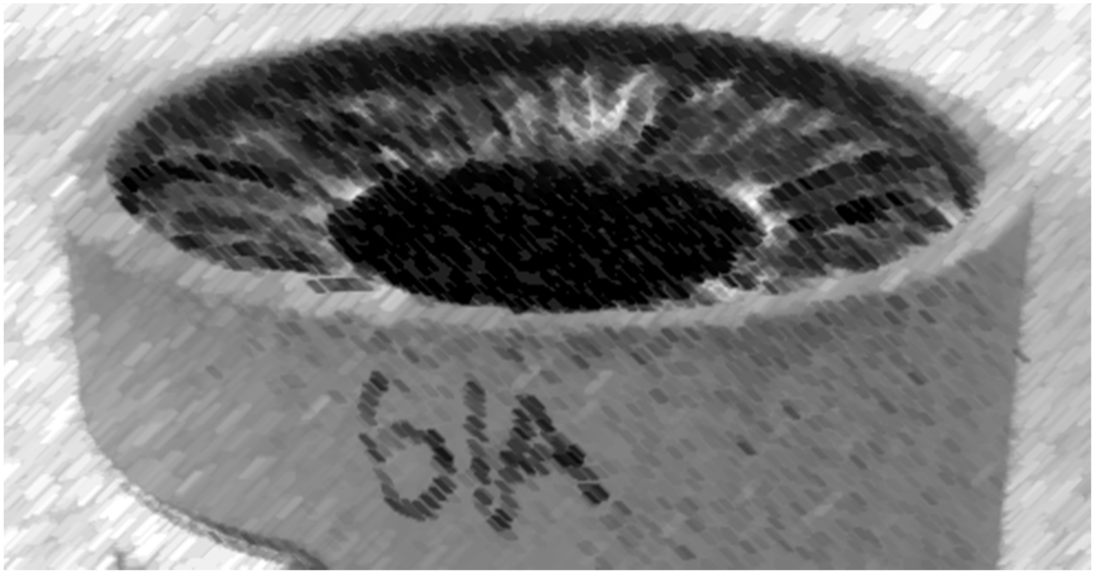

CS61A Lecture 17

Amir Kamil
UC Berkeley
March 1, 2013

Announcements

- HW6 due next Thursday
- Trends project due on Tuesday
  - Partners are required; find one in lab or on Piazza
  - Will not work in IDLE
  - New bug submission policy; see Piazza

Practical Guidance: Choosing Names

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Names typically don't matter for correctness,

but they matter tremendously for legibility

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`boolean` **`d`** **`play_helper`**

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`boolean` → `turn_is_over` `d` → `dice` `play_helper` → `take_turn`

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Use names for repeated compound expressions

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```
if sqrt(square(a) + square(b)) > 1:
    x = x + sqrt(square(a) + square(b))
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    x = x + sqrt(square(a) + square(b))
```

```
h = sqrt(square(a) + square(b))
if h > 1:
    x = x + h
```

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h = sqrt(square(a) + square(b))
if h > 1:
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```

Use names for meaningful parts of compound expressions

```
x = (-b + sqrt(square(b) - 4 * a * c)) / (2 * a)
```

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Use names for meaningful parts of compound expressions

```
x = (-b + sqrt(square(b) - 4 * a * c)) / (2 * a)
```

```
disc_term = sqrt(square(b) - 4 * a * c)
x = (-b + disc_term) / (2 * a)
```

Practical Guidance: DRY

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Sometimes, removing repetition requires restructuring the code

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```
def find_quadratic_root(a, b, c, plus=True):
    """Applies the quadratic formula to the polynomial
    ax^2 + bx + c."""
    if plus:
        return (-b + sqrt(square(b) - 4 * a * c)) / (2 * a)
    else:
        return (-b - sqrt(square(b) - 4 * a * c)) / (2 * a)
```

Practical Guidance: DRY

Sometimes, removing repetition requires restructuring the code

```
def find_quadratic_root(a, b, c, plus=True):
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        return (-b + sqrt(square(b) - 4 * a * c)) / (2 * a)
    else:
        return (-b - sqrt(square(b) - 4 * a * c)) / (2 * a)
```

```
def find_quadratic_root(a, b, c, plus=True):
    """Applies the quadratic formula to the polynomial
    ax^2 + bx + c."""
    disc_term = sqrt(square(b) - 4 * a * c)
    if not plus:
        disc_term *= -1
    return (-b + disc_term) / (2 * a)
```

Test-Driven Development

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Write the test of a function before you write a function

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Write the test of a function before you write a function

- A test will clarify the (one) job of the function
- Your tests can help identify tricky edge cases

Develop incrementally and test each piece before moving on

- You can’t depend upon code that hasn’t been tested
- Run your old tests again after you make new changes

Hog Contest

Hog Contest

Contest rules:

- All entries run against every other entry
- An entry wins a match if its true win rate is > 0.5
- All strategies must be deterministic, pure functions and must not use pre-computed data
- Extra credit for entries with the most wins or the highest cumulative win rate
- Total of 54 valid submissions

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- Total of 54 valid submissions

We used **`itertools.combinations`** to determine the set of matches

Top Finishers

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Congratulations to the team of Colin Lockard and Sherry Xu, who achieved a perfect 53-0 record <u>and</u> the highest win rate (28.77)!

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Complete rankings will be posted on the website

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A strategy is a table

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Computing Win Rates Exactly

A state in the game:
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A strategy is a table

(me,0,0): 5

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Computing Win Rates Exactly

A state in the game:
(who rolls next?, player score, opponent score)

A strategy is a table

(me,0,0): 5
(me,0,70): 9

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(me,0,0): 5
(me,0,70): 9
...

