Python Generators, Iterators and Comprehensions

Generators: Motivation

The goal is to conveniently provide a means of ”lazy evaluation”

Lazy vs Eager Evaluation: Definitions

”Lazy Evaluation” means you write an expression or computation at one time, and it is evaluated at a later time – when it becomes necessary.

”Eager Evaluation” means things are evaluated when they're defined.

Iterators: Why do we need them?

Iterators are the underlying protocol used to implement generators.

Usually best avoided in favor of Generators.

Quick Aside: What is the Fibonacci Sequence?

- 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, …
- The first two numbers are defined as 0, 1
- fib(n) = fib(n-1) + fib(n-2)
- Appears in nature: tree branches, leaves on a stem, pinecones, etc.

Generator Example: The Fibonnaci Sequence

```
# works in Python 2 or Python 3
def fibonacci_sequence():
    a, b = 0, 1
    yield a
    while True:
        yield b
        a, b = b, a + b
```

Generator example: Using fibonacci_sequence()

```
# works in Python 2 or Python 3
def gen_for_1_second():
    t0 = time.time()
    for number in fibonacci_sequence():
        print(number)
        t1 = time.time()
        if t1 - t0 >= 1.0:
            break
```

Generator Example: Alternative Means of Use (Python 2)

```
# works with Python 2
def gen_1st_3():
    gen = fibonacci_sequence()
    print(gen.next())
    print(gen.next())
    print(gen.next())
```

Generator Example: Alternative Means of Use (Python 3)

```
# works with Python 3
def gen_1st_3():
    gen = fibonacci_sequence()
    print(next(gen))
    print(next(gen))
    print(next(gen))
```

Iterator: Alternative to a Generator, (Python 3.x) page 1 of 2

```
class fibonacci_sequence:

    def __init__(self):

        self.a = 0

        self.b = 1

        self.first_time = True


    def __iter__(self):

        return self
```

Iterator: Alternative to a Generator, (Python 3.x) page 2 of 2

```
def __next__(self):
    if self.first_time:
        self.first_time = False
        return self.a
    else:
        result = self.b
        self.a, self.b = self.b, self.a + self.b
        return result
```

Generators and Iterators Summary

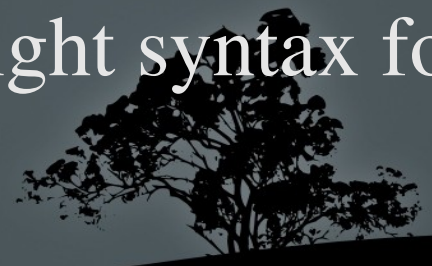
- Lazy evaluation of a sequence
- Generators and Iterators look the same to a caller
- The Generator is simpler to write
- Iterators look different in Python 2 and Python 3
- Generators are often the same in Python 2 and 3

Comprehensions and Generator Expressions – first introduced

- List Comprehensions (2.0)
- Generator Expressions (2.4)
- Dictionary Comprehensions (2.7, 3.0)
- Set Comprehensions (2.7, 3.0)

Comprehensions and Generator Expressions: Purpose

- List Comprehensions – Lightweight syntax for creating lists
- Generator Expressions – Lightweight syntax for creating generators
- Dictionary Comprehensions – Lightweight syntax for creating dictionaries
- Set Comprehensions – Lightweight syntax for creating sets



List Comprehension – Simple Example

```
>>> [2**i for i in range(4)]
[1, 2, 4, 8]
```

Generator Expression – Simple Example

```
>>> (2**i for i in range(4))
<generator object <genexpr> at 0xb7483a2c>
>>> gen = (2**i for i in range(4))
>>> print(list(gen))
[1, 2, 4, 8]
```

List Comprehensions Compared to Generator Expressions - Helpers

```
#!/usr/local/cpython-3.1/bin/python3

def fn(description, x):
  print('%s: %d' % (description, x))
  return x + 1

def main():
  list_comprehension_examples()
  generator_expression_examples()

# main()
```

Sequential List Comprehension Example

```
def list_comprehension_examples():
    list1 = [fn('comprehension 1', x) for x in range(3)]
    list2 = [fn('comprehension 2', x) for x in list1]
    for element in list2:
        print(element)
```

Cascading Generator Expression Example

```
def generator_expression_examples():
    genexp1 = (fn('genexp 1', x) for x in range(3))
    genexp2 = (fn('genexp 2', x) for x in genexp1)
    for element in genexp2:
        print(element)
```

Sequential/Cascading Example Outputs

comprehension 1: 0

comprehension 1: 1

comprehension 1: 2

comprehension 2: 1

comprehension 2: 2

comprehension 2: 3

2

3

4

genexp 1: 0

genexp 2: 1

2

genexp 1: 1

genexp 2: 2

3

genexp 1: 2

genexp 2: 3

4

Dictionary Comprehensions

```
>>> print({i : chr(65+i) for i in range(4)})
{0: 'A', 1: 'B', 2: 'C', 3: 'D'}
```

Set Comprehensions

```
>>> print({chr(i+65) for i in range(4)})
{'A', 'C', 'B', 'D'}
```

A Brief Return to Generators: Bidirectional Generators

- These are basically a generator that's able to accept input from the outside
- Naturally used for ”coroutines” or ”cooperative multitasking”
- Another kind of use follows...

Bidi Generator: Daffy Duck, main

```
def main():
    gen = generator()
    first_time = True
    while True:
        if random.random() < 0.9 or first_time:
            first_time= False
            value = gen.send(None)
            show_reverse = ''
        else:
            show_reverse = ' manual reverse'
            value = gen.send('reverse')
        time.sleep(0.1)
        print '%2d >%s*%s< %s' % (value, (value - 1) * ' ', (10 - value) * ' ', show_reverse)
```

Bidi Generator: Daffy Duck: The Generator

```
def generator():
   position = 1
   direction = 1
   while True:
      received_value = yield position
      position += direction
      assert received_value in [ None, 'reverse' ]
      if received_value == 'reverse' or direction == 1 and position == 10 or
direction == -1 and position == 1:
         direction *= -1
```

Bidi Generator: Daffy Duck: Example Output

1 >* <

2 > * <

3 > * < manual reverse

2 > * <

1 >* <

2 > * <

3 > * <

4 >   * <

5 >   * <

For Further Study

- On the difference between Iterables and Iterators: http://treyhunner.com/2018/02/python-range-is-not-an-iterator

Fini

- We've discussed:
  - Generators
  - Iterators
  - List Comprehensions
  - Generator Expressions
  - Dictionary Comprehensions
  - Set Comprehensions
  - Bidirectional Generators

Questions or Comments?