CptS 355- Programming Language Design

Python

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WASHINGTON STATE UNIVERSITY

World Class. Face to Face.

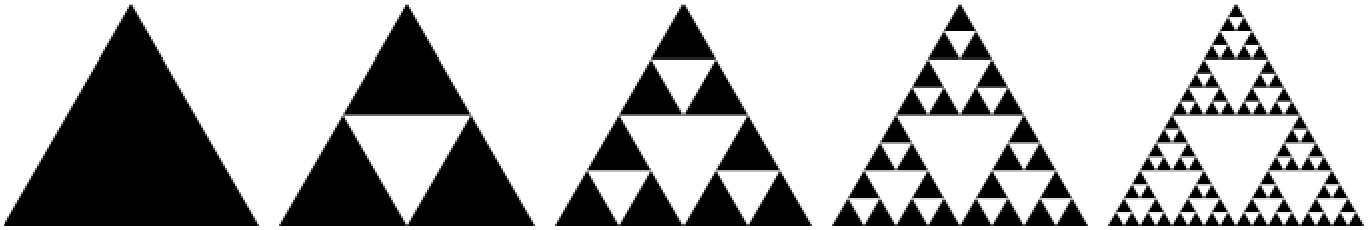
Python

TO-DO:

- Download and install Python
  - https://www.python.org/downloads/
  - Install Python3 (not Python 2.7) -- latest Python 3 version is Python3.6.0
- Python comes with the IDLE
  - IDLE is Python’s Integrated Development and Learning Environment.
- Also install PyCharm (optional)
  - https://www.jetbrains.com/pycharm/download/#section=windows
  - PyCharm is a full featured IDE for Python developed by JetBrains.
- Start the Python tutorial
  - https://docs.python.org/3/tutorial/
  - Sections 1 through 6

Recursive Functions

- A function is called recursive if the body of that function calls itself, either directly or indirectly.



Iteration vs Recursion

- Iteration is a special case of recursion
  - Example: factorial
    - 4! = 4*3*2*1

	Iterative Control:	Recursion:
MATH:	$n! = \prod_{i=1}^{n} i$	$n! = \begin{cases} 1 & \text{if } n = 1 \\ n \cdot (n-1)! & \text{otherwise} \end{cases}$
Names:	`n, total, k`	`n`

Using iterative control:

```
def fact_iter(n):
    total, k = 1, 1
    while k <= n:
        total, k = total*k, k+1
    return total
```

Using recursion:

```
def fact(n):
    if n == 1:
        return 1
    return n * fact(n-1)
```

Iteration vs Recursion

- Example: reverse

Recursion:

```
def reverse(s):
    if s == '':
        return s
    return reverse(s[1:]) + s[0]
```

Using iterative Control:

```
def reverse2(s):
    r = ''
    i = 0
    while i < len(s):
        r = s[i] + r
        i = i + 1
    return r
```

Higher Order Functions- map, reduce, filter

- map/transform
  - map takes a unary function and a list and produces a same-sized list of mapped/transformed values based on substituting each value with the result of calling the parameter function on it.
  - For example,

```
def sq(x):
    return x**2        #i.e.,x²
L = [i for i in range(0,5)]
map( sq, L )
```

Higher Order Functions- map, reduce, filter

- map/transform
  - Here is a simple implementation of the map function.

```
def map(f,alist):
    answer = []
    for v in alist:    # generate each value v in a list
       answer.append(f(v)) # put (v) in a list to return
    return answer
```

  - Python's built-in map function is more general and faster.

```
map ((lambda x,y: x+y),[1,2,3,4],[5,6,7,8])
```

returns ?

Higher Order Functions- map, reduce, filter

- filter
  - Filter takes a predicate (a unary function returning a bool) and some list of values and produces a list with only those values for which the predicate returns True (or a value that is interpreted as True).

  - For example:

```
filter((lambda x: x>0), [-4,3,1,-2,3,-5,1,9,0])
```

returns ?