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A state in the game:
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(me,0,0): 5
(me,0,70): 9
...
(me,96,99): 0

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Each state has a chance to win

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(me,0,0): 5
(me,0,70): 9
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Each state has a chance to win

(me,99,100+)

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(me,0,0): 5
(me,0,70): 9
...
(me,96,99): 0
...
(me,99,99): 10

Each state has a chance to win

(you,100+,99)
(me,99,100+) 0

Requires access to both strategies, which must be deterministic

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A state in the game:
(who rolls next?, player score, opponent score)

A strategy is a table

(me,0,0): 5
(me,0,70): 9
...
(me,96,99): 0
...
(me,99,99): 10

Each state has a chance to win

(you,100+,99)	1
(me,99,100+)	0

Requires access to both strategies, which must be deterministic

Computing Win Rates Exactly

A state in the game:
(who rolls next?, player score, opponent score)

A strategy is a table

(me,0,0): 5
(me,0,70): 9
...
(me,96,99): 0
...
(me,99,99): 10

Each state has a chance to win

(you,98,99)	
(you,100+,99)	1
(me,99,100+)	0

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A state in the game:
(who rolls next?, player score, opponent score)

A strategy is a table

(me,0,0): 5
(me,0,70): 9
...
(me,96,99): 0
...
(me,99,99): 10

Each state has a chance to win

(you,98,99)	
(you,100+,99)	1
(me,99,100+)	0

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(me,0,0): 5
(me,0,70): 9
...
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...
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Each state has a chance to win

...	...
(you,98,99)	0
(you,100+,99)	1
(me,99,100+)	0

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A state in the game:
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(me,0,0): 5
(me,0,70): 9
...
(me,96,99): 0
...
(me,99,99): 10

Each state has a chance to win

(you,90,99)	
...	...
(you,98,99)	0
(you,100+,99)	1
(me,99,100+)	0

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Computing Win Rates Exactly

A state in the game:
(who rolls next?, player score, opponent score)

A strategy is a table

(me,0,0): 5
(me,0,70): 9
...
(me,96,99): 0
...
(me,99,99): 10

Each state has a chance to win

(you,90,99)	0
...	...
(you,98,99)	0
(you,100+,99)	1
(me,99,100+)	0

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A state in the game:

(who rolls next?, player score, opponent score)

A strategy is a table

(me,0,0): 5
(me,0,70): 9
...
(me,96,99): 0
...
(me,99,99): 10

Each state has a chance to win

(you,88,99)	
(you,90,99)	0
...	...
(you,98,99)	0
(you,100+,99)	1
(me,99,100+)	0

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A strategy is a table

(me,0,0): 5
(me,0,70): 9
...
(me,96,99): 0
...
(me,99,99): 10

Each state has a chance to win

...	
(me,87,99)	
...	
(you,88,99)	0
(you,90,99)	0
...	...
(you,98,99)	0
(you,100+,99)	1
(me,99,100+)	0

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Each state has a chance to win

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...	
(you,88,99)	0
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(you,98,99)	0
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...
(me,99,99): 10

Each state has a chance to win

	When rolling 2 dice:
...	
(me,87,99)	1/36 * 1 + 35/36 * 0
...	
(you,88,99)	0
(you,90,99)	0
...	...
(you,98,99)	0
(you,100+,99)	1
(me,99,100+)	0

Requires access to both strategies, which must be deterministic

Achieving the Perfect Strategy

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Optimal strategy given an opponent:

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- At each state, compute probability of winning for each allowed number of dice

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- Initial guess: always roll 5

Achieving the Perfect Strategy

Optimal strategy given an opponent:

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The perfect strategy: use iterative improvement!

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- Update to: optimal opponent of current strategy

Achieving the Perfect Strategy

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Takes only 16 steps to converge!

Achieving the Perfect Strategy

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- At each state, compute probability of winning for each allowed number of dice
- Choose the number of dice that maximizes the probability

The perfect strategy: use iterative improvement!

- Initial guess: always roll 5
- Update to: optimal opponent of current strategy
- Done when: 0.5 win rate against optimal opponent

Takes only 16 steps to converge!

Can also compute perfect strategy directly using table

A Function with Evolving Behavior

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

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```
>>> withdraw(25)
```

A Function with Evolving Behavior

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

```
>>> withdraw(25)
75
```

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75

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```

A Function with Evolving Behavior

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

```
>>> withdraw(25)
75

>>> withdraw(25)
50
```

A Function with Evolving Behavior

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

```
>>> withdraw(25)
75

>>> withdraw(25)
50

>>> withdraw(60)
```

A Function with Evolving Behavior

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

```
>>> withdraw(25)
75

>>> withdraw(25)
50

>>> withdraw(60)
'Insufficient funds'
```

A Function with Evolving Behavior

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

```
>>> withdraw(25)
75

>>> withdraw(25)
50

>>> withdraw(60)
'Insufficient funds'

>>> withdraw(15)
```

A Function with Evolving Behavior

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

Return value: remaining balance

```
>>> withdraw(25)
75
```

Argument: amount to withdraw

Different return value!

```
>>> withdraw(25)
50
```

Second withdrawal of the same amount

```
>>> withdraw(60)
'Insufficient funds'

>>> withdraw(15)
35
```

A Function with Evolving Behavior

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

Return value: remaining balance

Argument: amount to withdraw

```
>>> withdraw(25)
75
```

Different return value!

Second withdrawal of the same amount

```
>>> withdraw(25)
50
```

```
>>> withdraw(60)
'Insufficient funds'
```

Where's this balance stored?

```
>>> withdraw(15)
35
```

A Function with Evolving Behavior

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

Return value: remaining balance

Different return value!

```
>>> withdraw(25)
75

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50

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35
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Argument: amount to withdraw

