CS61A Lecture 25
Delayed Sequences

Jom Magrotker
UC Berkeley EECS

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COMPUTER SCIENCE IN THE NEWS

JULY 30, 2012, 7:05 PM | 3 Comments

Bots Raise Their Heads Again on Facebook

By SOMINI SENGUPTA

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Any business that advertises on Facebook wants eyes looking at its ads and then fingers clicking on them. Facebook gets paid based on how many clicks that ad receives – effectively, on how many users it can send to a particular brand.

Kimihiro Hoshino/Agence France-Presse — Getty Images

http://bits.blogs.nytimes.com/2012/07/30/bots-raise-their-heads-again-on-facebook/?ref=technology

TODAY

- Review Iterators
- Review Streams
- Another way of defining a sequence of values using delayed evaluation: Generators

REVIEW: ITERATORS

Python natively supports iterators.

Iterators are objects that give out one item at a time and save the next item until they are asked: this evaluation is *lazy*.

Review: Iterators

Python has the following *interface* for iterators:

- The `__iter__` method should return an iterator object.
- The `__next__` method should:
  - return a value, *or*
  - raise a `StopIteration` when the end of the sequence is reached, and on all subsequent calls.

REVIEW: ITERATORS

What does a `for`-loop do "under the hood"?

```
for x in iterable:
    function(x)
```

is equivalent to

```
iterator = iterable.__iter__()
try:
    while True:
        element = iterator.__next__()
        function(element)
except StopIteration as e:
    pass
```

Create an iterator.

Try to get an element from the iterator.

Apply the function on the element.

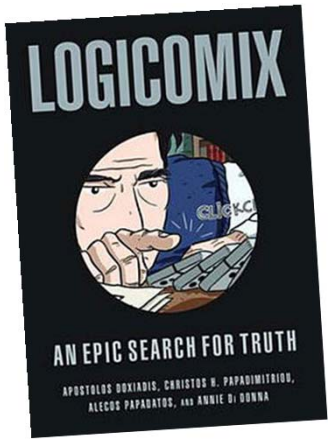
If we could not get an element, we *catch* the `StopIteration` exception and do not apply the function.

Announcements

- Homework 12 due **Today**.
- Homework 13 due **Friday**.
  - Out later today.
  - Includes Py, Streams, Iterators, and Generators
  - Also includes the Project 4 contest.
- Project 4 due **Tuesday, August 7**.
  - Partnered project, in two parts.
  - Twelve questions, so *please start early*!
  - Two extra credit questions.

ANNOUNCEMENTS

- Project 4 contest due **Friday, August 3**.
  - Generate recursive art using Scheme.
  - Prizes awarded in two categories:
    - **Featherweight**: At most 128 words of Scheme.
    - **Heavyweight**: At most 1024 words of Scheme.
  - One question on homework 14 will ask you to vote for your favorite drawing.
  - Extra credit point to the top 3 in each category.
  - *Prize*: *Logicomix*



http://upload.wikimedia.org/wikipedia/en/thumb/6/60/Logicomix_cover.jpg/250px-Logicomix_cover.jpg

ANNOUNCEMENTS: MIDTERM 2

- Scores available on `glookup`.
  - Average: 39.9, standard deviation: 6.9.
- Solutions are available online.
  - Regrade requests due **Tuesday, August 7**.
- Post-midterm de-stress potluck this week.
  - Food and games.
  - Come and leave when you want.

ANNOUNCEMENTS: FINAL

- Final is **Thursday, August 9**.
  - *Where*? 1 Pimentel.
  - *When*? 6PM to 9PM.
  - *How much*? *All* of the material in the course, from June 18 to August 8, will be tested.
- Closed book and closed electronic devices.
- One 8.5” x 11” ‘cheat sheet’ allowed.
- No group portion.
- We will get back to you this week if you have conflicts and have told us. If you haven’t told us yet, please *let us know*.

