Lecture 9: Memory in Python

CS 1110

Introduction to Computing Using Python

Text in fusia and extra slides were added after lecture for clarification. See slides 24 - 27.

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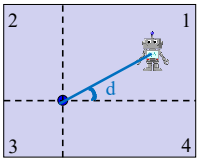
Announcements

- A1 revision process: A1 closed now on CMS for grading. Set your CMS notifications to "receive email when …" When feedback is released, expected on Mar 13 afternoon, read *re*submission instructions
- A2 to be released Thursday

Review: Nested Conditionals

Where is the robot?

- Angle of the robot relative to the sensor is d degrees, where d is non-negative
- Robot is in which quadrant?
- To avoid ambiguity, use this convention:
  - 1 if $0 \le d < 90$
  - 2 if $90 \le d < 180$
  - 3 if $180 \le d < 270$
  - 4 if $270 \le d < 360$



WARNING
Robot Operating in Quadrant **1**

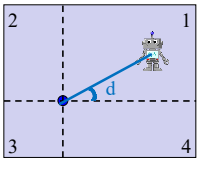
Can solve using if-elif-elif… Other options?

Nesting Conditionals

- Separate choices into 2 general categories
- Subdivide each category into subcategories
- Subdivide each subcategory further…

```
if <above x-axis>:
    if <left of y-axis>:
    else:
else:
    if <left of y-axis>:
    else:
```

See quadrants.py

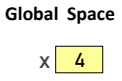


- 1 if $0 \le d < 90$
- 2 if $90 \le d < 180$
- 3 if $180 \le d < 270$
- 4 if $270 \le d < 360$

Memory in Python

Global Space

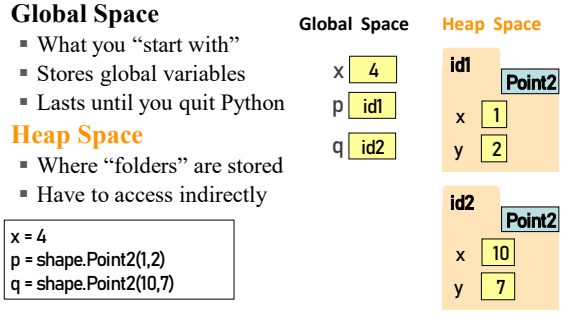
- **Global Space**
  - What you "start with"
  - Stores global variables
  - Lasts until you quit Python




```
x = 4
```

Enter Heap Space

- **Global Space**
  - What you "start with"
  - Stores global variables
  - Lasts until you quit Python
- **Heap Space**
  - Where "folders" are stored
  - Have to access indirectly



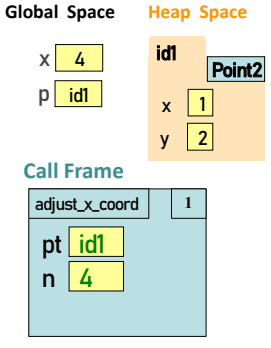

```
x = 4
p = shape.Point2(1,2)
q = shape.Point2(10,7)
```

p & q live in Global Space. Their folders live on the Heap.

Calling a Function Creates a Call Frame

What's in a Call Frame?

- Boxes for parameters **at the start of the function**
- Boxes for variables local to the function **as they are created**



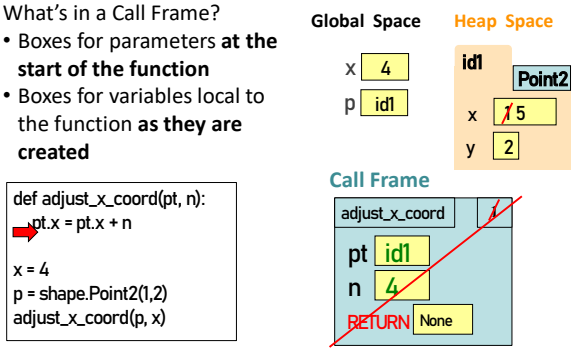

```
def adjust_x_coord(pt, n):
    pt.x = pt.x + n

x = 4
p = shape.Point2(1,2)
adjust_x_coord(p, x)
```

Calling a Function Creates a Call Frame

What's in a Call Frame?