Second withdrawal of the same amount

Where's this balance stored?

```
>>> withdraw = make_withdraw(100)
```

A Function with Evolving Behavior

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35
```
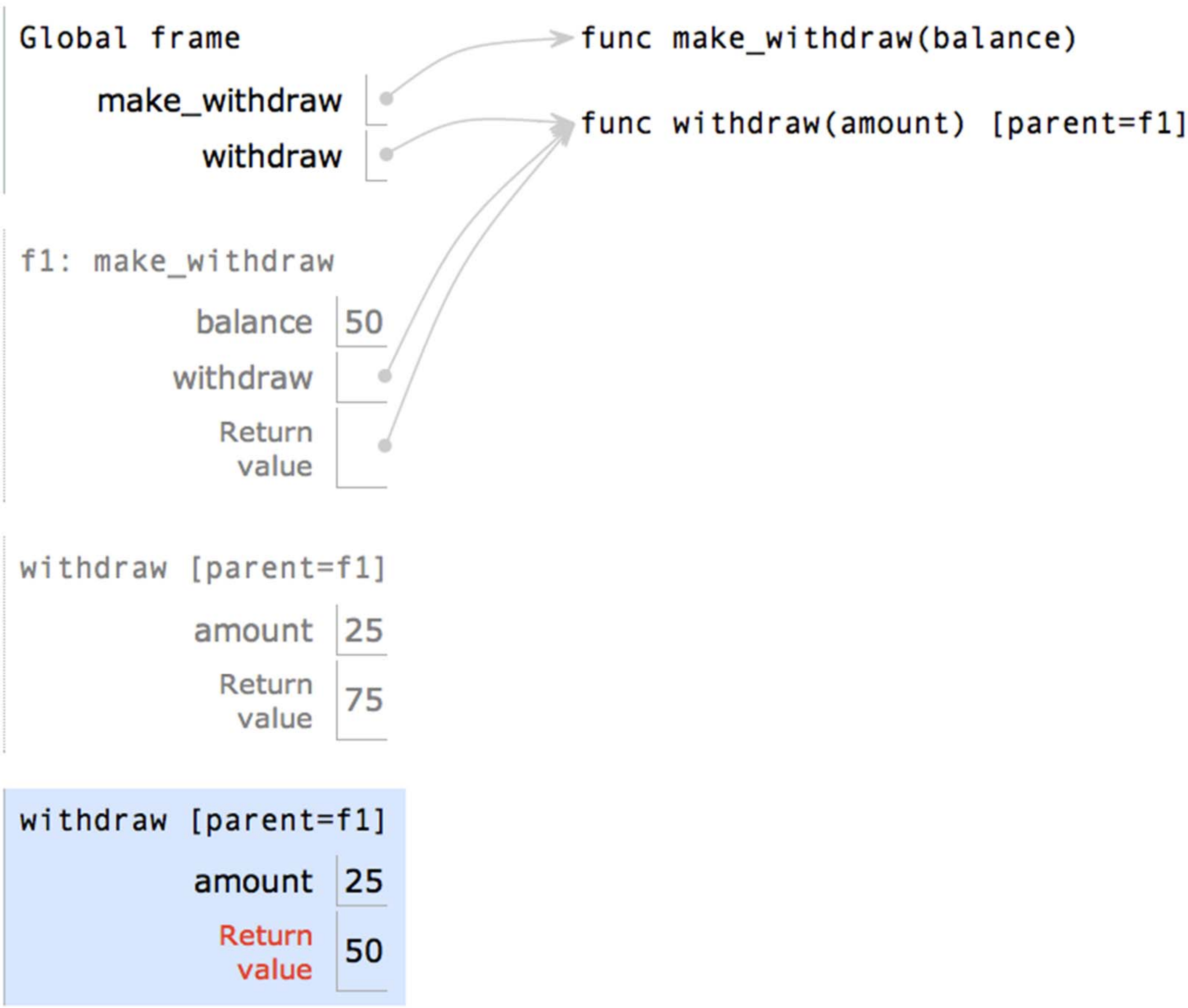