Review: Streams

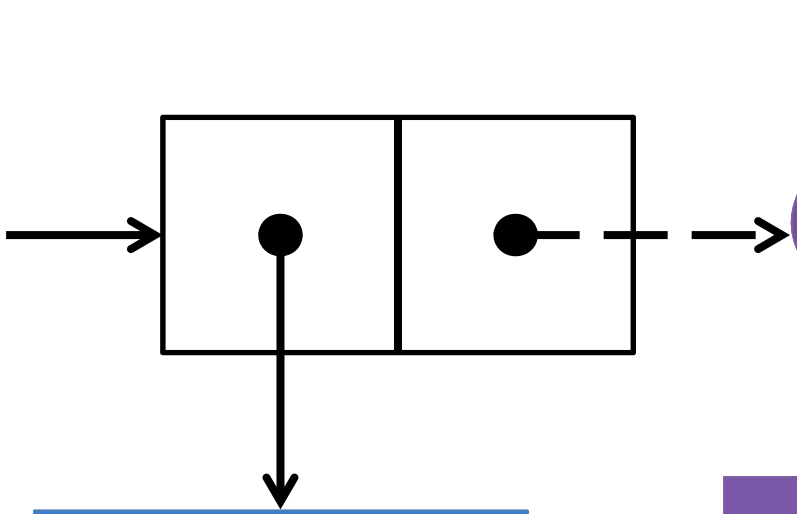
Streams are *lazily computed* recursive lists that represent (potentially infinite) sequences.

Like a recursive list, a stream is a *pair*:

the first element is *the first element* of the stream,

the second element stores how to compute the rest of the stream when needed, and will compute it when asked.

Review: Streams

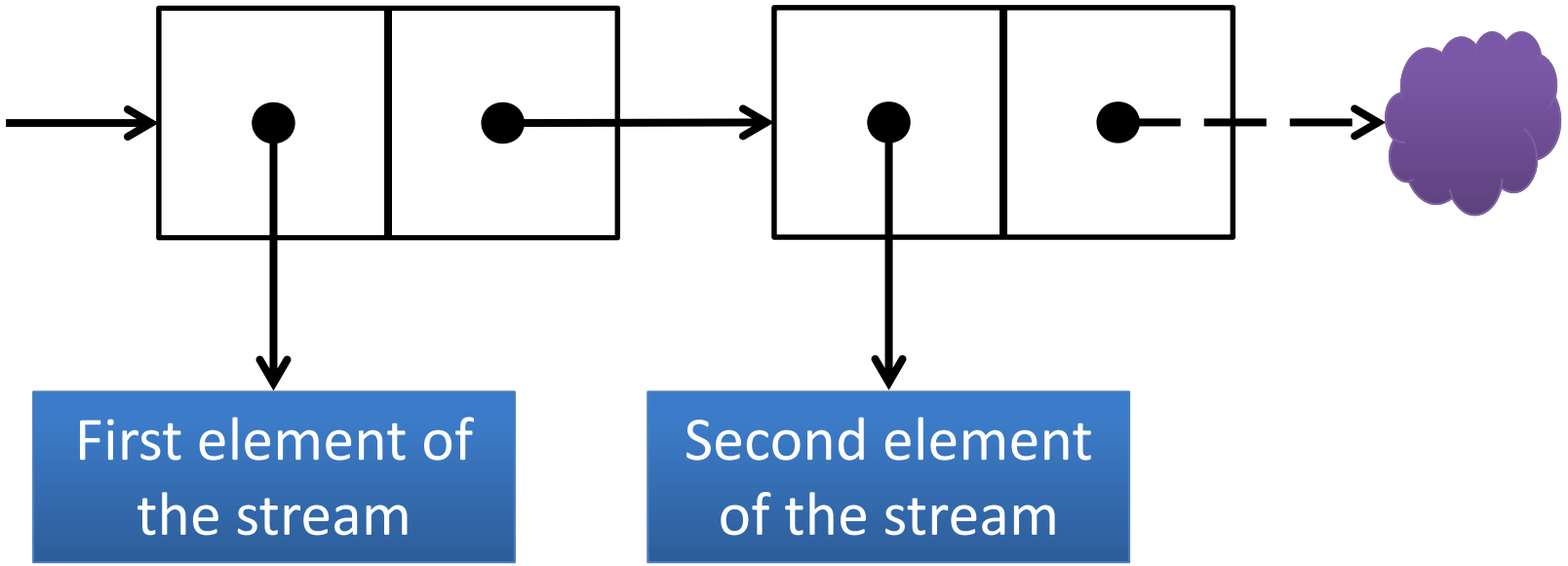


How to compute the rest of the stream.

First element of the stream

The stream "promises" to compute the rest when you ask for it.

