1 Iterators

An iterator is an object that tracks the position in a sequence of values. It can return an element at a time, and it is only good for one pass through the sequence. The following is an example of a class that implements Python’s iterator interface. This iterator calculates all of the natural numbers one-by-one, starting from zero:

```python
class Naturals():
    def __init__(self):
        self.current = 0

    def __next__(self):
        result = self.current
        self.current += 1
        return result

    def __iter__(self):
        return self
```

An iterator is an object that has a `__next__` and an `__iter__` method.

1.1 __next__

The `__next__` method checks if it has any values left in the sequence; if it does, it computes the next element. To return the next value in the sequence, the `__next__` method keeps track of its current position in the sequence. If there are no more values left to compute, it must raise an exception called `StopIteration`. This signals the end of the sequence.

*Note: the `__next__` method defined in the `Naturals` class does not raise `StopIteration` because there is no “last natural number”.*
1.2 __iter__

The `__iter__` method returns an iterator object. If a class implements both a `__next__` method and an `__iter__` method, its `__iter__` method can simply return `self` as the class itself is an iterator. In fact, the Python docs require that all iterators’ `__iter__` methods must return `self`.

1.3 Implementation

When defining an iterator, you should always keep track of current position in the sequence. In the `Naturals` class, we use `self.current` to save the position.

Iterator objects maintain state. Each successive call to `__next__` will return the next element, which may be different, so `__next__` is considered *non-pure*.

Python has built-in functions called `next` and `iter` that call `__next__` and `__iter__` respectively.

For example, this is how we could use the `Naturals` iterator:

```python
>>> nats = Naturals()
>>> next(nats)
0
>>> next(nats)
1
>>> next(nats)
2
```

1.4 Questions

1. Define an iterator whose $i$th element is the result of combining the $i$th elements of two input iterators using some binary operator, also given as input. The resulting iterator should have a size equal to the size of the shorter of its two input iterators.

```python
>>> from operator import add
>>> evens = IteratorCombiner(Naturals(), Naturals(), add)
>>> next(evens)
0
>>> next(evens)
2
>>> next(evens)
4
```


class IteratorCombiner(object):
    def __init__(self, iterator1, iterator2, combiner):

        def __next__(self):

        def __iter__(self):

2. What is the result of executing this sequence of commands?
   >>> nats = Naturals()
   >>> doubled_nats = IteratorCombiner(nats, nats, add)
   >>> next(doubled_nats)
   >>> next(doubled_nats)

1.5 Extra Question

1. Create an iterator that generates the sequence of Fibonacci numbers.
   class FibIterator(object):
       def __init__(self):

           def __next__(self):

               def __iter__(self):
                   return self

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An iterable object represents a sequence. Examples of iterables are lists, tuples, strings, and dictionaries. The iterable class must implement an \_\_iter\_\_ method, which returns an iterator. Note that since all iterators have an \_\_iter\_\_ method, they are all iterable.

In general, a sequence’s \_\_iter\_\_ method will return a new iterator every time it is called. This is because an iterator cannot be reset. Returning a new iterator allows us to iterate through the same sequence multiple times.

In the following example, we’ve defined a simple iterable Range class, which represents the integers from 0 to stop.

```python
class Range:
    def __init__(self, stop):
        self.stop = stop
    def __iter__(self):
        return RangeIterator(self.stop)

class RangeIterator:
    def __init__(self, stop):
        self.current = 0
        self.stop = stop
    def __iter__(self):
        return self
    def __next__(self):
        curr = self.current
        if curr >= self.stop:
            raise StopIteration
        self.current += 1
        return curr
```

Iterables can be used in for loops and as arguments to functions that require a sequence (e.g. map and zip). For example:

```python
>>> for n in Range(2):
    ...     print(n)
    ...
0
1
```

This works because the for loop implicitly creates an iterator using the \_\_iter\_\_ method. Python then repeatedly calls next repeatedly on the iterator, until it raises StopIteration. In other words, the loop above is (basically) equivalent to:

```python
range_iterator = iter(Range(2))
is_done = False
while not is_done:
    try:
        val = next(range_iterator)
        print(val)
    except StopIteration:
        is_done = True
```
2.1 Questions

1. What would Python display in an interactive session?
   >>> range3 = Range(3)
   >>> for i in range3:
   ...     print(i)
   ...

