61A Lecture 5

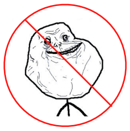
Wednesday, September 11

Announcements

- Take-home quiz released Wednesday 9/11 at 1pm, due Thursday 9/12 at 11:59pm.
  - http://inst.eecs.berkeley.edu/~cs61a/fa13/hw/quiz1.html
  - 3 points; graded for correctness.
  - Submit in the same way that you submit homework assignments.
  - If you receive 0/3, you will need to talk to the course staff or be dropped.
  - *Open-computer*: You can use the Python interpreter, watch course videos, and read the online text (http://composingprograms.com).
  - *No external resources*: Please don't search for answers, talk to your classmates, etc.
- Homework 2 due Tuesday 9/17 at 5pm.
- Project 1 due Thursday 9/19 at 11:59pm.
- Solutions to homeworks: http://inst.eecs.berkeley.edu/~cs61a/fa13/hw/solutions

Office Hours: You Should Go!

You are not alone!



http://inst.eecs.berkeley.edu/~cs61a/fa13/staff.html

The Purpose of Higher-Order Functions

Functions are first-class: Functions can be manipulated as values in our programming language.

Higher-order function: A function that takes a function as an argument value or returns a function as a return value

Higher-order functions:

- Express general methods of computation
- Remove repetition from programs
- Separate concerns among functions

Environments for Higher-Order Functions

Environments Enable Higher-Order Functions

Higher-order function: A function that takes a function as an argument value or returns a function as a return value

Functions as arguments:

Our current evaluation rules handle that case already!

We'll discuss an example today

Functions as return values:

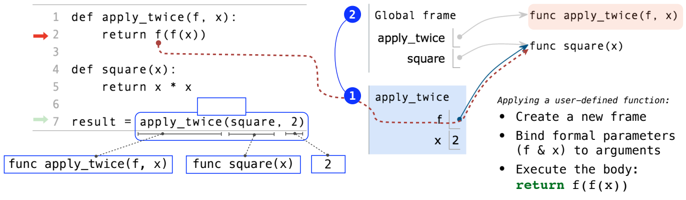
We need to extend our rules a little

Functions need to know where they were defined

Almost everything stays the same

(demo)

Names can be Bound to Functional Arguments



```
def apply_twice(f, x):
    return f(f(x))

def square(x):
    return x * x

result = apply_twice(square, 2)
```

Applying a user-defined function:

- Create a new frame
- Bind formal parameters (f & x) to arguments
- Execute the body: **return** f(f(x))

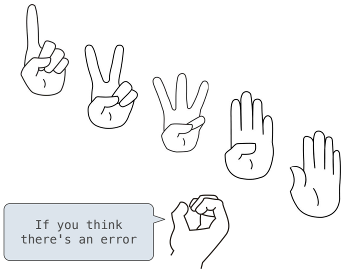
- Functions are values.
- Names can refer to functions (just as they can refer to any values).
- Multiple names can all refer to the same function, even in different frames.

Example: http://goo.gl/mwVuIF

Discussion Question

What is the value of the final expression below?

```
def repeat(f, x):
    while f(x) != x:
        x = f(x)
    return x

def g(y):
    return (y + 5) // 3

repeat(g, 5)
```



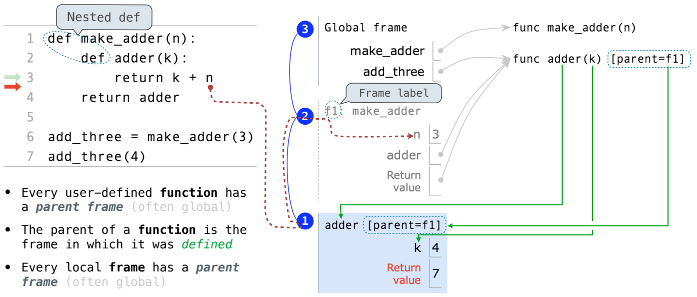
Example: http://goo.gl/EDiOIr

Environments for Nested Definitions

(Demo)

