

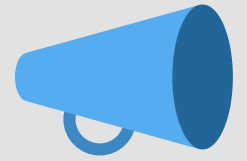
Discussion 02

Environment Diagrams, Higher-Order Functions

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Announcements



- First Project (Hog) released !!!
 - Checkpoint due 7/1
 - Project due 7/6
 - Extra Credit (start early)
- First Homework released (HW01)
 - Getting started videos
 - Due Thursday (6/30)
- Quick note
 - 61a is 2x speed
 - Make sure to use resources

Agenda

- Mini-Lecture on environment diagrams,

Environment Diagrams



Enviroment Diagrams

- What are they?
 - A way to model how our program runs line by line
 - Keep track of variables, function calls and what they return, etc.
- Why use them?
 - Can help us understand where there is a bug in program (debugging)
 - Useful for other questions (WWPD, coding)
 - Exam points!

Important Concepts

- Expressions
 - Evaluate to values
 - `1 + 1` -> `2`
- Statements
 - Bind **names** to **values**
 - **Names**
 - `def` statements, assignment statements, variable names
 - **Values**
 - numbers, strings, functions, or other objects
 - `x = 2`
 - doesn't return anything

Frames

- What are they?
 - Frames list the bindings of variables and their corresponding value
- What are they used for?
 - Used to look up the value of a variable
- **Global Frame** always exists

Assignment Statements

- Assignment statements (denoted by =) creates new binding in frame
- Evaluate right side **completely** before binding to left side
- Example

```
x = 11 % 4  
y = x  
x **= 2
```

Python 3.6
([known limitations](#))

→ 1 x = 3

[Edit this code](#)

Frames

Global frame

x 3

Def statements

- `def` statements are used to bind **function objects** to a **variable**
- Binding name is function name
- Parent of the function is frame where function is defined
- Keep track of *name, parameters, parent frame*
- Example

```
x = 3
def square(x):
    return x ** 3
square(x)
```

Def statements

- Only bind, **NO** execution until function is called
 - `def foo():` -> define function called `foo` with no parameters
 - `foo()` -> execute `foo`

Python 3.6
([known limitations](#))

```
1 x = 3
→ 2 def square(x):
3     return x ** 2
```

[Edit this code](#)

Frames Objects

The diagram illustrates the state of memory during function definition. On the left, under 'Frames', is the 'Global frame' which contains two entries: 'x' with the value '3', and 'square' which points to a function object. On the right, under 'Objects', is the function object 'func square(x) [parent=Global]'. A blue arrow points from the 'square' entry in the Global frame to the function object.

Call Expressions

- Syntax: `function_name(arg1, arg2, ...)`
- `sum(square(2), 2 + 2)`
- Create new frame for call expression
- Steps for evaluating:
 1. Evaluate operator (function)
 - See if it exists
 - `sum` adds two numbers
 2. Evaluate operands (args)
 - simplify args
 - `square(2)` -> `4`
 - `2 + 2` -> `4`
 3. Apply operator to the operands
 - `sum(4, 4)` -> `8`

Creating New Frames

- Give frame with unique index (`f1` , `f2` , `f3`)
- Label frame with name of function object
 - not always the variable name
- Label function's parent
- Every function has return value
 - Return value can be `None`

Variable Lookup

- Start in current frame
- If variable does not exist, search parent frame
- If variable still does not exist, continue looking in parent frames
- If variable does not exist, program errors

Question 1 (5 minutes)

Let's put it all together! Draw an environment diagram for the following code. You may not have to use all of the blanks provided to you.

```
def double(x):  
    return x * 2
```

```
hmmm = double  
wow = double(3)  
hmmm(wow)
```

Question 2 (walkthrough)

Draw the environment diagram that results from executing the code below.

```
def f(x):  
    return x  
  
def g(x, y):  
    if x(y):  
        return not y  
    return y  
  
x = 3  
x = g(f, x)  
f = g(f, 0)
```