- Boxes for parameters **at the start of the function**
- Boxes for variables local to the function **as they are created**

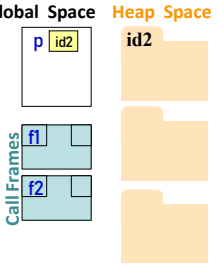



```
def adjust_x_coord(pt, n):
    pt.x = pt.x + n

x = 4
p = shape.Point2(1,2)
adjust_x_coord(p, x)
```

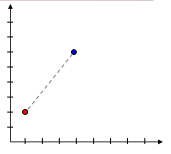
Putting it all together

- **Global Space**
  - What you "start with"
  - Stores global variables
  - Lasts until you quit Python
- **Heap Space**
  - Where "folders" are stored
  - Have to access indirectly
- **Call Frames**
  - Parameters
  - Other variables local to function
  - Lasts until function returns



Two Points Make a Line

```
start = shape.Point2(0,0)
stop = shape.Point2(0,0)
print("Where does the line start?")
x = input("x: ")
start.x = int(x)
y = input("y: ")
start.y = int(y)
print("The line starts at ("+x+","+y+").")
print("Where does the line stop?")
x = input("x: ")
stop.x = int(x)
y = input("y: ")
stop.y = int(y)
print("The line stops at ("+x+","+y+").")
```



```
Where does the line start?
x: 1
y: 2
The line starts at (1,2).
Where does the line stop?
x: 4
y: 6
The line stops at (4,6).
```

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Redundant Code is BAAAAD!

```
start = shape.Point2(0,0)
stop = shape.Point2(0,0)
print("Where does the line start?")
x = input("x: ")
start.x = int(x)
y = input("y: ")
start.y = int(y)
print("The line starts at ("+x+","+y+")." )
print("Where does the line stop?")
x = input("x: ")
stop.x = int(x)
y = input("y: ")
stop.y = int(y)
print("The line stops at ("+x+","+y+")." )
```


Let's make a function!

```
def configure(pt, role):
   print("Where does the line " + role + "?")
   x = input("x: ")
   pt.x = int(x)
   y = input("y: ")
   pt.y = int(y)
   print("The line " +role+ "s at ("+x+","+y+")." )

start = shape.Point2(0,0)
stop = shape.Point2(0,0)
configure(start, "start")
configure(stop, "stop")
```


Still a bit of redundancy

```
def configure(pt, role):
   print("Where does the line " + role + "?")
   x = input("x: ")
   pt.x = int(x)
   y = input("y: ")
   pt.y = int(y)
   print("The line " +role+ "s at ("+x+","+y+")." )

start = shape.Point2(0,0)
stop = shape.Point2(0,0)
configure(start, "start")
configure(stop, "stop")
```


Yay, Helper Functions!

```
def get_coord(name):
   x = input(name+": ")
   return int(x)

def configure(pt, role):
   print("Where does the line " + role + "?")
   pt.x = get_coord("x")
   pt.y = get_coord("y")
   print("The line " +role+ "s at ("+x+","+y+")." )

start = shape.Point2(0,0)
stop = shape.Point2(0,0)
configure(start, "start")
configure(stop, "stop")
```

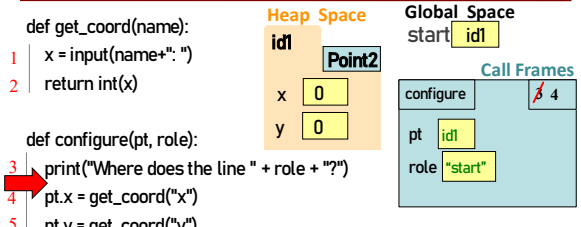

Frames and Helper Functions

- Functions can call each other!
- Each call creates a *new call frame*
- Writing the same several lines of code in 2 places? Or code that accomplishes some conceptual sub-task? Or your function is getting too long? Write a **helper function!** Makes your code easier to
  - **read**
  - **write**
  - **edit**
  - **debug**

Drawing Frames for Helper Functions (1)

```
def get_coord(name):
1    x = input(name+": ")
2    return int(x)

def configure(pt, role):
3    print("Where does the line " + role + "?")
4    pt.x = get_coord("x")
5    pt.y = get_coord("y")
6    print("The line " +role+ "s at ("+str(pt.x)+
          ","+str(pt.y)+")." )
start = shape.Point2(0,0)
configure(start, "start")
```



Q1: what do you do next?

```
def get_coord(name):
1   x = input(name+": ")
2   return int(x)

def configure(pt, role):
3   print("Where does the line " + role + "?")
4   pt.x = get_coord("x")
5   pt.y = get_coord("y")
6   print("The line " +role+ "s at ("+str(pt.x)+
          ","+str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```

Heap Space: id1 → Point2 { x: 0, y: 0 }

Global Space: start → id1

Call Frames: configure (3 4) { pt: id1, role: "start" }

A: Cross out the configure call frame.
B: Create a get_coord call frame.
C: Cross out the 4 in the call frame.
D: A & B
E: B & C

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Drawing Frames for Helper Functions (2)

