up equation:

```
final_result = (a + b)**2 - d // 12 + (a**2 - 0.5*a*c) + alpha * (dx**2 + dy**2)
```

What if x, y, and z weren’t expressions, but more complicated computation requiring (for example) for loops to compute?

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Function Composition

Here’s a made-up equation:

```
final_result = (a + b)**2 - d // 12 + (a**2 - 0.5*a*c) + alpha * (dx**2 + dy**2)
```

What if x, y, and z weren’t expressions, but more complicated computation requiring (for example) for loops to compute?

What if this is just an intermediate result that goes into an even larger calculation?

```python
def calc_x(a, b, d):
    # calculation of x

def calc_y(a, c):
    # calculation of y

def calc_z(alpha, dx, dy):
    # calculation of z

def calc_gamma(a,b,c,d,alpha,dx,dy):
    x = calc_x(a, b, d)
    y = calc_y(a, c)
    z = calc_z(alpha, dx, dy)
    return x + y + z
```