```
>>> withdraw = make_withdraw(100)
```

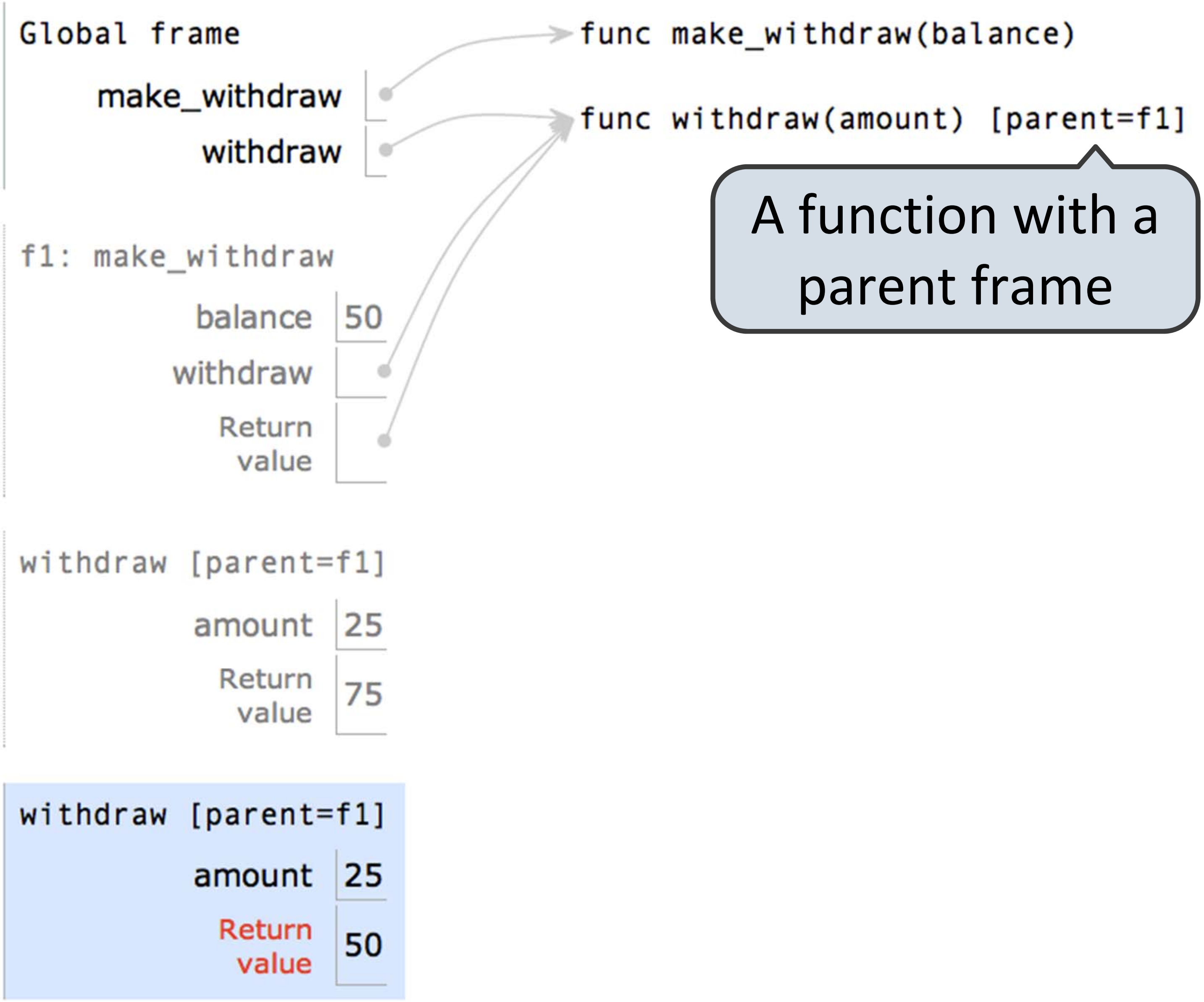
Within the function!

Persistent Local State



Example: http://goo.gl/5LZ6F

Persistent Local State



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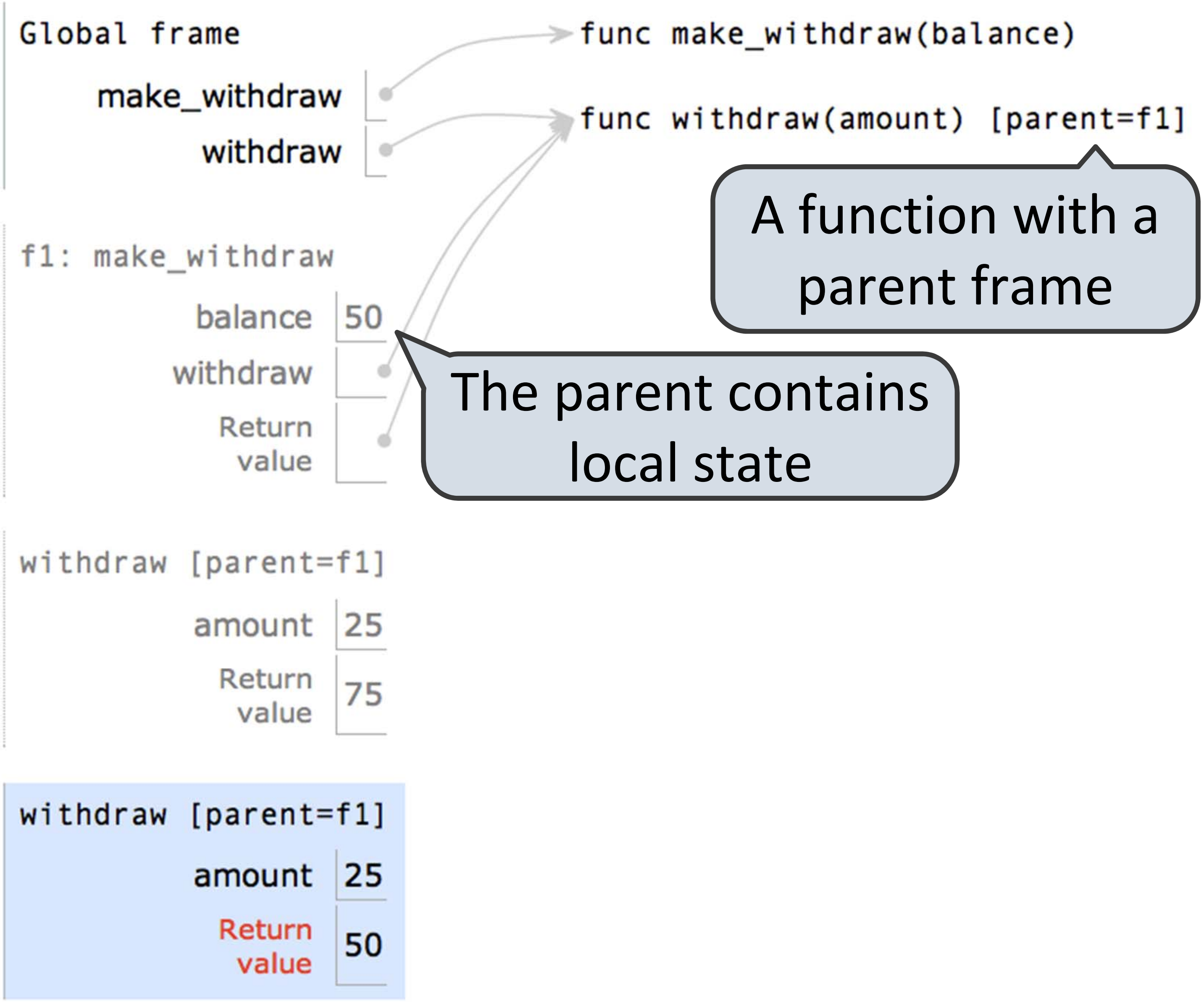
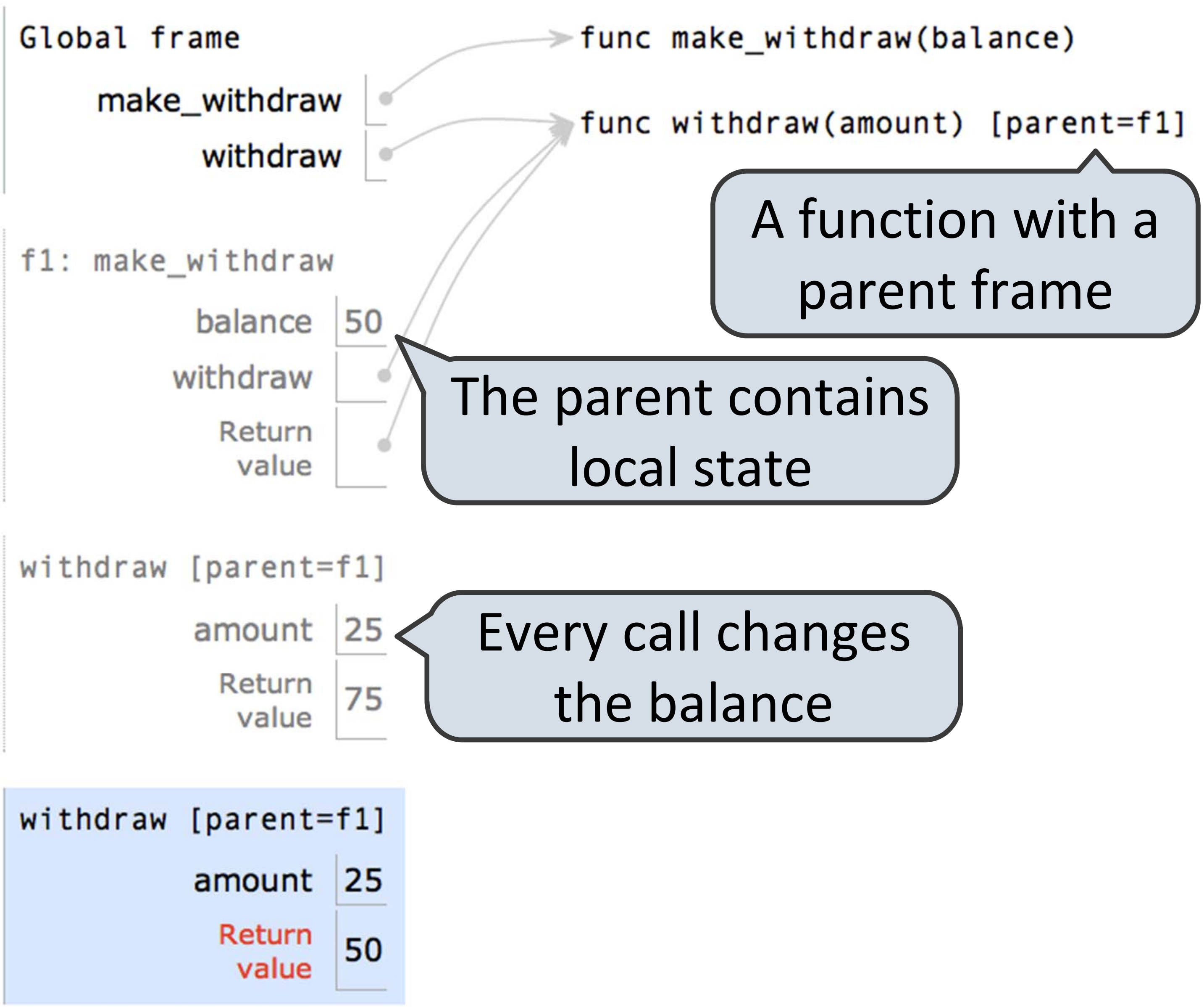


Example: http://goo.gl/5LZ6F

Persistent Local State



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Reminder: Local Assignment

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def percent_difference(x, y):
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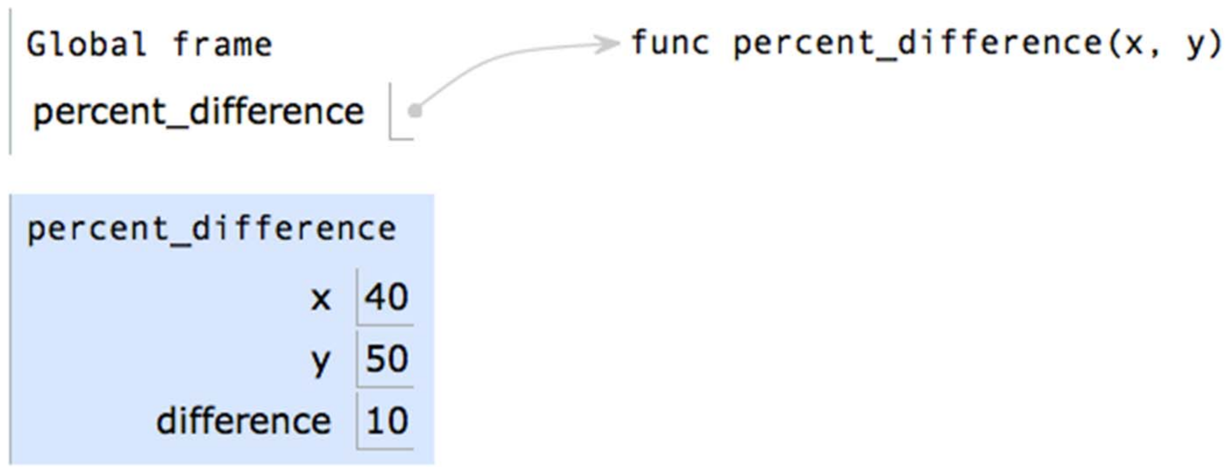

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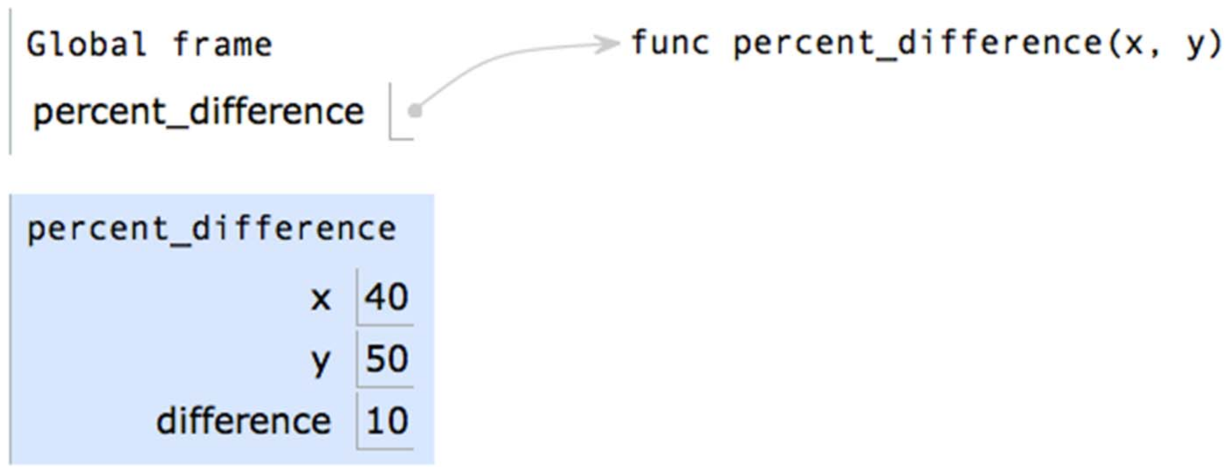

Execution rule for assignment statements:

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

