

Mutable Functions

Announcements

Mutable Functions

A Function with Behavior That Varies Over Time

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

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

Return value: remaining balance

Different return value!

Argument: amount to withdraw

Second withdrawal of the same amount

Within the parent frame of the function!

Where's this balance stored?

Persistent Local State Using Environments

```
Global frame
  make_withdraw
  withdraw
  func make_withdraw(balance) (parent=Global)
  func withdraw(amount) (parent=f1)
f1: make_withdraw [parent=Global]
  balance 50
  withdraw
  Return value
f2: withdraw [parent=f1]
  amount 25
  Return value 75
f3: withdraw [parent=f1]
  amount 25
  Return value 50
```

All calls to the same function have the same parent

The parent frame contains the balance, the local state of the withdraw function

Every call decreases the same balance by (a possibly different) amount

Reminder: Local Assignment

```
def percent_difference(x, y):
    difference = abs(x-y)
    return 100 * difference / x
diff = percent_difference(40, 50)
```

Assignment binds name(s) to value(s) in the first frame of the current environment

```
Global frame
  percent_difference
  func percent_difference(x, y) (parent=Global)
f1: percent_difference [parent=Global]
  x 40
  y 50
  difference 10
```

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

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

https://docs.python.org/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 "x" 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
```

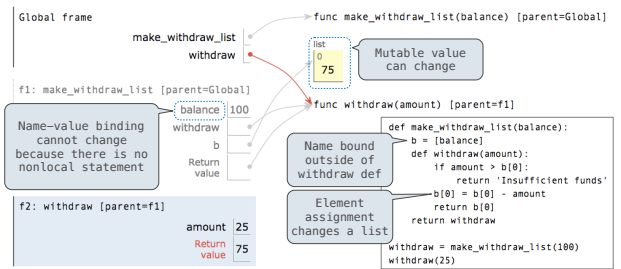
Local assignment

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

UnboundLocalError: local variable 'balance' referenced before assignment

Mutable Values & Persistent Local State

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



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**.

Review Problem