Review: Streams



Review: 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
```

First element of the stream

Is this stream empty?

How to compute the rest of the stream when needed

Has the rest of this stream already been computed?

Review: Streams

```
class Stream:
    ...
    @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

Stream.the_empty_stream = Stream(None, None, True)
```

If the rest of the stream has not been computed yet...

... compute it and remember the result.

Practice: Streams

What are the first 9 elements of the stream s defined below?

```
>>> s = Stream(1, lambda: add_streams(s, s))
```

???

Practice: Streams

What are the first 9 elements of the stream s defined below?

```
>>> s = Stream(1, lambda: add_streams(s, s))
```

Position	0	1	2	3	4	5	6	7	8
Computation	1	S + S							
S	1	2	4	8	16	32	64	128	256

EXAMPLE: STREAMS

Say I wanted to take two input streams and return a stream which alternates between items from each of the input streams. Let's call this `interleave(s1, s2)`.

The way it should behave is like this:

```
>>> ones = Stream(1, lambda: ones)
>>> ints = Stream(1,
                  lambda: add_streams(ones,
                                      ints))
>>> mixed = interleave(ones, ints)
>>> show_stream(mixed)
1, 1, 1, 2, 1, 3, 1, 4, 1, 5, ...
```

EXAMPLE: STREAMS

Say I wanted to take two input streams and return a stream which alternates between items from each of the input streams. Let's call this `interleave(s1, s2)`.

How do we implement it?

The result of interleaving s1 and s2 is...

the first item of s1...

followed by items of s2 interleaved with the remaining items of s1.

```
def interleave(s1, s2):
    return Stream(s1.first,
                  lambda: interleave(s2,
                                     s1.rest))
```

PRACTICE: STREAMS

Say I wanted to create `ab_stream`, which is a stream that contains all strings created using some number of "a" and "b" strings, including the empty string "". Using `stream_map` and `interleave`, create `ab_stream`.

```
add_a = lambda x: x + "a"
add_b = lambda x: x + "b"

ab_stream = Stream("", ???)
```

PRACTICE: STREAMS

Say I wanted to create `ab_stream`, which is a stream that contains all strings created using some number of "a" and "b" strings, including the empty string "". Using `stream_map` and `interleave`, create `ab_stream`.

```
add_a = lambda x: x + "a"
add_b = lambda x: x + "b"

ab_stream = \
Stream("",
  lambda: interleave(stream_map(add_a, ab_stream),
                     stream_map(add_b, ab_stream)))
```

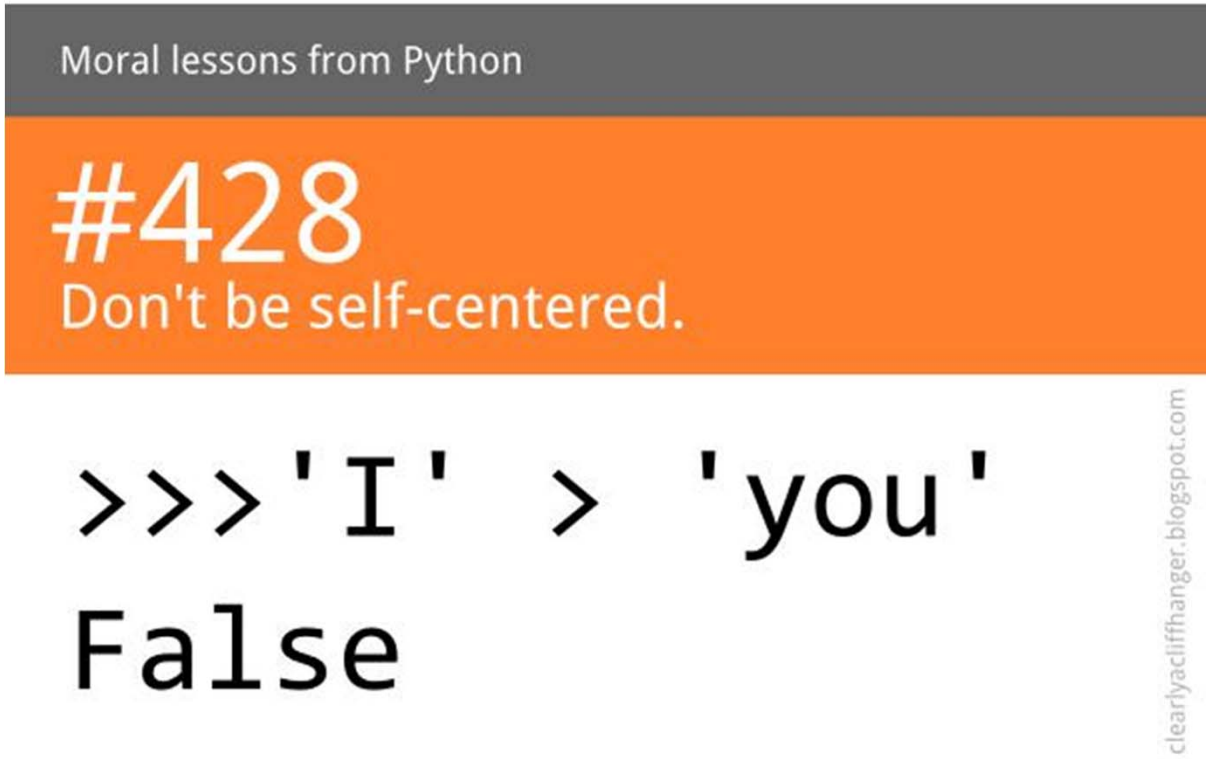
Start with the empty string.

items where we add an "a"...

Alternate between...

items where we add a "b"...

BREAK



http://2.bp.blogspot.com/-V5UttslRzf8/TpfcgrHag-I/AAAAAAAAAc4/pHGoq7zyMNE/s1600/2011-10-14_py-self-centered.jpg

GENERATORS

Generators are an elegant and concise way to define an iterator. Example: Make an iterator that returns the sequence [0], [0, 1], [0, 1, 2], …

