Iterators

Class outline:

- Iterators
- For loops with iterators
- Built-in functions for iterators

Iterators

An **iterator** is an object that provides sequential access to values, one by one.

`iter(iterable)` returns an iterator over the elements of an iterable.

`next(iterator)` returns the next element in an iterator.

```
toppings = ["pineapple", "pepper", "mushroom", "roasted red pepper"]

topperator = iter(toppings)
next(iter)
next(iter)
next(iter)
next(iter)
next(iter)
```

Iterators

An **iterator** is an object that provides sequential access to values, one by one.

`iter(iterable)` returns an iterator over the elements of an iterable.

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```
toppings = ["pineapple", "pepper", "mushroom", "roasted red pepper"]

topperator = iter(toppings)
next(iter) # 'pineapple'
next(iter) # 'pepper'
next(iter) # 'mushroom'
next(iter) # 'roasted red pepper'
next(iter)
```

Iterators

An **iterator** is an object that provides sequential access to values, one by one.

`iter(iterable)` returns an iterator over the elements of an iterable.

`next(iterator)` returns the next element in an iterator.

```
toppings = ["pineapple", "pepper", "mushroom", "roasted red pepper"]

topperator = iter(toppings)
next(iter) # 'pineapple'
next(iter) # 'pepper'
next(iter) # 'mushroom'
next(iter) # 'roasted red pepper'
next(iter) # ✕ StopIteration exception
```

A useful detail

Calling `iter()` on an iterator just returns the iterator:

```
numbers = ["一つ", "二つ", "三つ"]
num_iter = iter(numbers)
num_iter2 = iter(num_iter)

assert num_iter is num_iter2
```

Iterables

Lists, tuples, dictionaries, strings, and ranges are all **iterable** objects.

```
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]

ranked_chocolates = ("Dark", "Milk", "White")

best_topping = "pineapple"

scores = range(1, 21)

prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
```

Making iterators for iterables

`iter()` can return an iterator for any iterable object.

```
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
order_iter = iter(order)
next(order_iter)

ranked_chocolates = ("Dark", "Milk", "White")
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)

best_topping = "pineapple"
topping_iter = iter(best_topping)
next(topping_iter)

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter)
```

Making iterators for iterables

`iter()` can return an iterator for any iterable object.

```
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
order_iter = iter(order)
next(order_iter)  # "Yuca Shepherds Pie"

ranked_chocolates = ("Dark", "Milk", "White")
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)

best_topping = "pineapple"
topping_iter = iter(best_topping)
next(topping_iter)

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter)
```

Making iterators for iterables

`iter()` can return an iterator for any iterable object.

```
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
order_iter = iter(order)
next(order_iter)  # "Yuca Shepherds Pie"

ranked_chocolates = ("Dark", "Milk", "White")
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)  # "Dark"

best_topping = "pineapple"
topping_iter = iter(best_topping)
next(topping_iter)

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter)
```

Making iterators for iterables

`iter()` can return an iterator for any iterable object.

```
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
order_iter = iter(order)
next(order_iter)  # "Yuca Shepherds Pie"

ranked_chocolates = ("Dark", "Milk", "White")
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)  # "Dark"

best_topping = "pineapple"
topping_iter = iter(best_topping)
next(topping_iter) # "p"

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter)
```

Making iterators for iterables

`iter()` can return an iterator for any iterable object.

```
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
order_iter = iter(order)
next(order_iter)  # "Yuca Shepherds Pie"

ranked_chocolates = ("Dark", "Milk", "White")
chocolate_iter = iter(ranked_chocolates)
next(chocolate_iter)  # "Dark"

best_topping = "pineapple"
topping_iter = iter(best_topping)
next(topping_iter) # "p"

scores = range(1, 21)
score_iter = iter(scores)
next(score_iter) # 1
```

Making iterators for dictionaries

In Python 3.6+, items in a dict are ordered according to when they were added.

```
prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
```

An iterator for the keys:

```
price_iter = iter(prices.keys())
next(price_iter)
```

An iterator for the values:

```
price_iter = iter(prices.values())
next(price_iter)
```

An iterator for key/value tuples:

```
price_iter = iter(prices.items())
next(price_iter)
```

Making iterators for dictionaries

In Python 3.6+, items in a dict are ordered according to when they were added.

```
prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
```

An iterator for the keys:

```
price_iter = iter(prices.keys())
next(price_iter)  # "pineapple"
```

An iterator for the values:

```
price_iter = iter(prices.values())
next(price_iter)
```

An iterator for key/value tuples:

```
price_iter = iter(prices.items())
next(price_iter)
```

Making iterators for dictionaries

In Python 3.6+, items in a dict are ordered according to when they were added.

