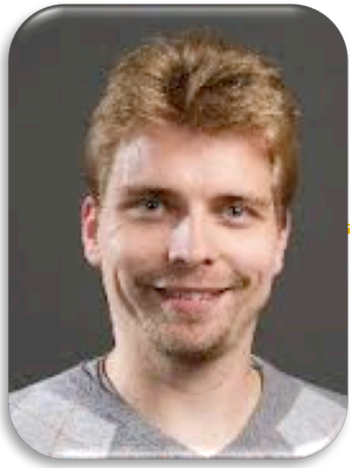

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Computational Structures in Data Science

Lecture 7: Lambda & Abstract Data Types

March 4, 2019

http://inst.eecs.berkeley.edu/~cs88

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

Universality

- Everything that can be computed, can be computed with what you know now.

- Poorly or Well

Evolution of Programming Languages

Mother Tongues

Tracing the roots of computer languages through the ages

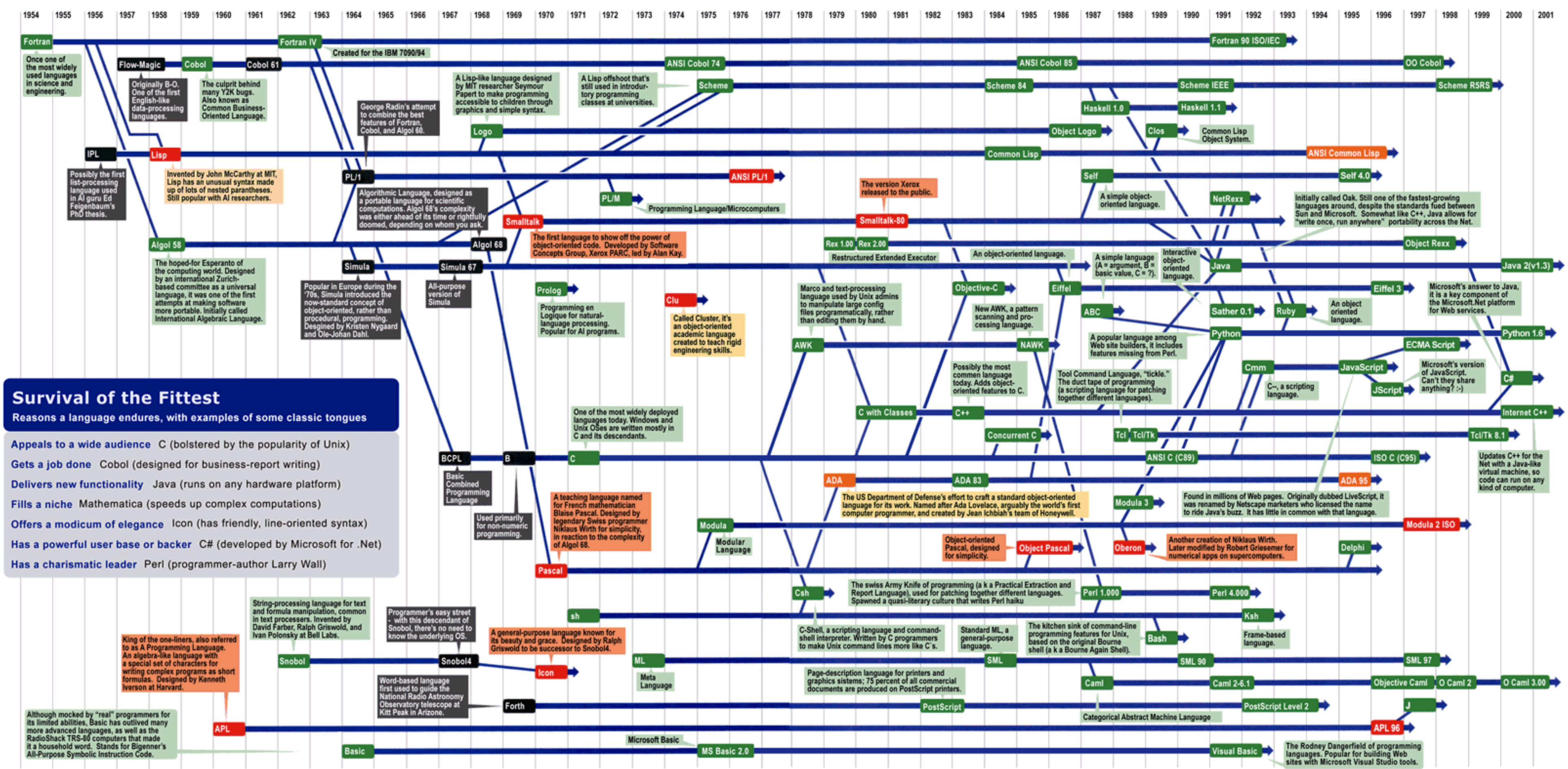
Just like half of the world's spoken tongues, most of the 2,300-plus computer programming languages are either endangered or extinct. As powerhouses C/C++, Visual Basic, Cobol, Java and other modern source codes dominate our systems, hundreds of older languages are running out of life.

