Iterators
Iterators, Generators
Iterators, Generators, Coroutines
Iterators – what is the problem?

- Problem: accidentally large intermediary lists

- Example, we want to printout:
  - a stream of positive random numbers $n < 1$ where
  - $\text{abs}(n_{i+1} - n_i) > 0.4$
  - stream stops when $n < 0.1$

How would you do this?
Iterators – 1ˢᵗ attempt

```python
import random

def randomwalk_list():
    last, rand = 1, random.random()  # init candidate elements
    nums = []                        # empty list
    while rand > 0.1:                # threshold terminator
        if abs(last-rand) >= 0.4:   # accept the number
            last = rand
            nums.append(rand)       # add latest candidate to nums
        else:                      # display the rejection
            print '*',              # new candidate
            rand = random.random()  # add the final small element
    nums.append(rand)
    return nums

for num in randomwalk_list():
    print num,
```

We need to generate the entire list before printing any number out!
Iterators – 2nd attempt

import random

def randomwalk_static(last=[1]):
    rand = random.random()
    if last[0] < 0.1:
        return None
    while abs(last[0] - rand) < 0.4:
        print '*',
        rand = random.random()
    last[0] = rand
    return rand

num = randomwalk_static()
while num is not None:
    print num,
    num = randomwalk_static()
Import random

Class randomwalk_iter:

    def __init__(self):
        self.last = 1 # init the prior value
        self.rand = random.random() # init a candidate value

    def __iter__(self):
        return self # simplest iterator creation

    def next(self):
        if self.rand < 0.1: # threshold terminator
            raise StopIteration # end of iteration
        else: # look for usable candidate
            while abs(self.last-self.rand) < 0.4:
                print '*', # candidate's existence
                self.rand = random.random() # new candidate
                self.last = self.rand # update prior value
            return self.rand

For num in randomwalk_iter():
    print num,
What are iterators, really?

- Objects that keep state for traversing an abstract collection
- Closures that get passed around in every next()
- btw, objects and closures are related...
import java.util.Iterator;

class IterExample implements Iterator<Double> {
    private double last = 1;
    private double rand = Math.random();

    public boolean hasNext() {
        return (rand >= 0.1);
    }

    public Double next() {
        if (rand >= 0.1) {
            while (Math.abs(last - rand) < 0.4) {
                System.out.print("* ");
                rand = Math.random();
            }
        }
        last = rand;

        return rand;
    }

    public void remove() {
    }
}
Same iterator in Java

// ...continued
public static void main(String[] args) {
    IterExample it = new IterExample();
    while (it.hasNext())
        System.out.print(it.next() + " ");
}
}
Generators

- Generators are functions that “yield” values every time they are called

```python
def gen123():
    yield 1
    yield 2
    yield 3
```
Generator

```python
import random
def randomwalk_gen():
    last = 1
    rand = random.random()
    while rand > 0.1:
        print '*',
        if abs(last - rand) >= 0.4:
            last = rand
            yield rand
    rand = random.random()
    yield rand

for num in randomwalk_gen():
    print num,
```

Nice here too!
using System;
using System.Collections.Generic;

namespace GenExample {
    class Program {
        static Random random = new Random();

        static IEnumerable<double> RandomWalkGen() {
            double last = 1;
            double rand = random.NextDouble();
            while (rand > 0.1) {
                Console.Write("* ");
                if (Math.Abs(last - rand) >= 0.4) {
                    last = rand;
                    yield return rand;
                }
                rand = random.NextDouble();
            }
            yield return rand;
        }
    }
}
Same generator in C#  

    // ... continued

    static void Main(string[] args)
    {
        foreach (double d in RandomWalkGen())
            Console.Write(d + " ");
    }
}
Generators – the magic “yield”


- Key idea: toggle between 2 continuations: one in the outer code and one in the generator
Generators