Lambda

Functions λ

lambda Functions λ

- What are they?
 - A quicker and simpler way to define a function
 - Can also be used as the operator for a function
- Why use them?
 - Useful for scenarios in which you only want to use a function once and never again
- Syntax
 - written in 1 line
 - `lambda <args> : <body>`

lambda Function Examples Pt. 1

```
def add_and_square(x, y, z):  
    return (x + y + z) ** 2
```

```
lambda_add_and_square = lambda x, y, z : (x + y + z) ** 2
```

```
def error():  
    return 1 + 2 / 0
```

```
lambda_error = lambda : 1 + 2 / 0
```

lambda Examples Pt. 2

```
>>> lambda x : x // 3
```

```
>>> (lambda x : x / 3)(5)
```

```
>>> wow = lambda x: lambda y: lambda z: x * y * z
```

```
>>> wow(3)(7)(5)
```

```
>>> (lambda x: x(3,4))(lambda a,b: a ** b)
```

lambda Examples Pt. 2

```
>>> lambda x : x // 3
```

```
Function
```

```
>>> (lambda x : x / 3)(5)
```

```
>>> wow = lambda x: lambda y: lambda z: x * y * z
```

```
>>> wow(3)(7)(5)
```

```
>>> (lambda x: x(3,4))(lambda a,b: a ** b)
```

lambda Examples Pt. 2

```
>>> lambda x : x // 3
```

```
Function
```

```
>>> (lambda x : x / 3)(5)
```

```
1
```

```
>>> wow = lambda x: lambda y: lambda z: x * y * z
```

```
>>> wow(3)(7)(5)
```

```
105
```

```
>>> (lambda x: x(3,4))(lambda a,b: a ** b)
```

lambda Examples Pt. 2

```
>>> lambda x : x // 3
```

```
Function
```

```
>>> (lambda x : x / 3)(5)
```

```
1
```

```
>>> wow = lambda x: lambda y: lambda z: x * y * z
```

```
>>> wow(3)(7)(5)
```

```
105
```

```
>>> (lambda x: x(3,4))(lambda a,b: a ** b)
```

```
81
```

lambda Examples Pt. 2

```
>>> lambda x : x // 3
```

```
Function
```

```
>>> (lambda x : x / 3)(5)
```

```
1
```

```
>>> wow = lambda x: lambda y: lambda z: x * y * z
```

```
>>> wow(3)(7)(5)
```

```
105
```

```
>>> (lambda x: x(3,4))(lambda a,b: a ** b)
```

```
81
```

Question 3 (5 minutes)

Draw the environment diagram for the following code and predict what Python will output.

```
a = lambda x: x * 2 + 1
def b(b, x):
    return b(x + a(x))
x = 3
x = b(a, x)
```


Higher Order Functions

Higher Order Functions (HOF)

- What are they?
 - Functions that either return functions as output or take in other functions as inputs
- Why use them?
 - When you want to use a function within another function
 - Treat them as an object
- Important Note
 - Let's see we have function `foo()` that takes in zero parameters
 - `foo` refers to the function object and is **NOT** calling the function
 - `foo()` shows that we are actually calling the function

HOF Function as Input Example

```
>>> def exec_func(func, a):  
    return func(a)
```

```
>>> exec_func(lambda x : x * 4, 4)  
16
```

```
>>> exec_func(lambda x : pow(x, 2), 2)  
4
```

HOF Function as Output Example

```
>>> def first(x):  
    def square(y):  
        def mod(z):  
            return (x ** y) % z  
        return h  
    return g  
  
>>> a = first(2)  
>>> b = a(4)  
>>> b(3)
```

HOF Function as Output Example

```
>>> def first(x):  
    def square(y):  
        def mod(z):  
            return (x ** y) % z  
        return h  
    return g  
  
>>> a = first(2)  
>>> b = a(4)  
>>> b(3)  
1
```

Question 4 (5 minutes)

Draw the environment diagram for the following code and predict what Python will output.

```
n = 9
def make_adder(n):
    return lambda k: k + n
add_ten = make_adder(n+1)
result = add_ten(n)
```

Question 5 (10 minutes)

```
n = 9
def make_adder(n):
    return lambda k: k + n
add_ten = make_adder(n+1)
result = add_ten(n)
```