Computational Structures in Data Science

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Lecture 7
Abstract Data Types

Computational Concepts Toolbox

- Data type: values, literals, operations,
  - e.g., int, float, string
- Expressions, Call expression
- Variables
- Assignment Statement
- Sequences: tuple, list
  - indexing
- Data structures
- Tuple assignment
- Call Expressions
- Function Definition Statement
- Conditional Statement

- Iteration:
  - data-driven (list comprehension)
  - control-driven (for statement)
  - while statement
- Higher Order Functions
  - Functions as Values
  - Functions with functions as argument
  - Assignment of function values
- Recursion
- Lambda - function valued expressions

Announcements

- Midterm Tonight!
- Monday 10/21 7-9pm, 155 Dwinelle
- 1 page, double-sided handwritten cheat sheet

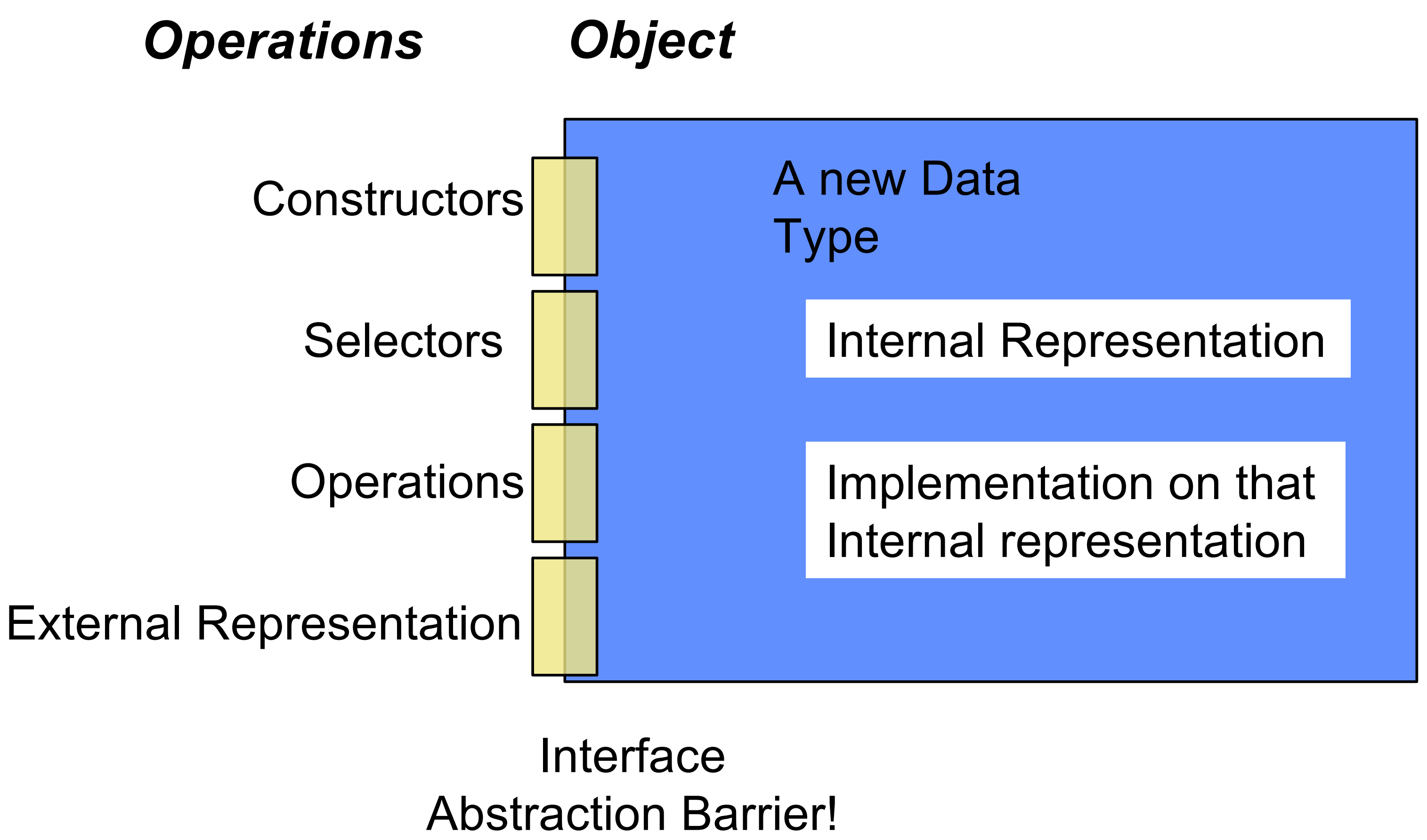
Today's Lecture

- Abstract Data Types
  - More use of functions!
  - Value in documentation and clarity
- New Python Data Types
  - Dictionaries, a really useful too!

Why ADTs?

- "Self-Documenting"
  - contact_name(contact)
    - » Vs contact[0]
  - "0" may seem clear now, but what about in a week? 3 months?
- Change your implementation
  - Maybe today it's just a Python List
  - Tomorrow: It could be a file on your computer; a database in web

Abstract Data Type



Creating Abstractions

- **Compound values combine other values together**
  - **date: a year, a month, and a day**
  - **geographic position: latitude and longitude**

- **• Data abstraction lets us manipulate compound values as units**
- **Isolate two parts of any program that uses data:**
  - **How data are represented (as parts)**
  - **How data are manipulated (as units)**
- **Data abstraction: A methodology by which functions enforce an abstraction barrier between *representation* and *use***

Reminder: Lists

- **Lists**
  - Constructors:
    - » `list( … )`
    - » `[ <exps>,…  ]`
    - » `[<exp> for <var> in <list> [ if <exp> ] ]`
  - Selectors: `<list> [ <index or slice> ]`
  - Operations: `in, not in, +, *, len, min, max`
    - » Mutable ones too (but not yet)

A Small ADT

```