Higher Order Functions- map, reduce, filter

- filter
  - Here is a simple implementation of the filter function.

```
def filter(p,alist):
    answer = []
    for v in alist:
        if p(v):
            answer.append(v)
    return answer
```

  - Python's built-in filter function is faster

Higher Order Functions- map, reduce, filter

- reduce (fold or accumulate)
  - Reduce takes a binary function and some list of values and reduces or accumulates these results into a single value.
  - For example:

```
from functools import reduce
reduce((lambda x,y : x+y), [i for i in range(1,100)] )
reduce( max, [4,2,-3,8,6] )
```

- Unlike `map` and `filter` (which are defined and automatically imported from the builtins module) we must import reduce from the `functools` module explicitly.

Higher Order Functions- map, reduce, filter

- reduce
  - Here is a simple implementation of the reduce function.

```
def reduce(f,alist):
    if alist == []:
        return None

    answer = alist[0]
    for v in alist[1:]:
        answer = f(answer,v)
    return answer
```

Higher Order Functions- map, reduce, filter

Additional remarks:

- The map, filter, and reduce function work on anything that is iterable (which list and tuple are, but so are sets, dicts, and even strings).
  - We can call `map(lambda x : x.upper(), 'Hello')` to produce the list `['H','E','L','L','O']`.
- The map and filter functions built into Python produce an iterable as a result (not a real list). So if we call:

```
print(map(lambda x : x.upper(),'Hello'))
```

prints `<map object at 0x02DFFE30>`

We need to create a list from that iteratable object, i.e.,

```
print(list(map(lambda x : x.upper(), 'Hello')))
```

Python prints: `['H','E','L','L','O']`

The Class Statement

```
class <name> <base class>
    <suite>
```

- A class statement creates a new class and binds that class to `<name>` in the current environment.
- Statements in the `<suite>` create attributes of the class.
- As soon as an instance is created, it is passed to `__init__`, which is an attribute of the class.

```
class Account(object):
    def __init__(self, account_holder):
        self.balance = 0
        self.holder = account_holder
```

The Class Statement

```
>>> a = Account('Jim')
>>> a.holder
'Jim'
>>> a.balance
0
```

- Classes are "called" to construct instances.
- The constructor `__init__` is called on newly created instances.
- The new object is bound to `__init__`'s first parameter, `self`.

```
class Account(object):
    def __init__(self, account_holder):
        self.balance = 0
        self.holder = account_holder
```

Object Identity

- Every object that is an instance of a user-defined class has a unique identity

```
>>> a = Account('Sam')
>>> b = Account('Sean')
```

- Identity testing is performed by "is" and "is not" operators:

```
>>> a is b
False
>>> a is not b
True
```

- Binding an object to a new name using assignment does not create a new object:

```
>>> c = a
>>> c is a
True
```

Class Methods

- Methods are defined in the suite of a class statement

```
class Account(object):
    def __init__(self, account_holder):
        self.balance = 0
        self.holder = account_holder

    def deposit(self, amount):
        self.balance = self.balance + amount
        return self.balance

    def withdraw(self, amount):
        if amount > self.balance:
            return 'Insufficient funds'
        self.balance = self.balance - amount
        return self.balance
```

- These `def` statements create function objects as always, but their names are bound as attributes of the class.

Invoking Methods

- All invoked methods have access to the object via the self parameter, and so they can all access and manipulate the object's state.

```
class Account(object):
    …
    def deposit(self, amount):
        self.balance = self.balance + amount
        return self.balance
```

two arguments

- Dot notation automatically supplies the first argument to a method.

Invoked with one argument

```
>>> sam_account = Account('Sam')
>>> sam_account.deposit(100)
100
```

Methods and Functions

- Python distinguishes between:
  - *function objects*, which we have been creating since the beginning of the course, and
  - *bound method objects*, which couple together a function and the object on which that method will be invoked

```
>>> type(Account.deposit)
<class 'function'>
>>> type(sam_account.deposit)
<class 'method'>

>>> Account.deposit(sam_account, 1001)
1011
>>> sam_account.deposit(1000)
2011
```

Sequential Data

- Some of the most interesting real-world problems in computer science center around sequential data.
  - DNA sequences
  - Web and cell-phone traffic streams
  - The social data stream
  - Series of measurements from instruments on a robot
  - Stock prices, weather patterns

Working with Sequences

- Memory
  - Each item must be explicitly represented
  - Even if all can be generated by a common formula or function

- Up-front computation
  - Have to compute all items up-front
  - Even if using them one by one
  - Can’t be infinite