An ad hoc collection of engineers-electronic lexicographers, if you will-aim to save, or at least document the lingo of classic software. They're combing the globe's 9 million developers in search of coders still fluent in these nearly forgotten lingua frangas. Among the most endangered are Ada, APL, B (the predecessor of C), Lsp, Oberon, Smalltalk, and Simula.

Code-raker Grady Booch, Rational Software's chief scientist, is working with the Computer History Musuem in Silicon Valley to record and, in some cases, maintain languages by writing new compilers so our ever-changing hardware can grok the code. Why bother? "They tell us about the state of software practice, the minds of their inventors, and the technical, social, and economic forces that shaped history at the time," Booch explains. "They'll provide the raw material for software archaeologists, historians, and developers to learn what worked, what was brilliant, and what was an utter failure." Here's a peek at the strongest branches of programming's family tree. For a nearly exhaustive rundown, check out the Language List at *HTTP://www.informatik.uni-freiburg.de/Java/misc/lang_list.html.* - Michael Mendeno

Key

- 1954 — Year Introduced
- **Active:** thousands of users
- **Protected:** taught at universities; compilers available
- **Endangered:** usage dropping off
- **Extinct:** no known active users or up-to-date compilers
- Lineage continues



Sources: Paul Boutin; Brent Hailpern, associate director of computer science at IBM Research; The Retrocomputing Museum; Todd Proebsting, senior researcher at Microsoft; Gio Wiederhold, computer scientist, Stanford University

Today's Lecture

http://bit.ly/cs88-fa18-L07

- Lambda
- New Concept: Abstract Data Type
- Example Illustration: key-value store
  – Internal representation 1: list of pair
  – Internal representation 2: pair of lists (including zip intro)
- A simple application over the KV interface
- New language construct: dict
- Key-Value store 3: dict
- Optional Exercises

http://datahub.berkeley.edu/user-redirect/interact?account=data-8&repo=cs-connector&branch=gh-pages&path=ADT

lambda

- **Function expression**
  - **"anonymous" function creation**
  - **Expression, not a statement, no return or any other statement**

lambda <arg or arg_tuple> : <expression using args>

```
inc = lambda v : v + 1
```

```
def inc(v):
    return v + 1
```