   >>> list(range3)

   >>> iterator3 = iter(range3)
   >>> list(iterator3)
   >>> list(iterator3)

2. To make the Link class iterable, implement the LinkIterator class.
   class Link:
   empty = ()
   def __init__(self, first, rest=empty):
       self.first = first
       self.rest = rest
   def __iter__(self):
       return LinkIterator(self)

   class LinkIterator:
   def __init__(self, link):

   def __iter__(self):

   def __next__(self):
A **generator** function is a special kind of Python function that uses a `yield` statement instead of a `return` statement to report values. *When a generator function is called, it returns an iterable object.*

The following is a function that returns an iterator for the natural numbers:

```python
def generate_naturals():
    current = 0
    while True:
        yield current
        current += 1
```

Calling `generate_naturals()` will return a generator object, which you can use to retrieve values.

```python
>>> gen = generate_naturals()
>>> gen
<generator object gen at ...>
```

```python
>>> next(gen)
0
```

```python
>>> next(gen)
1
```

Think of a generator object as containing an implicit `__next__` method. This means, by definition, a generator object is an iterator.

### 3.1 yield

The `yield` statement is similar to a `return` statement. However, while a `return` statement closes the current frame after the function exits, a `yield` statement causes the frame to be saved until the next time `__next__` is called, which allows the generator to automatically keep track of the iteration state.

Once `__next__` is called again, execution resumes where it last stopped and continues until the next `yield` statement or the end of the function. A generator function can have multiple `yield` statements.

Including a `yield` statement in a function automatically tells Python that this function will create a generator. When we call the function, it returns a generator object instead of executing the body. When the generator’s `__next__` method is called, the body is executed until the first `yield` statement.
3.2 Implementation

Because generators are technically iterators, you can implement \_\_iter\_\_ methods using them. For example:

```python
class Naturals:
    def \_\_init\_\_(self):
        self.current = 0

    def \_\_iter\_\_(self):
        while True:
            yield self.current
            self.current += 1
```

Naturals' \_\_iter\_\_ method now returns a generator object. The behavior of Naturals is exactly the same as before:

```python
>>> nats = Naturals()
>>> nats_iterator = iter(nats)
>>> next(nats_iterator)
0
>>> next(nats_iterator)
1
```

There are a couple of things to note:

- **No \_\_next\_\_ method in Naturals.** \_\_iter\_\_ only needs to return an iterator, and a generator is an iterator
- nats is a Naturals object and nats_iterator is a generator
- Generator objects are iterators, so they can be used in for loops

3.3 Questions

1. Define a generator that yields the sequence of perfect squares. The sequence of perfect squares looks like: 1, 4, 9, 16...

```python
def perfect_squares():
```
2. To make the `Link` class iterable, implement the `__iter__` method using a generator.

```python
class Link:
    empty = ()

    def __init__(self, first, rest=empty):
        self.first = first
        self.rest = rest

    def __iter__(self):

3.4 Extra Questions

1. Write a generator function that returns all subsets of the positive integers from 1 to n. Each call to this generator’s `__next__` method will return a list of subsets of the set \[1, 2, \ldots, n\], where \(n\) is the number of times `__next__` was previously called.

```python
def generate_subsets():
    
    >>> subsets = generate_subsets()
    >>> for _ in range(3):
    ...     print(next(subsets))
    ...     print(next(subsets))
    
    [[]]
    [[], [1]]
    [[], [1], [2], [1, 2]]