CS61A Lecture 36

Soumya Basu

UC Berkeley

April 15, 2013
Announcements

- HW11 due Wednesday
- Scheme project, contest out
Our Sequence Abstraction
Recall our previous sequence interface:
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• A sequence has a finite, known length
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Problems?
• Infinite sequences- primes, positive integers
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Problems?

- Infinite sequences- primes, positive integers
- Really large sequences- all Twitter posts, votes in a presidential election
The Sequence of Primes
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Think about the sequence of prime numbers:
The Sequence of Primes

Think about the sequence of prime numbers:

• What’s the first one?
The Sequence of Primes

Think about the sequence of prime numbers:

• What’s the first one?

• The next one?
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• The next one?
• The next one?
• How about the next two?
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• The next one?
• The next one?
• How about the next two?
• How about the 105th prime?
Think about the sequence of prime numbers:

- What’s the first one?
- The next one?
- The next one?
- How about the next two?
- How about the 105th prime?
  - Our sequence abstraction would give an instant answer
Implicit Sequences
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• We compute each of the elements on demand.
Implicit Sequences

• We compute each of the elements on demand.

• Don’t explicitly store each element
Implicit Sequences

- We compute each of the elements on demand.
- Don’t explicitly store each element
- Called an **implicit sequence**.
A Python Example
Example: The `range` class represents a regular sequence of integers
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\text{length} = \max \left( \left\lfloor \frac{\text{end} - \text{start}}{\text{step}} \right\rfloor, 0 \right)
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\text{length} = \max \left( \left\lfloor \frac{\text{end} - \text{start}}{\text{step}} \right\rfloor, 0 \right)
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\[
\text{elem}(k) = \text{start} + k \cdot \text{step} \quad (\text{for } k \in [0, \text{length}])
\]
A Python Example

Example: The `range` class represents a regular sequence of integers

- The range is represented by three values: `start`, `end`, and `step`.
- The length and elements are computed on demand.
- Constant space for arbitrarily long sequences.

\[
\text{length} = \max \left( \left\lceil \frac{\text{end} - \text{start}}{\text{step}} \right\rceil, 0 \right)
\]

\[
\text{elem}(k) = \text{start} + k \cdot \text{step} \quad (\text{for } k \in [0, \text{length}])
\]
class Range(object):
    def __init__(self, start, end=None, step=1):
        if end is None:
            start, end = 0, start
        self.start = start
        self.end = end
        self.step = step

    def __len__(self):
        return max(0, ceil((self.end - self.start) / self.step))

    def __getitem__(self, k):
        if k < 0:
            k = len(self) + k
        if k < 0 or k >= len(self):
            raise IndexError('index out of range')
        return self.start + k * self.step
The Iterator Interface
An iterator is an object that can provide the next element of a (possibly implicit) sequence.
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The iterator interface has two methods:
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• `__next__(self)` returns the next element in the sequence.
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  - If no next, raises `StopIteration` exception.
The Iterator Interface

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The iterator interface has two methods:

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• `__next__(self)` returns the next element in the sequence
  • Next prime, etc.
  • If no next, raises `StopIteration` exception.
class RangeIter(object):
    def __init__(self, start, end, step):
        self.current = start
        self.end = end
        self.step = step
        self.sign = 1 if step > 0 else -1

    def __next__(self):
        if self.current * self.sign >= self.end * self.sign:
            raise StopIteration
        result = self.current
        self.current += self.step
        return result

    def __iter__(self):
        return self
```python
class FibIter(object):
    def __init__(self):
        self.prev = -1
        self.current = 1

    def __next__(self):
        self.prev, self.current = (self.current,
                                  self.prev + self.current)
        return self.current

    def __iter__(self):
        return self
```

Fibonacci
The For Statement
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```
for <name> in <expression>:
    <suite>
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1. Evaluate the header `<expression>`, which yields an iterable object.
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1. Evaluate the header `<expression>`, which yields an iterable object.
2. For each element in that sequence, in order:
   A. Bind `<name>` to that element in the first frame of the current environment.
   B. Execute the `<suite>`
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```python
>>> nums, sum = [1, 2, 3], 0
>>> for item in nums:
    sum += item
>>> sum
6
```
The For Statement

for <name> in <expression>:
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   A. Bind <name> to that element in the first frame of the current environment.
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An iterable object has a method __iter__ that returns an iterator

```python
>>> nums, sum = [1, 2, 3], 0
>>> items = nums.__iter__()
>>> try:
    while True:
        item = items.__next__()
        sum += item
    except StopIteration:
        pass
>>> sum
6
```
Generators and Generator Functions
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• An iterator backed by a function, called a generator function.
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• A function that returns a generator.
• Can tell by looking for the `yield` keyword.
Generators and Generator Functions

Generators:
• An iterator backed by a function, called a **generator function**.

Generator Functions:
• A function that returns a generator.
• Can tell by looking for the **yield** keyword.
• Another example of a **continuation**
Fibonacci Generator

A generator function that lazily computes the Fibonacci sequence:
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```python
def fib_generator():
    yield 0
    prev, current = 0, 1
    while True:
        yield current
        prev, current = current, prev + current
```
Fibonacci Generator

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A generator expression is like a list comprehension, but it produces a lazy generator rather than a list:
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double_fibs = (fib * 2 for fib in fib_generator())
```
def fib_generator():
    yield 0
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    while True:
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        prev, current = current, prev + current
Generator Semantics

def fib_generator():
    yield 0
    prev, current = 0, 1
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Calling a generator function returns an iterator that stores a frame for the function, its body, and the current location in the body
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Calling `next` on the iterator resumes execution of the body at the current location, until a `yield` is reached
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Calling a generator function returns an iterator that stores a frame for the function, its body, and the current location in the body.

Calling **next** on the iterator resumes execution of the body at the current location, until a **yield** is reached.

The yielded value is returned by **next**, and execution of the body is halted until the next call to **next**.
def fib_generator():
    yield 0
    prev, current = 0, 1
    while True:
        yield current
        prev, current = current, prev + current

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Calling `next` on the iterator resumes execution of the body at the current location, until a `yield` is reached.

The yielded value is returned by `next`, and execution of the body is halted until the next call to `next`.

When execution reaches the end of the body, a `StopIteration` is raised.
def map_gen(fn, iterable):
    iterator = iter(iterable)
    while True:
        yield fn(next(iterator))
Map and Filter

def map_gen(fn, iterable):
    iterator = iter(iterable)
    while True:
        yield fn(next(iterator))

def filter_gen(fn, iterable):
    iterator = iter(iterable)
    while True:
        item = next(iterator)
        if fn(item):
            yield item
from itertools import product

def bitstrings():
    """Generate bitstrings in order of increasing size."

    >>> bs = bitstrings()
    >>> [next(bs) for _ in range(0, 8)]
    ['', '0', '1', '00', '01', '10', '11', '000']
    """

    size = 0
    while True:
        tuples = product(('0', '1'), repeat=size)
        for elem in tuples:
            yield ''.join(elem)
        size += 1