- Why care about “infinite” sequences?
  - They’re everywhere!
  - Internet and cell phone traffic
  - Instrument measurement feeds, real-time data
  - Mathematical sequences

Iterators: An abstraction for sequential data

- Iterators
  - Store how to compute items instead of items themselves
  - Give out one item at a time
  - Save the next until asked (lazy evaluation)

- Compared with sequences
  - Length not explicitly defined
  - Element selection not supported
    - Sequences -- random access
    - Iterators -- sequential access
  - No up-front computation of all items
  - Only one item stored at a time
  - CAN be infinite

Python Iterators

- The Python iterator interface includes two attributes:
  - The `__next__` attribute compute the next element in an underlying series.
    - Calls to `__next__` advance the position of the iterator.
    - Python signals that the end of an underlying series has been reached by raising a `StopIteration` exception during a call to `__next__`.
  - The `__iter__` message simply returns the iterator.
    - It is useful for providing a common interface to iterators and sequences

Iterator Example - 1

```
class Letters(object):
   def __init__(self):
      self.current = 'a'

   def __next__(self):
      if self.current > 'd':
         raise StopIteration
      result = self.current
      self.current = chr(ord(result)+1)
      return result

   def __iter__(self):
      return self
```

```
>>> letters = Letters()
>>> letters.__next__()
'a'
>>> letters.__next__()
'b'
>>> letters.__next__()
'c'
>>> letters.__next__()
'd'
>>> letters.__next__()
Traceback (most recent call last):
  File "<stdin>", line 1, in
<module>
  File "<stdin>", line 12, in next
StopIteration
```

- A `Letters` instance can only be iterated through once.
- Once its `__next__()` method raises a `StopIteration` exception, it continues to do so from then on.
- There is no way to reset it; one must create a new instance.

Iterator Example - 2

```
class Evens(object):
    def __init__(self):
        self.current = 2

    def __next__(self):
        result = self.current
        self.current += 2
        return result

    def __iter__(self):
        return self
```

```
evenNums= Evens()
n = 10
while n > 0:
    item = evenNums.__next__()
    print(item)
    n -= 1
```

This prints even numbers 2 through 20.

- Iterators also allow us to represent infinite series by implementing a `__next__` method that never raises a `StopIteration` exception

Native Python Iterators

- Python natively supports iterators
- The Iterator interface in python:

  `__iter__` : should return an iterator object

  `__next__` : should return a value OR raise `StopIteration` when end of sequence is reached on all subsequent calls

- In Python, most of built-in containers like: list, tuple, string, dictionary, etc. are iterables.
  - The `iter()` function (which in turn calls the `__iter__()` method) returns an iterator from them.

`for` statements and Iterators

- The iterator returned by invoking the `__iter__` method of counts is bound to a name `i` so that it can be queried for each element in turn

```
>>> counts = [1, 2, 3]
>>> for item in counts:
        print(item)
```

=

```
>>> i = counts.__iter__()
>>> try:
        while True:
            item = i.__next__()
            print(item)
    except StopIteration:
        pass
```

Python Generators

- The `Letters` iterator can be implemented much more compactly using a generator function.

Iterator version

```
class Letters(object):
   def __init__(self):
      self.current = 'a'

   def __next__(self):
      if self.current > 'd':
         raise StopIteration
      result = self.current
      self.current = chr(ord(result)+1)
      return result

   def __iter__(self):
      return self
```

Generator version

```
def letters(start, finish):
   current = start
   while current <= finish:
      yield current
      current = chr(ord(current)+1)
```

Yield: a built-in flow-control statement

```
def letters(start, finish):
    current = start
    while current <= finish:
        yield current
        current = chr(ord(current)+1)
```

Generator function.
When called, creates a Generator object

```
>>> g = letters('a', 'd')
>>> g
<generator instance at..>
```

Automatically creates:

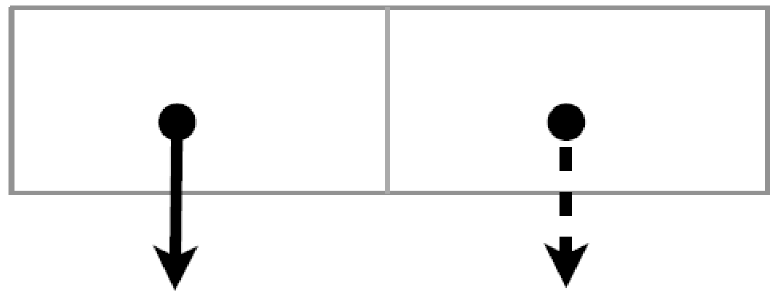
```
g.__iter__()
g.__next__()
```

The generator function:

- Does nothing at first
- When `__next__()` is called, starts
- Goes through executing body of function
- Pauses at "`yield`" -- returns value
- All local state is preserved
- When `__next__()` is called, resumes.