Lambda Examples

```
>>> sort([1,2,3,4,5], lambda x: x)
    [1, 2, 3, 4, 5]

>>> sort([1,2,3,4,5], lambda x: -x)
    [5, 4, 3, 2, 1]

>>> sort([(2, "hi"), (1, "how"), (5, "goes"), (7, "I")],
           lambda x:x[0])
[(1, 'how'), (2, 'hi'), (5, 'goes'), (7, 'I')]

>>> sort([(2, "hi"), (1, "how"), (5, "goes"), (7, "I")],
          lambda x:x[1])
    [(7, 'I'), (5, 'goes'), (2, 'hi'), (1, 'how')]

>>> sort([(2,"hi"),(1,"how"),(5,"goes"),(7,"I")],
          lambda x: len(x[1]))
    [(7, 'I'), (2, 'hi'), (1, 'how'), (5, 'goes')]
```

http://cs88-website.github.io/assets/slides/adt/mersort.py

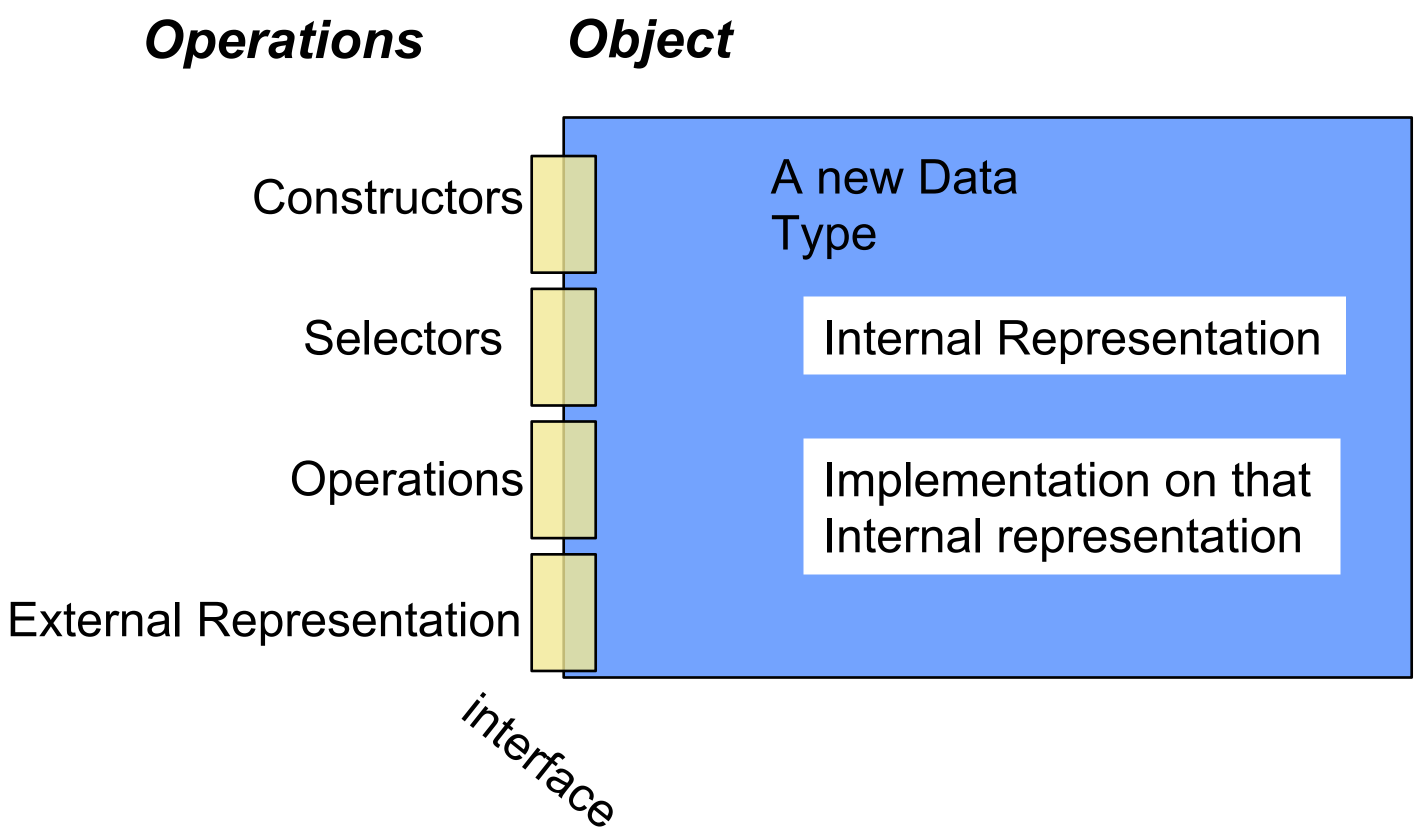
Lambdas

```
>>> def inc_maker(i):
...     return lambda x:x+i
...
>>> inc_maker(3)
<function inc_maker.<locals>.<lambda> at 0x10073c510>

>>> inc_maker(3)(4)
7
>>> map(lambda x:x*x, [1,2,3,4])
<map object at 0x1020950b8>

>>> list(map(lambda x:x*x, [1,2,3,4]))
[1, 4, 9, 16]
>>>
```