def point(x, y): # constructor
      return [x, y]

x = lambda point: point[0] # selector
y = lambda point: point[1]

def distance(p1, p2): # Operator
      return ((x(p2) - x(p1)**2 + (y(p2) -
y(p1))**2) ** 0.5

origin = point(0, 0)
my_house = point(5, 5)
campus = point(25, 25)
distance_to_campus = distance(my_house, campus)
```

Creating an Abtract Data Type

- **Constructors & Selectors**
- **Operations**
  - Express the behavior of objects, invariants, etc
  - Implemented (abstractly) in terms of Constructors and Selectors for the object
- **Representation**
  - 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

Clicker ?: Changing Representations?

Assuming we update our selectors, what are valid representations for our `point(x, y)` ADT?

Currently `point(1, 2)` is represented as `[1, 2]`

- A) `[y, x] # [2, 1]`
- B) `“X: ” + str(x) + “ Y: ” + str(y)`
  `# “X: 1 Y: 2”`
- C) `str(x) + “ ” + str(y) # “1 2”`
- D) All of the above
- E) None of the above

An Abstract Data Type: Key-Value Pair

- Collection of key-Value bindings
  - Key : Value
- Many real-world examples
  - Dictionary, Directory, Phone book, Course Schedule, Facebook Friends, Movie listings, …

Given some Key, What is the value associated with it?

Key-Value ADT

- Constructors
  - kv_empty: create an empty KV
  - kv_add: add a key:value binding to a KV
  - kv_create: create a KV from a list of key,value tuples
- Selectors
  - kv_items: list of (key,value) tuple in KV
  - kv_keys: list of keys in KV
  - kv_values: list of values in KV
- Operations
  - kv_len: number of bindings
  - kv_in: presence of a binding with a key
  - kv_display: external representation of KV

A little application

```
phone_book_data = [
    ("Christine Strauch", "510-842-9235"),
    ("Frances Catal Buloan", "932-567-3241"),
    ("Jack Chow", "617-547-0923"),
    ("Joy De Rosario", "310-912-6483"),
    ("Casey Casem", "415-432-9292"),
    ("Lydia Lu", "707-341-1254")
]


phone_book = pb_create(phone_book_data)

print("Jack Chows's Number: ", pb_get(phone_book, "Jack Chow"))

print("Area codes")
area_codes = list(map(lambda x:x[0:3], pb_numbers(phone_book)))
print(area_codes)
```