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Non-Local Assignment

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Declare the name "balance" nonlocal

Re-bind balance where it was bound previously

The Effect of Nonlocal Statements

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http://docs.python.org/release/3.1.3/reference/simple_stmts.html#the-nonlocal-statement

http://www.python.org/dev/peps/pep-3104/

Effects of Assignment Statements

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x = 2
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Effects of Assignment Statements

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Local assignment

UnboundLocalError: local variable 'balance' referenced before assignment

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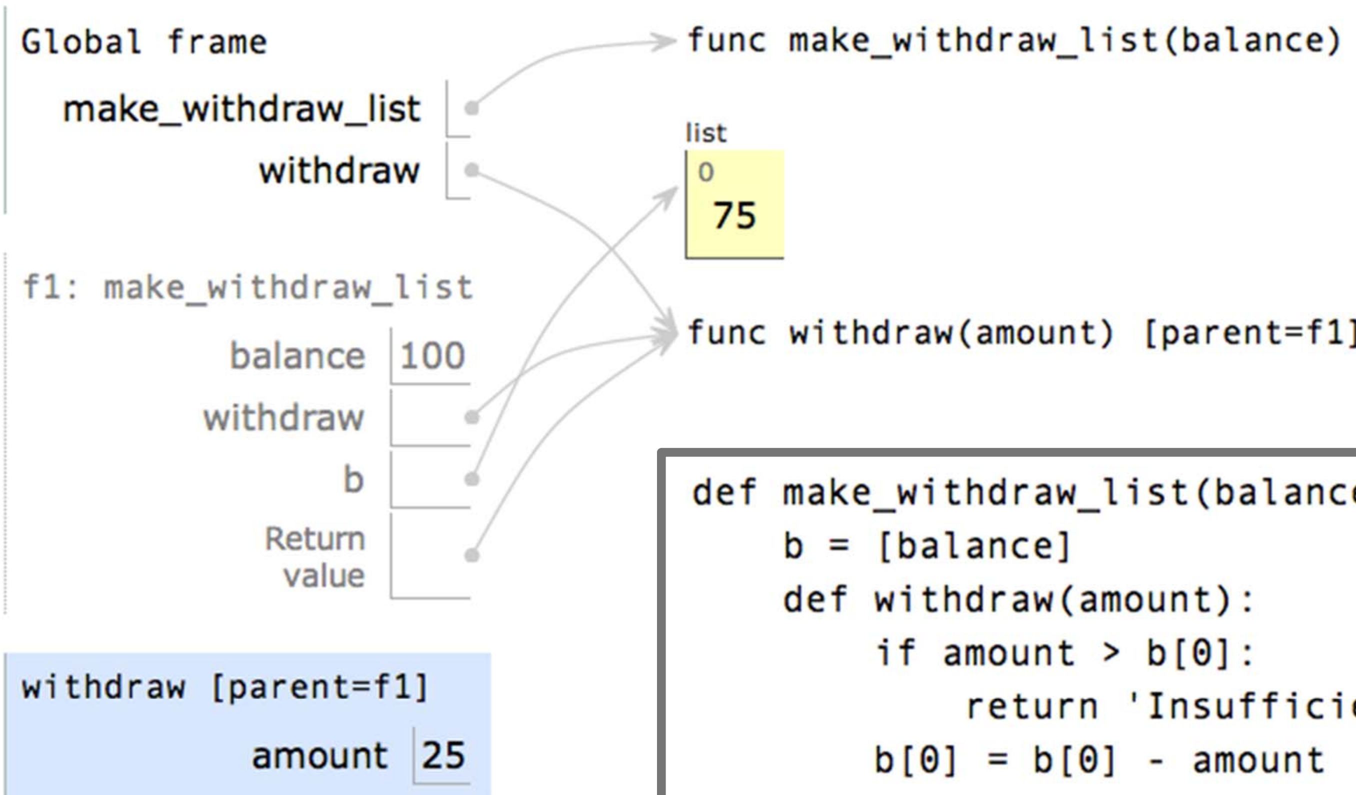