```
prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
```

An iterator for the keys:

```
price_iter = iter(prices.keys())
next(price_iter)   # "pineapple"
```

An iterator for the values:

```
price_iter = iter(prices.values())
next(price_iter)   # 9.99
```

An iterator for key/value tuples:

```
price_iter = iter(prices.items())
next(price_iter)
```

Making iterators for dictionaries

In Python 3.6+, items in a dict are ordered according to when they were added.

```
prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
```

An iterator for the keys:

```
price_iter = iter(prices.keys())
next(price_iter)   # "pineapple"
```

An iterator for the values:

```
price_iter = iter(prices.values())
next(price_iter)   # 9.99
```

An iterator for key/value tuples:

```
price_iter = iter(prices.items())
next(price_iter)   # ("pineapple", 9.99)
```

For loops

For loop with iterator

When used in a for loop, Python will call `next()` on the iterator in each iteration:

```
nums = range(1, 4)
num_iter = iter(nums)
for num in nums:
    print(num)
```

For loops with used-up iterators

```
nums = range(1, 4)
num_iter = iter(nums)
first = next(num_iter)

for num in num_iter:
    print(num)
```

For loops with used-up iterators

```
nums = range(1, 4)
num_iter = iter(nums)
first = next(num_iter)

for num in num_iter:
    print(num)
```

Iterators are mutable! Once the iterator moves forward, it won't return the values that came before.

```
nums = range(1, 4)
sum = 0
num_iter = iter(nums)

for num in num_iter:
    print(num)
for num in num_iter:
    sum += num
```

Iterating over iterables

If you want all the items from start to finish, it's better to use a for-in loop.

```
my_order = ["Yuca Shepherds Pie", "Pão de queijo", "Guaraná"]
for item in my_order:
    print(item)
lowered = [item.lower() for item in my_order]

ranked_chocolates = ("Dark", "Milk", "White")
for chocolate in ranked_chocolates:
    print(chocolate)

prices = {"pineapple": 9.99, "pen": 2.99, "pineapple-pen": 19.99}
for product in prices:
    print(product, " costs ", prices[product])
discounted = { item: prices[item] * 0.75 for item in prices }

best_topping = "pineapple"
for letter in best_topping:
    print(letter)
```

Useful built-in functions

Functions that return iterables

Function	Description
`list(iterable)`	Returns a list containing all items in `iterable`
`tuple(iterable)`	Returns a tuple containing all items in `iterable`
`sorted(iterable)`	Returns a sorted list containing all items in `iterable`

Functions that return iterators

Function	Description
`reversed(sequence)`	Iterate over item in `sequence` in reverse order (See example in PythonTutor)
`zip(*iterables)`	Iterate over co-indexed tuples with elements from each of the `iterables` (See example in PythonTutor)
`map(func, iterable, ...)`	Iterate over `func(x)` for `x` in `iterable` Same as `[func(x) for x in iterable]` (See example in PythonTutor)
`filter(func, iterable)`	Iterate over `x` in `iterable` if `func(x)` Same as `[x for x in iterable if func(x)]` (See example in PythonTutor)

Built-in map function

`map(func, iterable)`: Applies `func(x)` for `x` in `iterable` and returns an `iterator`

```
def double(num):
    return num * 2

for num in map(double, [1, 2, 3]):
    print(num)
```

```
for word in map(lambda text: text.lower(), ["SuP", "HELLO", "Hi"]):
    print(word)
```

Built-in map function

`map(func, iterable)`: Applies `func(x)` for `x` in `iterable` and returns an `iterator`

```
def double(num):
    return num * 2

for num in map(double, [1, 2, 3]):
    print(num)
```

```
for word in map(lambda text: text.lower(), ["SuP", "HELLO", "Hi"]):
    print(word)
```

Turn the iterator into a list using `list()`

```
doubled = list(map(double, [1, 2, 3]))

lowered = list(map(lambda text: text.lower(), ["SuP", "HELLO", "Hi"]))
```

Exercise: Termified

Let's implement this without using a list comprehension.

```
def termified(n, term):
    """Returns every the result of calling TERM
    on each element in the range from 0 to N (inclusive).

    >>> termified(5, lambda x: 2 ** x)
    [1, 2, 4, 8, 16, 32]
    """
```

Exercise: Termified (solution)

Using map:

```
def termified(n, term):
    """Returns every the result of calling TERM
    on each element in the range from 0 to N (inclusive).