A Layered Design Process

- Build the application based entirely on the ADT interface
  - Operations, Constructors and Selectors
- Build the operations in ADT on Constructors and Selectors
  - Not the implementation representation
- Build the constructors and selectors on some concrete representation

Example 1

- **KV represented as list of (key, value) pairs**

Dictionaries

- Lists, Tuples, Strings, Range
- Dictionaries
  - Constructors:
    - » dict(<list of 2-tuples>)
    - » dict(<key>=<val>, ...) # like kwargs
    - » { <key exp>:<val exp>, … }
    - » { <key>:<val> for <iteration expression> }
  - Selectors: <dict> [<key>]
    - » <dict>.keys(), .items(), .values()
    - » <dict>.get(key [, default])
  - Operations:
    - » Key in, not in, len, min, max
    - » <dict>[<key>] = <val>

Dictionary Example

```
In [1]: text = "Once upon a time"
        d = {word : len(word) for word in text.split()}
        d

Out[1]: {'Once': 4, 'a': 1, 'time': 4, 'upon': 4}

In [2]: d['Once']

Out[2]: 4

In [3]: d.items()

Out[3]: [('a', 1), ('time', 4), ('upon', 4), ('Once', 4)]

In [4]: for (k,v) in d.items():
            print(k,"=>",v)

        ('a', '=>', 1)
        ('time', '=>', 4)
        ('upon', '=>', 4)
        ('Once', '=>', 4)

In [5]: d.keys()

Out[5]: ['a', 'time', 'upon', 'Once']

In [6]: d.values()

Out[6]: [1, 4, 4, 4]
```

Clicker ?: Dictionaries

- **What is the result of the final expression?**

```
my_dict = { ‘course’: ’CS 88’, semester = ‘Fall’ }
my_dict[‘semester’] = ’Spring’

my_dict[‘semester’]
```

A) ‘Fall’
B) ‘Spring’
C) Error

Limitations

- **Dictionaries are unordered collections of key-value pairs**
- Dictionary keys have two restrictions:
  - A key of a dictionary cannot be a list or a dictionary (or any *mutable type*)
  - Two keys cannot be equal; There can be at most one value for a given key

This first restriction is tied to Python's underlying implementation of dictionaries

The second restriction is part of the dictionary abstraction

If you want to associate multiple values with a key, store them all in a sequence value

Beware

- **Built-in data type `dict` relies on mutation**
  - **Clobbers the object, rather than "functional" – creating a new one**
- **Throws an errors of key is not present**
- **We will learn about mutation shortly**

Example 3

- KV represented as dict

C.O.R.E concepts

Abstract Data Type (Operations, Representation)

Compute	Perform useful computations treating objects abstractly as whole values and operating on them.
Operations	Provide operations on the abstract components that allow ease of use – independent of concrete representation.
Representation	Constructors and selectors that provide an abstract interface to a concrete representation
Evaluation	Execution on a computing machine

Abstraction Barrier

Building Apps over KV ADT

```
friend_data = [
    ("Christine Strauch", "Jack Chow"),
    ("Christine Strauch", "Lydia Lu"),
    ("Jack Chow", "Christine Strauch"),
    ("Casey Casem", "Christine Strauch"),
    ("Casey Casem", "Jack Chow"),
    ("Casey Casem", "Frances Catal Buloan"),
    ("Casey Casem", "Joy De Rosario"),
    ("Casey Casem", "Casey Casem"),
    ("Frances Catal Buloan", "Jack Chow"),
    ("Jack Chow", "Frances Catal Buloan"),
    ("Joy De Rosario", "Lydia Lu"),
    ("Joy De Lydia", "Jack Chow")
    ]
```

- **Construct a table of the friend list for each person**