- Java: no equivalent
  - must use iterators

- C++: no equivalent
  - But boost library supports them via coroutines

- All other [major] languages have support for them
Coroutines
Coroutines

- Procedures/functions that allow multiple entry points
  - They ‘remember’ the last state of their execution
  - They call on each other as peers rather than caller/callee

- Appropriate scenario:
  - A function that produces a stream of data
  - A function that consumes a stream of data
  - Which one calls which?
Motivating example

### Decompression followed by parsing

```c
/* Decompression code */
while (1) {
    c = getchar();
    if (c == EOF)
        break;
    if (c == 0xFF) {
        len = getchar();
        c = getchar();
        while (len--)
            emit(c);
    } else
        emit(c);
} emit(EOF);
```

```c
/* Parser code */
while (1) {
    c = getchar();
    if (c == EOF)
        break;
    if (isalpha(c)) {
        do {
            add_to_token(c);
            c = getchar();
        } while (isalpha(c));
        got_token(WORD);
    }
    add_to_token(c);
    got_token(PUNCT);
}
```

http://www.chiark.greenend.org.uk/~sgtatham/coroutines.html
Motivating example

Decompression followed by parsing – **option 1: parser calls decompressor**

```c
int decompressor(void) {
    static int repchar;
    static int replen;
    if (replen > 0) {
        replen--;
        return repchar;
    }
    c = getchar();
    if (c == EOF)
        return EOF;
    if (c == 0xFF) {
        replen = getchar();
        repchar = getchar();
        replen--;
        return repchar;
    } else
        return c;
}

/* Parser code */
while (1) {
    c = decompressor();
    if (c == EOF)
        break;
    if (isalpha(c)) {
        do {
            add_to_token(c);
            c = decompressor();
        } while (isalpha(c));
        got_token(WORD);
    }
    add_to_token(c);
    got_token(PUNCT);
}
```
Motivating example

Decompression followed by parsing – **option 2: decompressor calls parser**

```c
/* Decompression code */
while (1) {
    c = getchar();
    if (c == EOF)
        break;
    if (c == 0xFF) {
        len = getchar();
        c = getchar();
        while (len--)
            parser(c);
    } else
        parser(c);
}
parser(EOF);
```

```c
void parser(int c) {
    static enum {
        START, IN_WORD
    } state;
    switch (state) {
    case IN_WORD:
        if (isalpha(c)) {
            add_to_token(c);
            return;
        }
        got_token(WORD);
        state = START;
        /* fall through */
        case START:
            add_to_token(c);
            if (isalpha(c)) state=IN_WORD;
            got_token(PUNCT);
            break;
    }
}
```
int decompressor(void) {
    static int c, len;
    crBegin;
    while (1) {
        c = getchar();
        if (c == EOF)
            break;
        if (c == 0xFF) {
            len = getchar();
            c = getchar();
            while (len--)
                crReturn(c);
        } else
            crReturn(c);
    } else
        crReturn(c);
    crReturn(EOF);
    crFinish;
}

void parser(int c) {
    crBegin;
    while (1) {
        * first char already in c */
        if (c == EOF)
            break;
        if (isalpha(c)) {
            do {
                add_to_token(c);
                crReturn( );
            } while (isalpha(c));
            got_token(WORD);
        }
        add_to_token(c);
        got_token(PUNCT);
        crReturn( );
    } else
        crReturn(c);
    crReturn(EOF);
    crFinish;
}
Motivating example

- Dirty little secrets of this code:
  - Hackery needed because C doesn’t want to do coroutines
  - crBegin, crFinish, crReturn are HORRIBLE macros that I don’t dare to show
Coroutines

- Not just pairs of functions, but any number of functions
- Functions can specify which other function to yield to
- Implementation: stack per coroutine, continuations
- Lightweight alternative to threads
  - No real concurrency, just switching functions
  - Very nice model for processing data streams
- Fell out of favor in the 80s
  - May result in spaghetti code
  - May see a come back