```
def make_withdraw_list(balance):
    b = [balance]
    def withdraw(amount):
        if amount > b[0]:
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        b[0] = b[0] - amount
        return b[0]
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withdraw = make_withdraw_list(100)
withdraw(25)
```

Example: http://goo.gl/cEpmz

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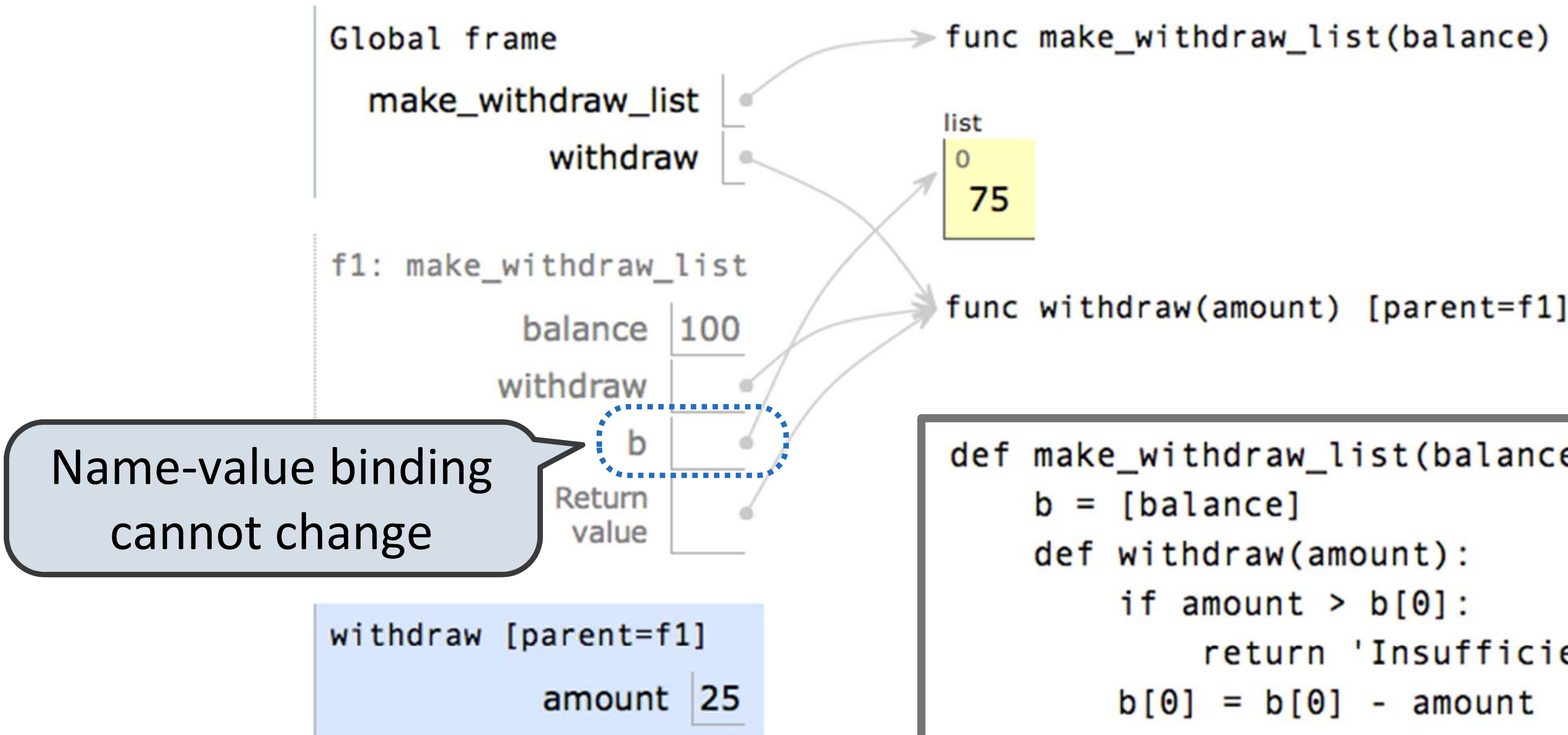


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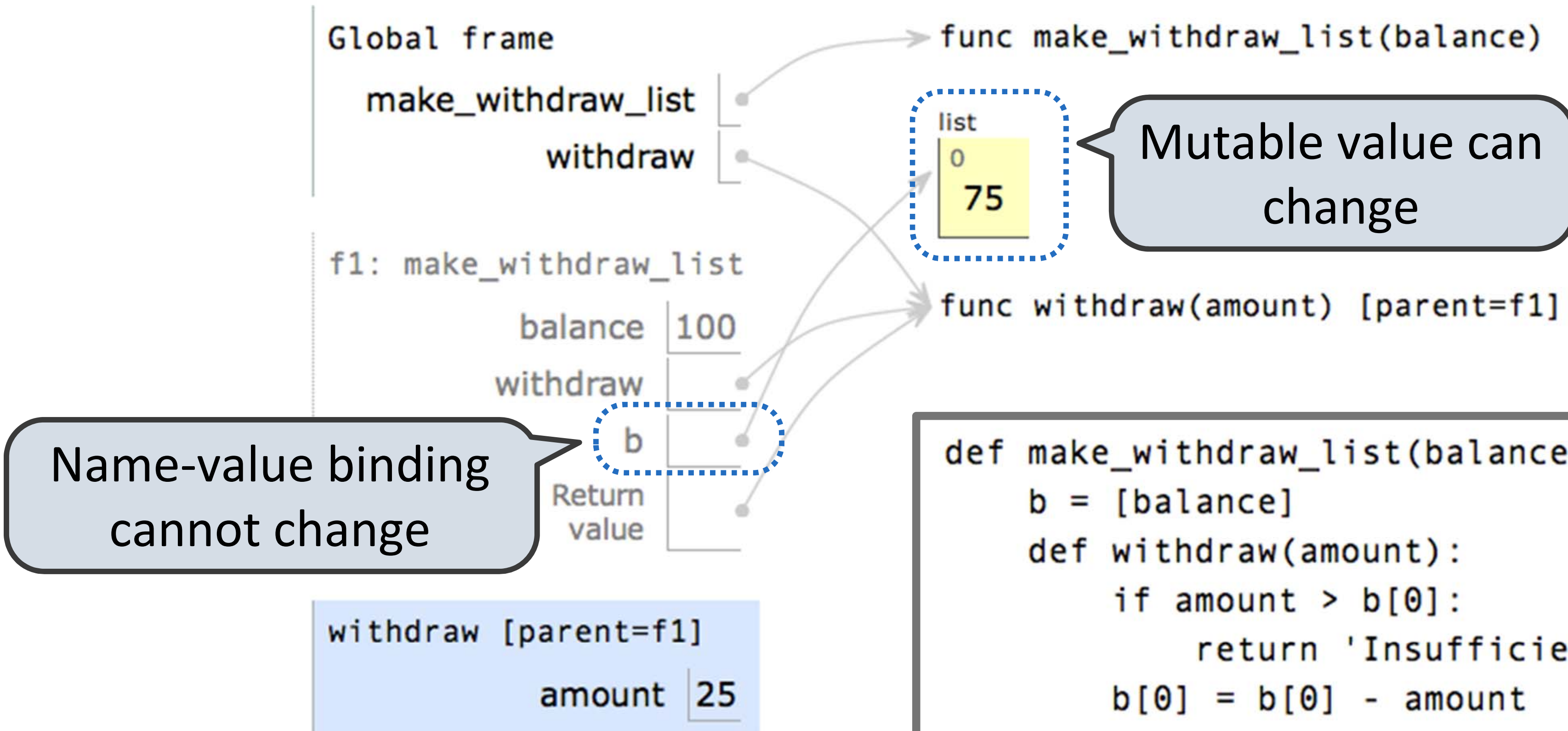


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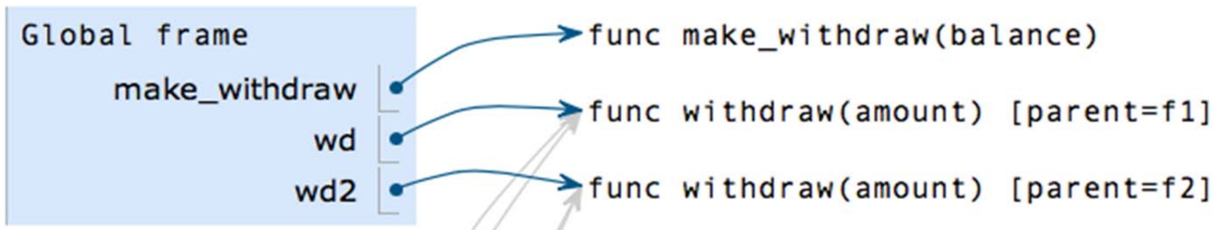
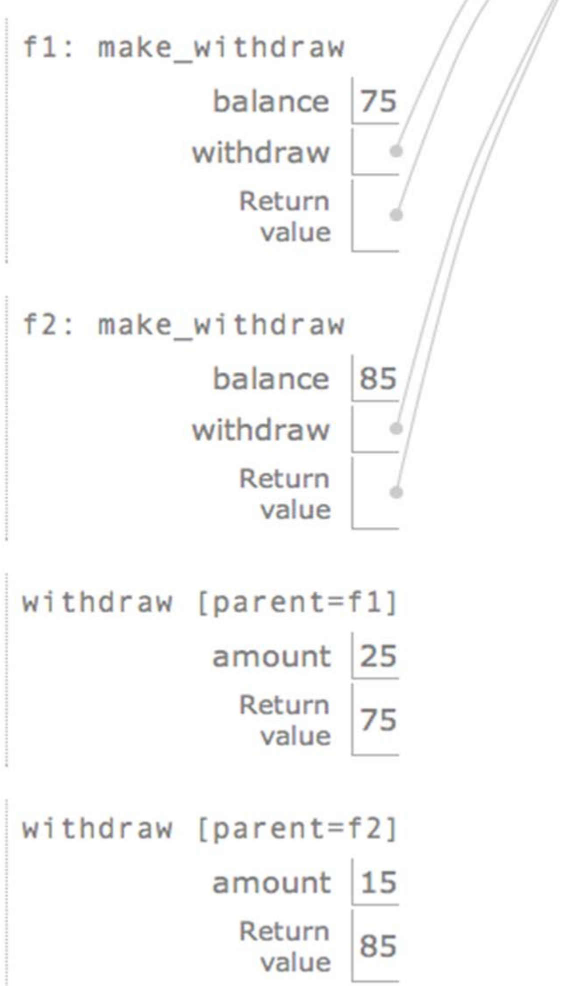
Creating Two Withdraw Functions



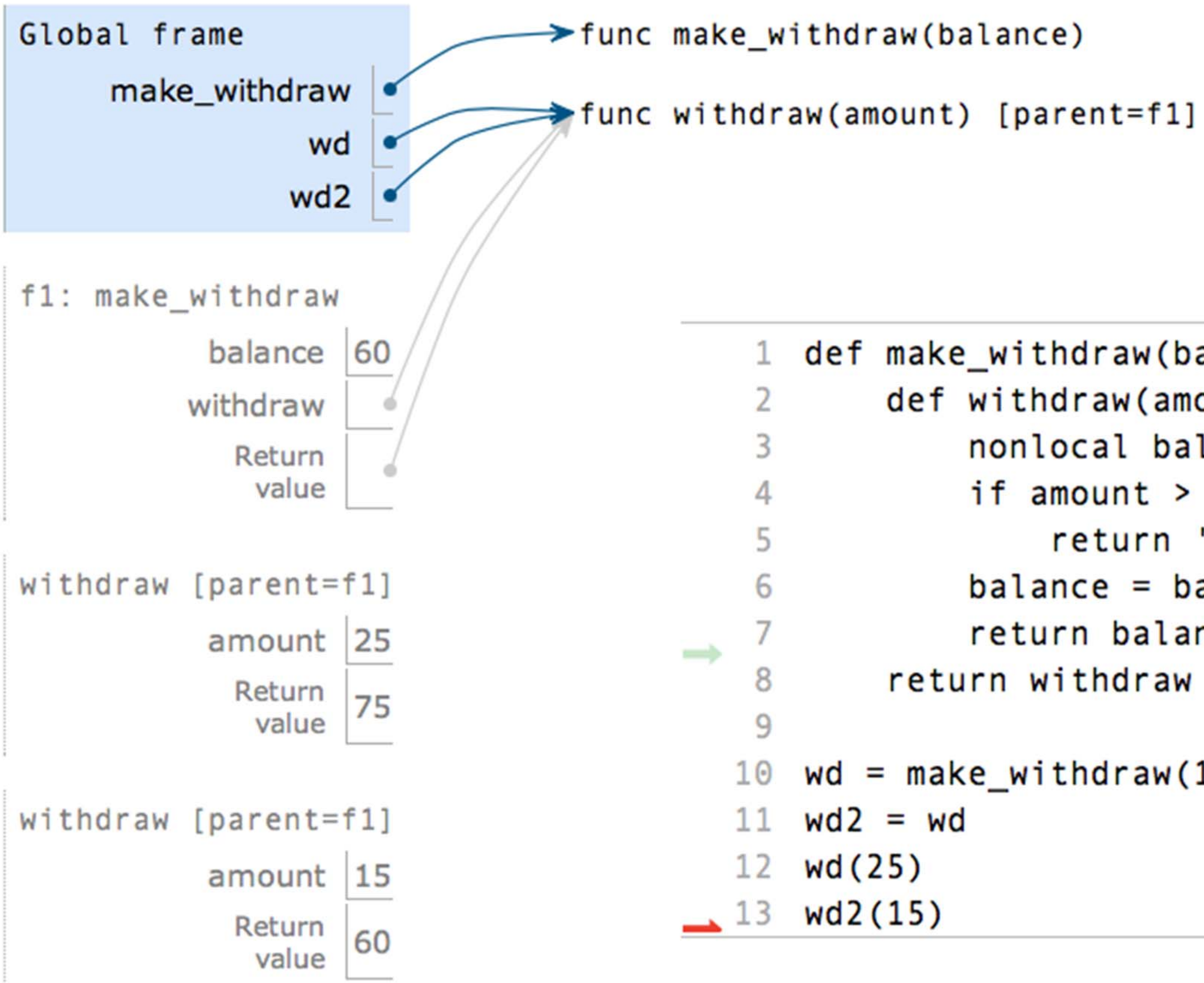



