Lecture 8: Mutability

Computational Concepts Toolbox
- Data type: values, literals, operations, expressions, Call expression
- Variables
- Assignment Statement
- Sequences: tuple, list
- Dictionaries
- Data structures
- Tuple assignment
- Function Definition Statement
- Conditional Statement
  - Iteration: list comp, for, while
- Lambda function expr.
- Higher Order Functions
  - Functions as Values
  - Functions with functions as argument
  - Assignment of function values
- Higher order function patterns
  - Map, Filter, Reduce
  - Function factories – create and return functions
- Recursion
  - Linear, Tail, Tree
- Abstract Data Types: Mutability

Review: C.O.R.E concepts
- Compute
- Operations
- Representation
- Evaluation
- Abstract Data Type
- Abstraction Barrier

Review: Creating an Abstract Data Type
- Operations
  - Express the behavior of objects, invariants, etc
  - Implemented (abstractly) in terms of Constructors and Selectors for the object
- Representation
  - Constructors & Selectors
  - Implement the structure of the object
- An abstraction barrier violation occurs when a part of the program that can use the higher level functions uses lower level ones instead
  - At either layer of abstraction
- Abstraction barriers make programs easier to get right, maintain, and modify
  - Few changes when representation changes

Dictionaries – by example
- Constructors:
  - `dict( hi=32, lo=17)`
  - `dict({'hi', '212'}, 'lo', 32), {17, 3})`
  - `{ 'w', 'y': 2, 3:4 }`
  - `{wd:len(wd) for wd in "The quick brown fox".split()}`
- Selectors:
  - `water[ 'lo' ]`
  - `<dict>.keys(), .items(), .values()`
  - `<dict>.get(key [, default] )`
- Operations:
  - `in, not in, len, min, max`
  - `'lo' in water`
- Mutators:
  - `water[ 'lo' ] = 33`

Objects
- An Abstract Data Type consist of data and behavior bundled together to abstract a view on the data
- An object is a concrete instance of an abstract data type.
- Objects can have state
  - mutable vs immutable
- Next lectures: Object-oriented programming
  - A methodology for organizing large programs
  - So important it is supported in the language (classes)
- In Python, every value is an object
  - All objects have attributes
  - Manipulation happens through methods
- Functions do one thing (well)
  - Object do a collection of related things with respect to certain types of data

Review: Creating an Abstract Data Type
- Operations
- Representation
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- Operations:
  - `in, not in, len, min, max`
  - `'lo' in water`
- Mutators:
  - `water[ 'lo' ] = 33`
**Mutability**

- Immutable – the value of the object cannot be changed
  - integers, floats, booleans
  - strings, tuples
- Mutable – the value of the object can...
  - Lists
  - Dictionaries

```python
>>> alist = [1, 2, 3, 4]
>>> alist
[1, 2, 3, 4]
>>> alist[2]
3
>>> alist[2] = 'elephant'
>>> alist
[1, 2, 'elephant', 4]
```

**From value to storage...**

- A variable assigned a compound value (object) is a reference to that object.
- Mutable object can be changed but the variable(s) still refer to it

```python
x = [1, 2, 3]
y = 6
```

**Mutation makes sharing visible**

```python
>>> alist = [1, 2, 3, 4]
>>> adict = {'a':1, 'b':2}
```

**Sharing**

- Global frame
- Grid:

**Copies, ‘is’ and ‘==’**

```python
>>> alist = [1, 2, 3, 4]
>>> blist = alist          # assignment refers to same object
>>> alist is blist         # to same object
True
```

**Are these ‘mutations’?**

```python
def reverse(seq):
    rev = []
    for x in seq:
        rev = [x] + rev
    return rev
```

- A) Yes, both
- B) Only sum
- C) Only reverse
- D) None of them

**Solution:**

D) No change of seq
Creating mutating ‘functions’

• Pure functions have referential transparency
• Result value depends only on the inputs
  – Same inputs, same result value
• Functions that use global variables are not pure
• Higher order function returns embody state
• They can be “mutating”

```python
>>> counter = -1
>>> def count_fun():
...     global counter
...     counter += 1
...     return counter
...     return counter

>>> count_fun()
0
>>> count_fun()
1
```

