

61A Lecture 15

Monday, October 6

Announcements

- Homework 4 due Tuesday 10/7 @ 11:59pm
- Project 2 due Thursday 10/9 @ 11:59pm
 - Project Party Monday 5pm–7pm in 271, 273, and 275 Soda (labs)
 - Extra credit point for submitting your project at least 24 hours before the deadline
- Improving lab and discussion questions
- Tips for approaching computer science problems

Mutable Functions

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of \$100

```

>>> withdraw(25)
75
>>> withdraw(25)
50
>>> withdraw(60)
'Insufficient funds'
>>> withdraw(15)
35
>>> withdraw = make_withdraw(100)
    
```

Return value: remaining balance

Different return value!

Argument: amount to withdraw

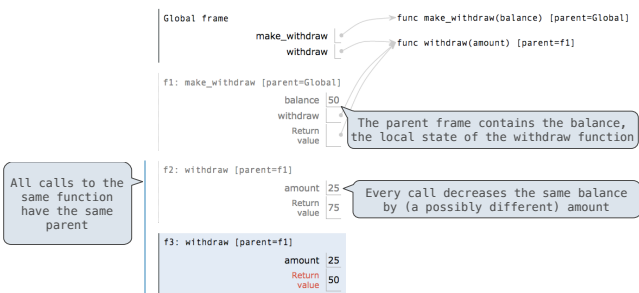
Second withdrawal of the same amount

Where's this balance stored?

Within the parent frame of the function!

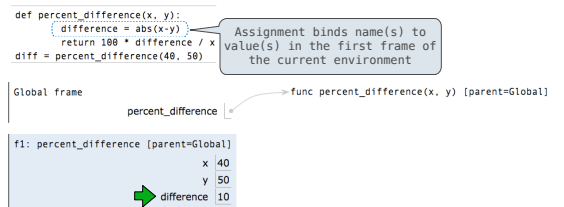
A function has a body and a parent environment

Persistent Local State Using Environments



Interactive Diagram

Reminder: Local Assignment



Execution rule for assignment statements:

1. Evaluate all expressions right of =, from left to right
2. Bind the names on the left to the resulting values in the **current frame**

Interactive Diagram

Non-Local Assignment & Persistent Local State

```

def make_withdraw(balance):
    """Return a withdraw function with a starting balance."""
    def withdraw(amount):
        nonlocal balance
        if amount > balance:
            return 'Insufficient funds'
        balance = balance - amount
        return balance
    return withdraw
    
```

Declare the name "balance" nonlocal at the top of the body of the function in which it is re-assigned

Re-bind balance in the first non-local frame in which it was bound previously

(Demo)

Non-Local Assignment

The Effect of Nonlocal Statements

```
nonlocal <name>, <name>, ...
```

Effect: Future assignments to that name change its pre-existing binding in the **first non-local frame** of the current environment in which that name is bound.

Python Docs: an "enclosing scope"

From the Python 3 language reference:

Names listed in a nonlocal statement must refer to pre-existing bindings in an enclosing scope.

Names listed in a nonlocal statement must not collide with pre-existing bindings in the local scope.

Current frame

http://docs.python.org/release/3.1.3/reference/simple_stmts.html#the-nonlocal-statement
<http://www.python.org/dev/peps/pep-3184/>

The Many Meanings of Assignment Statements

```
x = 2
```

Status

Effect

- No nonlocal statement
- "x" is not bound locally

Create a new binding from name "x" to object 2 in the first frame of the current environment

- No nonlocal statement
- "x" is bound locally

Re-bind name "x" to object 2 in the first frame of the current environment

- nonlocal x
- "x" is bound in a non-local frame

Re-bind "x" to 2 in the first non-local frame of the current environment in which it is bound

- nonlocal x
- "x" is not bound in a non-local frame

SyntaxError: no binding for nonlocal 'x' found

- nonlocal x
- "x" is bound in a non-local frame
- "x" also bound locally

SyntaxError: name 'x' is parameter and nonlocal

Python Particulars

Python pre-computes which frame contains each name before executing the body of a function.

Within the body of a function, all instances of a name must refer to the same frame.

```
def make_withdraw(balance):
    def withdraw(amount):
        if amount > balance:
            return 'Insufficient funds'
        balance = balance - amount
        return balance
    return withdraw
```

Local assignment

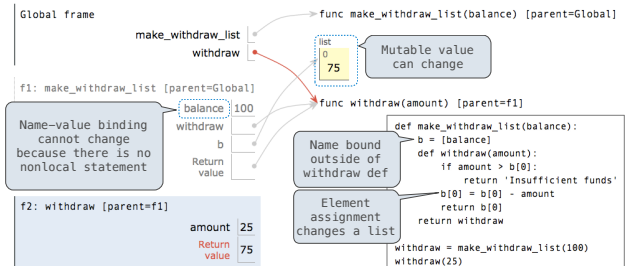
```
wd = make_withdraw(20)
wd(5)
```

UnboundLocalError: local variable 'balance' referenced before assignment

Interactive Diagram

Mutable Values & Persistent Local State

Mutable values can be changed *without* a nonlocal statement.



Interactive Diagram

Multiple Mutable Functions

(Demo)

Referential Transparency, Lost

Expressions are **referentially transparent** if substituting an expression with its value does not change the meaning of a program.



```
mul(add(2, mul(4, 6)), add(3, 5))
```

```
mul(add(2, 24), add(3, 5))
```

```
mul(26, add(3, 5))
```



Mutation operations violate the condition of referential transparency because they do more than just return a value; **they change the environment.**

Interactive Diagram