```python
def make_withdraw(balance):
    def withdraw(amount):
        nonlocal balance
        if amount > balance:
            return 'Insufficient funds'
        balance = balance - amount
        return balance
    return withdraw

wd = make_withdraw(100)
wd2 = make_withdraw(100)
wd(25)
wd2(15)
```

Example: http://goo.gl/glTyB

Multiple References to a Withdraw Function

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wd = make_withdraw(100)
wd2 = wd
wd(25)
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Example: http://goo.gl/X2qG9

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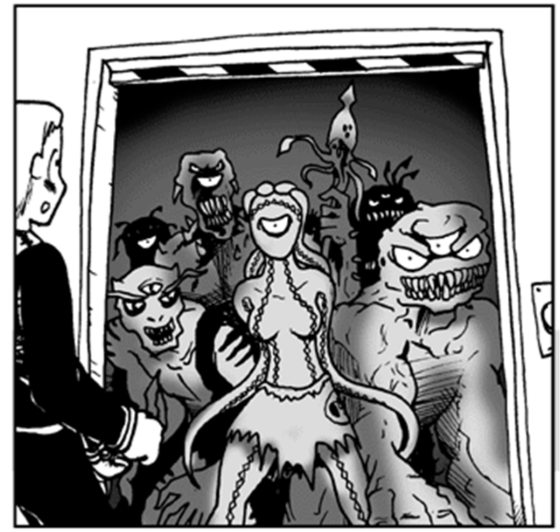

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