Abstract Data Type



Examples Data Types You have seen

- **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)
- **Tuples**
  - Constructors:
    - `tuple( … )`
    - `( <exps>,… )`
  - Selectors: `<tuple> [ <index or slice> ]`
  - Operations: `in, not in, +, *, len, min, max`

More “Built-in” Examples

- **Lists**
- **Tuples**
- **Strings**
  - Constructors:
    - » `str( … )`
    - » `“<chars>”, ‘<chars>’`
  - Selectors: `<str> [ <index or slice> ]`
  - Operations: `in, not in, +, *, len, min, max`
- **Range**
  - Constructors:
    - » `range(<end>), range(<start>,<end>), range(<start>,<end>,<step>)`
  - Selectors: `<range> [ <index or slice> ]`
  - Operations: `in, not in, len, min, max`

A New Abstract Data Type: Key-Value

- **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

```
from kv_pairs import *

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 = kv_create(phone_book_data)

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

print("Area codes")
area_codes = list(map(lambda x:x[0:3], kv_values(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**

Example 2

- KV represented as pair of lists – (keys, values)

zip

- **Zip (like a zipper) together k lists to form a list of k-tuples**

```
In [19]: # introduction to zip
         list(zip(['a', 'b', 'c'], [1, 2, 3]))

Out[19]: [('a', 1), ('b', 2), ('c', 3)]

In [20]: [a+b for (a,b) in zip([1, 2, 3], [10, 20, 30])]

Out[20]: [11, 22, 33]

In [16]: def zip2(a, b):
             return [(a[i], b[i]) for i in range(min(len(a), len(b)))]

In [18]: zip2(['a', 'b', 'c'], [1, 2, 3])

Out[18]: [('a', 1), ('b', 2), ('c', 3)]
```

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> }

```
>>> {x:y for x,y in zip(["a","b"],[1,2])}
{'a': 1, 'b': 2}
```

  - 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]
```

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**

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**

Example: make_friends

```
def make_friends(friendships):
    friends = kv_empty()
    for (der, dee) in friendships:
        if not kv_in(friends, der):
            friends = kv_add(friends, der, [dee])
        else:
            der_friends = kv_get(friends, der)
            friends = kv_add(kv_delete(friends, der),
                                 der, [dee] + der_friends)
    return friends
```

C.O.R.E concepts

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

Abstract Data Type

Abstraction Barrier

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

Exercises

- Read 2.2, reread 2.3, esp 2.3.6
- Modify all three KV ADTs to avoid ever adding duplicate keys
- Create and ADT for a shopping cart containing a collection of products and their order count
  - `cart()` – creates an empty cart
  - `cart_add(ct, product)` – returns a new cart that includes an additional order of product, or the first one
  - `cart_print(ct)` – prints the contents of the cart
  - `cart_products(ct)` – returns the list of products ordered
  - `cart_items(ct)` – returns list of (product, count)
  - `cart_remove(ct, product)` - returns a new cart with product removed
- Create an 1D array abstraction (like np.array) using lists as representation

Thoughts 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
```

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)?
- Could you predict using calculus (e.g., using the derivative of $f(x)=-x^2+4x$)?
- Could a neural network learn the function, given enough (input, output) tuples as training data?