```
def triangle():
    lst, cur = [], 0
    while True:
        yield lst + [cur]
        lst, cur = lst + [cur], cur + 1

for lst in triangle():
    print(lst)
```

GENERATORS: EXPLAINED

...wait, what?

Generators use the **`yield`** keyword.

When a function definition includes a yield statement, Python knows that a call to the function should return a generator object.

GENERATORS: EXPLAINED

To produce each item, Python starts executing code from the body of the function.

If a yield statement is reached, Python stops the function there and **yields** the value as the next value in the sequence. When the generator is asked for *another* value, the function **resumes** executing on the line after where it left off.

When the function returns, then there are no more values "in" the generator.

GENERATORS

```
>>> def triangle():
...     lst, cur = [], 0
...     while True:
...         yield lst + [cur]
...         lst, cur = lst + [cur], cur + 1
...
>>> for lst in triangle():
...     print(lst)
...
[0]
[0, 1]
[0, 1, 2]
```

Another Example: Generators

Suppose I wanted to make a new generator based on another generator. Let's write `generator_map`, which takes a function and a generator and produces the generator which yields the results of applying the function to each item yielded by the input generator.

```
def ints():
    cur = 1
    while True:
        yield cur
        cur += 1

for item in generator_map(lambda x: 2 * x, ints()):
    print(item)
2
4
6...
```

Another Example: Generators

Suppose I wanted to make a new generator based on another generator. Let's write `generator_map`, which takes a function and a generator and produces the generator which yields the results of applying the function to each item yielded by the input generator.

```
def generator_map(fn, gen):
    for item in gen:
        yield fn(item)
```

Go through each item in the original generator.

Yield each result of applying `fn` onto an item from the original generator.

Practice: Generators

Write the generator `generator_filter`, which takes a predicate, `pred`, and a generator, `gen`, and creates a generator which yields the items yielded by `gen` for which `pred` returns `True`.

```
>>> odd = lambda x: x % 2 == 1
>>> for item in generator_filter(odd, ints()):
...     print(item)
...
1
3
5...
```

Practice: Generators

Write the generator `generator_filter`, which takes a predicate, `pred`, and a generator, `gen`, and creates a generator which yields the items yielded by `gen` for which `pred` returns `True`.

```
def generator_filter(pred, gen):
    for item in gen:
        if pred(item):
            yield item
```

For each item in the original generator...

yield the item if pred(item) is True.

Conclusion

- In lazy evaluation, expressions are not evaluated until they are needed.
- Python has built-in support for iterators, or objects that give back a new value each time you ask.
- Streams allow us to represent infinite sequences using delayed evaluation.
- Streams are pairs whose first element is the first element of the stream, and whose second element stores how the rest of the stream can be calculated.
  - This way, only as much of the stream is created as is needed.
- Generators are a convenient and elegant way to define new iterators using yield statements.
- ***Preview:*** Declarative Programming