How do I make a second counter?

```python
>>> def make_counter():
...     counter = -1
...     def counts():
...         nonlocal counter
...         counter +=1
...         return counter
...     return counts
...     return counter

>>> count_fun = make_counter()
>>> count_fun()
0
>>> count_fun()
1
>>> nother_one = make_counter()
>>> nother_one()
0
>>> count_fun()
2
```

Creating mutable objects

• Follow the ADT methodology, enclosing state within the abstraction

```python
def account(name, initial_deposit):
    return (name, initial_deposit)
def account_name(acct):
    return acct[0]
def account_balance(acct):
    return acct[1]
def deposit(acct, amount):
    return (acct[0], acct[1]+amount)
def withdraw(acct, amount):
    return (acct[0], acct[1]-amount)

>>> my_acct = account('David Culler', 175)
>>> my_acct
('David Culler', 175)
>>> deposit(my_acct, 35)
('David Culler', 210)
>>> account_balance(my_acct)
175
```

```python
def account(name, initial_deposit):
    return {'Name' : name, 'Number': 0, 'Balance' : initial_deposit}
def account_name(acct):
    return acct['Name']
def account_balance(acct):
    return acct['Balance']
def account_number(acct):
    return acct['Number']
def deposit(acct, amount):
    acct['Balance'] += amount
    return acct['Balance']
def withdraw(acct, amount):
    acct['Balance'] -= amount
    return acct['Balance']

>>> my_acct = account('David Culler', 100)
>>> my_acct
{'Name': 'David Culler', 'Balance': 100, 'Number': 1001}
>>> my_acct['Number']
1001
```

```python
def account(name, initial_deposit, account_number_seed):
    global account_number_seed
    account_number_seed += 1
    return {'Name' : name, 'Number': account_number_seed, 'Balance' : initial_deposit}
def account_name(acct):
    return acct['Name']
def account_balance(acct):
    return acct['Balance']
def account_number(acct):
    return acct['Number']
def deposit(acct, amount):
    acct['Balance'] += amount
    return acct['Balance']
def withdraw(acct, amount):
    acct['Balance'] -= amount
    return acct['Balance']

>>> my_acct = account('David Culler', 175)
>>> my_acct
{'Name': 'David Culler', 'Balance': 175, 'Number': 1001}
>>> my_acct
{'Name': 'David Culler', 'Balance': 210, 'Number': 1002}
>>> account_balance(my_acct)
175
```

Useless bank account

```python
def account(name, initial_deposit): return (name, initial_deposit)
def account_name(acct):
    return acct[0]
def account_balance(acct):
    return acct[1]
def deposit(acct, amount):
    return (acct[0], acct[1]+amount)
def withdraw(acct, amount):
    return (acct[0], acct[1]-amount)

>>> my_acct = account('David Culler', 175)
>>> my_acct
('David Culler', 175)
>>> deposit(my_acct, 35)
('David Culler', 210)
>>> account_balance(my_acct)
175
```

Bank account using dict

```python
def account(name, initial_deposit):
    return {'Name' : name, 'Number': 0, 'Balance' : initial_deposit}
def account_name(acct):
    return acct['Name']
def account_balance(acct):
    return acct['Balance']
def deposit(acct, amount):
    acct['Balance'] += amount
    return acct['Balance']
def withdraw(acct, amount):
    acct['Balance'] -= amount
    return acct['Balance']

>>> my_acct = account('David Culler', 175)
>>> my_acct
{'Name': 'David Culler', 'Balance': 175, 'Number': 1001}
```