Environment Diagrams for Nested Def Statements

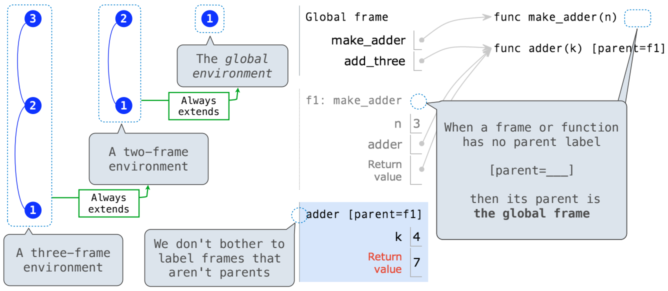
```
def make_adder(n):
    def adder(k):
        return k + n
    return adder

add_three = make_adder(3)
add_three(4)
```



- Every user-defined **function** has a ***parent frame*** (often global)
- The parent of a **function** is the frame in which it was *defined*
- Every local **frame** has a ***parent frame*** (often global)
- The parent of a **frame** is the parent of the function *called*

Example:

An Environment is a Sequence of Frames



A local frame extends the environment that begins with its parent.

How to Draw an Environment Diagram

When a function is defined:

1. Create a **function value**: func *<name>*(*<formal parameters>*)
2. If the **parent frame** of that function is not the global frame, add matching labels to the **parent frame** and the **function value** (such as *f1*, *f2*, or *f3*).

   f1: make_adder   func adder(k) [parent=f1]

3. Bind *<name>* to the **function value** in the first frame of the current environment.

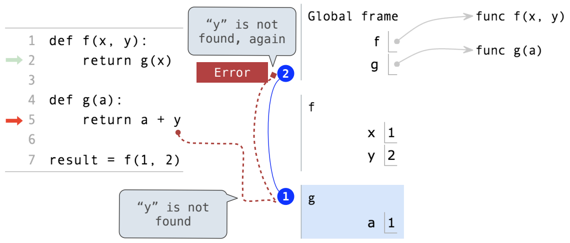
When a function is called:

1. Add a **local frame**, titled with the *<name>* of the function being called.
2. If the function has a parent label, copy it to the **local frame**: [parent=*<label>*]
3. Bind the *<formal parameters>* to the arguments in the **local frame**.
4. Execute the body of the function in the environment that starts with the **local frame**.

Local Names

(Demo)

Local Names are *not* Visible to Other (Non-Nested) Functions



```
def f(x, y):
    return g(x)

def g(a):
    return a + y

result = f(1, 2)
```

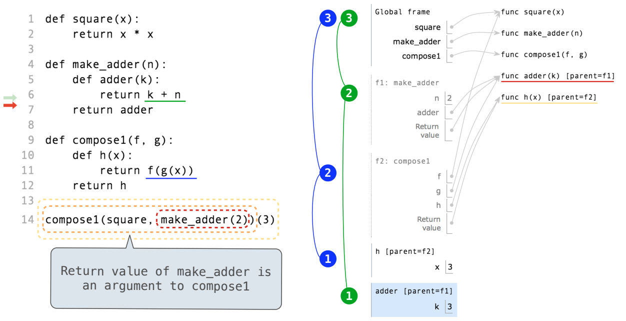
- An environment is a sequence of frames.
- The environment created by calling a top-level function (no def within def) consists of one local frame, followed by the global frame.

Example: http://goo.gl/b6WvUc

Function Composition

(Demo)

The Environment Diagram for Function Composition



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

def make_adder(n):
    def adder(k):
        return k + n
    return adder

def compose1(f, g):
    def h(x):
        return f(g(x))
    return h

compose1(square, make_adder(2))(3)
```

Return value of make_adder is an argument to compose1

Example:

The Game of Hog

(Demo)