

## CS61A Lecture 25 Delayed Sequences

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## COMPUTER SCIENCE IN THE NEWS

### Bots Raise Their Heads Again on Facebook

By SOMBI SENGUPTA

FACEBOOK  
TWITTER  
GOOGLE+  
E-MAIL  
SHARE  
PRINT

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.



<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__() ← Create an iterator.
try:
    while True:
        element = iterator.__next__() ← Try to get an element
        function(element) ← Apply the function on the element.
except StopIteration as e:
    pass ← 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*



## 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*.



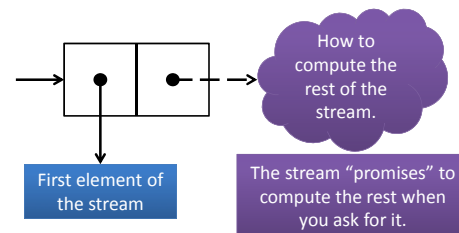
## REVIEW: STREAMS

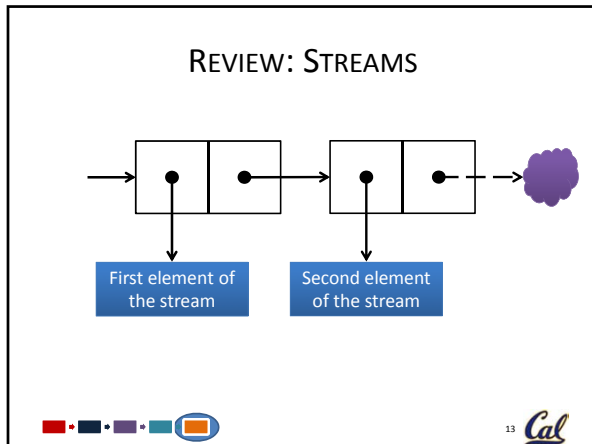
**Streams** are *lazily computed* recursive lists that represent (potentially infinite) sequences.

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





### 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
```

Annotations:
 

- First element of the stream (points to `first`)
- Is this stream empty? (points to `empty=False`)
- How to compute the rest of the stream when needed (points to `compute_rest`)
- Has the rest of this stream already been computed? (points to `_rest`)

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### 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
```

Annotations:
 

- If the rest of the stream has not been computed yet... (points to `if not self._computed:`)
- ... compute it and remember the result. (points to `self._rest = self._compute_rest()`)

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

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### PRACTICE: STREAMS

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

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

???

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### 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	<b>S + S</b>							
<b>S</b>	1	2	4	8	16	32	64	128	256

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### 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, ...
```

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## 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?

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



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## 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("", ???)
```



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## 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)))
```



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## BREAK

Moral lessons from Python

# #428

Don't be self-centered.

```
>>>'I' > 'you'
False
```

[http://2.bp.blogspot.com/-V5UtsiR2f8/7PfcgrHagI/AAAAAAAAAC4/pHG0q7yMNE/1600/2011-10-14\\_py-self-centered.jpg](http://2.bp.blogspot.com/-V5UtsiR2f8/7PfcgrHagI/AAAAAAAAAC4/pHG0q7yMNE/1600/2011-10-14_py-self-centered.jpg)



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## 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)
```



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## 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.



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## 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.



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## 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]
```



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## 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...
```



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## 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.



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## 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...
```



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## 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.



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## 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