State for a class of objects

```python
def account(name, initial_deposit, account_number_seed):
    global account_number_seed
    account_number_seed += 1
    return {'Name' : name, 'Number': account_number_seed, 'Balance' : initial_deposit}
def account_name(acct):
    return acct['Name']
def account_balance(acct):
    return acct['Balance']
def account_number(acct):
    return acct['Number']
def deposit(acct, amount):
    acct['Balance'] += amount
    return acct['Balance']
def withdraw(acct, amount):
    acct['Balance'] -= amount
    return acct['Balance']

>>> my_acct = account('David Culler', 175)
>>> my_acct
{'Name': 'David Culler', 'Balance': 175, 'Number': 1001}
>>> deposit(my_acct, 35)
{'Name': 'David Culler', 'Balance': 210, 'Number': 1002}
```

```python
def account(name, initial_deposit, account_number_seed):
    global account_number_seed
    account_number_seed += 1
    return {'Name' : name, 'Number': account_number_seed, 'Balance' : initial_deposit}
def account_name(acct):
    return acct['Name']
def account_balance(acct):
    return acct['Balance']
def account_number(acct):
    return acct['Number']
def deposit(acct, amount):
    acct['Balance'] += amount
    return acct['Balance']
def withdraw(acct, amount):
    acct['Balance'] -= amount
    return acct['Balance']

>>> my_acct = account('David Culler', 175)
>>> my_acct
{'Name': 'David Culler', 'Balance': 175, 'Number': 1001}
>>> deposit(my_acct, 35)
{'Name': 'David Culler', 'Balance': 210, 'Number': 1002}
```
Hiding the object inside

```python
account_number_seed = 1000
accounts = []

def account(name, initial_deposit):
global account_number_seed
global accounts
account_number_seed += 1
new_account = {'Name': name, 'Number': account_number_seed, 'Balance': initial_deposit}
accounts.append(new_account)
return len(accounts)-1

def deposit(acct, amount):
    account = accounts[acct]
    account['Balance'] += amount
    return account['Balance']

def account_by_number(number):
    for account, index in zip(accounts, range(len(accounts))):
        if account['Number'] == number:
            return index
    return -1
```

>>> my_acct = account('David Culler', 100)
>>> my_acct
0
>>> account_number(my_acct)
1001
>>> your_acct = account("Fred Jones", 475)
>>> your_acct
1
>>> account_name(your_acct)
'Fred Jones'

Hiding the object inside

```python
account_number_seed = 1000
accounts = []

def account(name, initial_deposit):
global account_number_seed
global accounts
account_number_seed += 1
new_account = {'Name': name, 'Number': account_number_seed, 'Balance': initial_deposit}
accounts.append(new_account)
return account_number_seed

def _get_account(number):
    for account in accounts:
        if account['Number'] == number:
            return account
    return None

def account_name(acct):
    return _get_account(acct)['Name']
```

>>> my_acct = account('David Culler', 100)
>>> your_acct = account("Fred Jones", 475)
>>> nother_acct = account("Wilma Flintstones", 999)
>>> account_name(your_acct)
'Fred Jones'
>>> remove_account(my_acct)
>>> account_name(your_acct)
'Wilma Flintstones'

Hazard Beware

```python
def remove_account(acct):
global accounts
accounts = accounts[0:acct] + accounts[acct+1:]
```

A better way ...

```python
account_number_seed = 1000
accounts = []

def account(name, initial_deposit):
global account_number_seed
global accounts
account_number_seed += 1
new_account = {'Name': name, 'Number': account_number_seed, 'Balance': initial_deposit}
accounts.append(new_account)
return account_number_seed

def _get_account(number):
    for account in accounts:
        if account['Number'] == number:
            return account
    return None

def account_name(acct):
    account = accounts[acct]
    if account['Number'] == number:
        return account['Name']
    return None
```

Solutions for the Wandering Mind

Consider the following simple Python code:
```
x = input("Enter a number between 0 and 1:"")
for i in range(10):
x = -x**2 + 4*x
print x
```
Run the program...

Input: 0.5 Output: 1.534...
Input: 0.51 Output: 0.007...
Input: 0.511 Output: 0.688...
Input: 0.512 Output: 2.103...
Input: 0.5109 Output: 0.577...
Small changes in the input: Large changes in the output! (butterfly effect)
Solutions for the Wandering Mind

Plot the function implemented by the code.
- Could you predict using sampling (e.g., interpolate from the results of inputs 0, 0.25, 0.5, 0.75, 1)?
  No. The program is not predictable in the input variable.
- Could you predict using calculus (e.g., using the derivative of f(x)=x^2+4x)?
  No. Recursive application of f changes it to chaotic behavior.
- Could a neural network learn the function, given enough (input, output) tuples as training data?
  Unlikely. A 10-layer deep network can be shown to be able to represent the function but is unlikely to learn using current methods due to reliance on calculus for neural network training.

Thoughts for the Wandering Mind

Consider the following Python3 code:

```python
z=\%r:print(\%r)\:'print_\%r
```

What does it do?
Can you find other ways to do the same?