Streams: A Lazy Structure

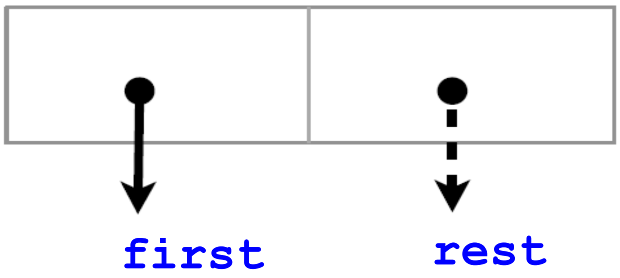
- Nested delayed evaluation



`first`
now, explicit

`rest`
store how to compute it
compute when asked

Streams

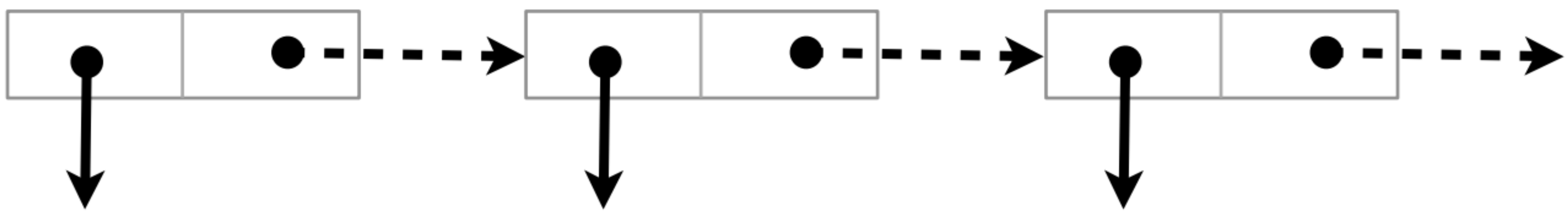



```
class Stream(object):
    def __init__(self, first, compute_rest, empty= False):
        self.first = first
        self._compute_rest = compute_rest
        self.empty = empty
        self._rest = None
        self._computed = False

    @property
    def rest(self):
        assert not self.empty, 'Empty streams have no rest.'
        if not self._computed:
            self._rest = self._compute_rest()
            self._computed = True
        return self._rest

empty_stream = Stream(None, None, True)
```

Sequential data as nested streams



- Nest streams inside each other
- Only compute one element of a sequence at a time
- Example: The positive integers (all of them)

```
def make_integer_stream(first=1):

   def compute_rest():
      return make_integer_stream(first+1)

   return Stream(first, compute_rest)
```

```
>>> N = make_integer_stream(1)
>>> N.first
1
>>> N = N.rest
>>> N.first
2
>>> N.rest.first
3
```

Streams in Action

- Initially, `L=make_integer_stream(1)` consists of one item with

  ```
  L.first = 1, L._computed = False
  ```
- When we fetch `L.rest`, it becomes

  ```
    L.first = 1, L._computed = True;
    L._rest = make_integer_stream(2),
  # where
    L._rest.first = 2, L2._rest._computed = False
  ```
- And so forth.

```
def make_integer_stream(first=1):
    def compute_rest():
        return make_integer_stream(first+1)
    return Stream(first, compute_rest)
```

Stream Examples

- Double the stream

```
def double_stream(s):
   if s.empty:
      return s
   def compute_rest():
      return double_stream(s.rest)
   return Stream(2*(s.first), compute_rest)
```

Stream Examples

- Combine streams

```
def combine_streams(fn, s0, s1):
    def compute_rest():
        return combine_streams(fn, s0.rest, s1.rest)
    if s0.empty or s1.empty:
        return empty_stream
    else:
        return Stream(fn(s0.first, s1.first), compute_rest)
```