```
def get_coord(name):
1   x = input(name+": ")
2   return int(x)

def configure(pt, role):
3   print("Where does the line " + role + "?")
4   pt.x = get_coord("x")
5   pt.y = get_coord("y")
6   print("The line " +role+ "s at ("+str(pt.x)+
          ","+str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```

Heap Space: id1 → Point2 { x: 0, y: 0 }

Global Space: start → id1

Call Frames: configure (3 4) { pt: id1, role: "start" }; get_coord (1) { name: "x" }

Not done!
Do not cross out!!

A
B CORRECT
C
D
E

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Drawing Frames for Helper Functions (3)

```
def get_coord(name):
1   x = input(name+": ")
2   return int(x)

def configure(pt, role):
3   print("Where does the line " + role + "?")
4   pt.x = get_coord("x")
5   pt.y = get_coord("y")
6   print("The line " +role+ "s at ("+str(pt.x)+
          ","+str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```

Assume user types **1** *at Python shell prompt*

Heap Space: id1 → Point2 { x: 0, y: 0 }

Global Space: start → id1

Call Frames: configure (3 4) { pt: id1, role: "start" }; get_coord (1 2) { name: "x", x: "1", RETURN: 1 }

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Drawing Frames for Helper Functions (4)

```
def get_coord(name):
1   x = input(name+": ")
2   return int(x)

def configure(pt, role):
3   print("Where does the line " + role + "?")
4   pt.x = get_coord("x")
5   pt.y = get_coord("y")
6   print("The line " +role+ "s at ("+str(pt.x)+
          ","+str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```

Heap Space: id1 → Point2 { x: 0 1, y: 0 }

Global Space: start → id1

Call Frames: configure (3 4 5) { pt: id1, role: "start" }; get_coord (1 2) { name: "x", x: "1", RETURN: 1 }

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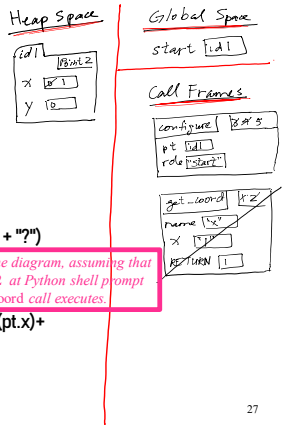
Drawing Frames for Helper Functions (5)

```
def get_coord(name):
1   x = input(name+": ")
2   return int(x)

def configure(pt, role):
3   print("Where does the line " + role + "?")
4   pt.x = get_coord("x")
5   pt.y = get_coord("y")
6   print("The line " +role+ "s at ("+str(pt.x)+
          ","+str(pt.y)+ ")." )
start = shape.Point2(0,0)
configure(start, "start")
```

To do: Finish the diagram, assuming that the user types **2** *at Python shell prompt when this* get_coord *call executes.*



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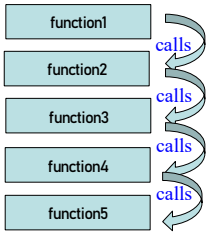
The Call Stack

- The set of function frames drawn in call order
- Functions frames are "stacked"
  - Cannot remove one above w/o removing one below
- Python must keep the **entire stack** in memory
  - Error if it cannot hold stack ("stack overflow")



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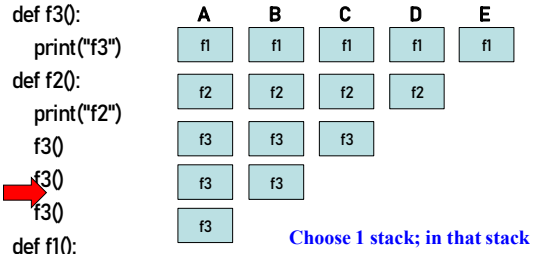
Errors and the Call Stack

```
def get_coord(name):
9     x = input(name+": ")
10    return int(x1)

def configure(pt, role):
13    print("Where does the line " +
14    pt.x = get_coord("x")
15    pt.y = get_coord("y")
16    print("The line " +role+ "s at ("+x+ ","+y+ ")." )

18 start = shape.Point2(0,0)
19 configure(start, "start")
```

```
Where does the line start?
x: 1
Traceback (most recent call last):
  File "v3.py", line 19, in <module>
    configure(start, "start")
  File "v3.py", line 14, in configure
    pt.x = get_coord("x")
  File "v3.py", line 10, in get_coord
    return str(x1)
NameError: name 'x1' is not defined
```


Q2: what does the call stack look like at this point in the execution of the code?

```
def f3():
    print("f3")
def f2():
    print("f2")
    f3()
    f3()
    f3()
def f1():
    print("f1")
    f2()
f1()
```

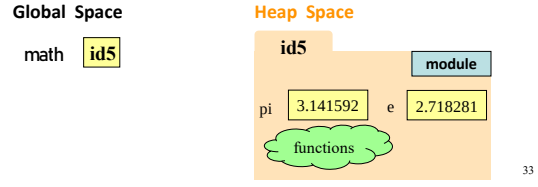


Choose 1 stack; in that stack cross out any frames that should have ended.

Modules and Global Space

Import `>>> import math`

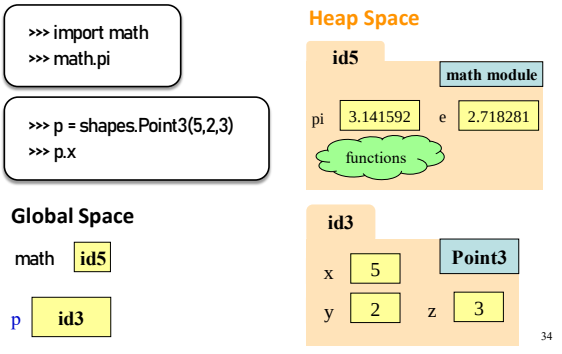
- Creates a global variable (same name as module)
- Puts variables, functions of module in a **folder**
- Puts folder id in the global variable



Modules vs Objects

```
>>> import math
>>> math.pi
```

```
>>> p = shapes.Point3(5,2,3)
>>> p.x
```



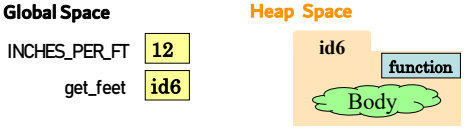
Functions and Global Space

A function definition

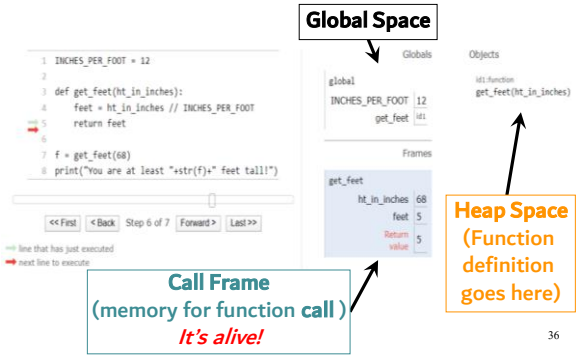
- Creates a global variable (same name as function)
- Creates a **folder** for body
- Puts folder id in the global variable

```
INCHES_PER_FT = 12
def get_feet(ht_in_inches):
    return ht_in_inches // INCHES_PER_FT
```

Body

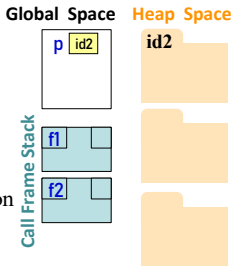


Function Definition vs. Call Frame



Storage in Python

- **Global Space**
  - What you "start with"
  - Stores global variables, modules & functions
  - Lasts until you quit Python
- **Heap Space**
  - Where "folders" are stored
  - Have to access indirectly
- **Call Frame Stack**
  - Parameters
  - Other variables local to function
  - Lasts until function returns



Don't draw module folder, function folder

Folders that we do not draw:

- Module folder is created upon import, for example,

  import math
- Function folder is created with def (the function header), for example,

  def get_feet(height_in_inches):

Don't draw those folders and the variables that store their ids; we only explained those folders to explain what you see in Python Tutor. *Do not draw them.*

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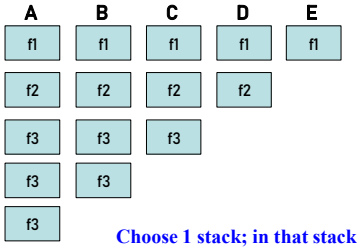
Q3: what does the call stack look like at this point in the execution of the code?

```
def f3():
    print("f3")
def f2():
    print("f2")
    f3()
    f3()
    f3()
def f1():
    print("f1")
    f2()
f1()
```



Choose 1 stack; in that stack cross out any frames that should have ended.

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