    >>> termified(5, lambda x: 2 ** x)
    [1, 2, 4, 8, 16, 32]
    """
    return list(map(term, range(n + 1)))
```

Exercise: Termified (solution)

Using map:

```
def termified(n, term):
    """Returns every the result of calling TERM
    on each element in the range from 0 to N (inclusive).

    >>> termified(5, lambda x: 2 ** x)
    [1, 2, 4, 8, 16, 32]
    """
    return list(map(term, range(n + 1)))
```

Compare to list comprehension version:

```
def termified(n, term):
    return [term(x) for x in range(n + 1)]
```

Built-in filter function

`filter(func, iterable)`: Returns an iterator from the items of `iterable` where `func(item)` is true.

```
def is_fourletterword(text):
    return len(text) == 4

for word in filter(is_fourletterword, ["braid", "bode", "brand", "band"]):
    print(word)
```

```
for num in filter(lambda x: x % 2 == 0, [1, 2, 3, 4]):
    print(num)
```

Built-in filter function

`filter(func, iterable)`: Returns an iterator from the items of `iterable` where `func(item)` is true.

```
def is_fourletterword(text):
    return len(text) == 4

for word in filter(is_fourletterword, ["braid", "bode", "brand", "band"]):
    print(word)
```

```
for num in filter(lambda x: x % 2 == 0, [1, 2, 3, 4]):
    print(num)
```

Turn the iterator into a list using `list()`

```
filtered = list(is_fourletterword, ["braid", "bode", "brand", "band"]))

evens = list(filter(lambda x: x % 2 == 0, [1, 2, 3, 4]))
```

Exercise: Divisors

Let's implement this without using a list comprehension.

```
def divisors(n):
    """Returns all the divisors of N.

    >>> divisors(12)
    [1, 2, 3, 4, 6]
    """
```

Exercise: Divisors (solution)

Using filter:

```
def divisors(n):
    """Returns all the divisors of N.

    >>> divisors(12)
    [1, 2, 3, 4, 6]
    """
    return list(filter(lambda x: n % x == 0, range(1, n)))
```

Exercise: Divisors (solution)

Using filter:

```
def divisors(n):
    """Returns all the divisors of N.

    >>> divisors(12)
    [1, 2, 3, 4, 6]
    """
    return list(filter(lambda x: n % x == 0, range(1, n)))
```

Compare to list comprehension version:

```
def divisors(n):
    return [x for x in range(1, n) if n % x == 0]
```

Built-in zip function

`zip(*iterables)`: Returns an `iterator` that aggregates elements from each of the `iterables` into co-indexed pairs

```
# From:
["one", "two", "three"]
["uno", "dos", "tres"]
```

Built-in zip function

`zip(*iterables)`: Returns an `iterator` that aggregates elements from each of the `iterables` into co-indexed pairs

```
# From:                    # To:
["one", "two", "three"]    -->  ("one", "uno")   ("two", "dos")   ("three", "tres")
["uno", "dos", "tres"]
```

Built-in zip function

`zip(*iterables)`: Returns an `iterator` that aggregates elements from each of the `iterables` into co-indexed pairs

```
# From:                      # To:
["one", "two", "three"]     --> ("one", "uno")  ("two", "dos")  ("three", "tres")
["uno", "dos", "tres"]
```

```
english_nums = ["one", "two", "three"]
spanish_nums = ["uno", "dos", "tres"]

zip_iter = zip(english_nums, spanish_nums)
english, spanish = next(zip_iter)
print(english, spanish)

for english, spanish in zip(english_nums, spanish_nums):
    print(english, spanish)
```

Turn the iterator into a list using `list()`

```
zipped = list(zip(english_nums, spanish_nums))
```

Exercise: matches

List comprehensions are allowed for this one...

```
def matches(a, b):
    """Return the number of values k such that A[k] == B[k].
    >>> matches([1, 2, 3, 4, 5], [3, 2, 3, 0, 5])
    3
    >>> matches("abdomens", "indolence")
    4
    >>> matches("abcd", "dcba")
    0
    >>> matches("abcde", "edcba")
    1
    >>> matches("abcdefg", "edcba")
    1
    """
```

Exercise: matches (solution)

```python
def matches(a, b):
    """Return the number of values k such that A[k] == B[k].
    >>> matches([1, 2, 3, 4, 5], [3, 2, 3, 0, 5])
    3
    >>> matches("abdomens", "indolence")
    4
    >>> matches("abcd", "dcba")
    0
    >>> matches("abcde", "edcba")
    1
    >>> matches("abcdefg", "edcba")
    1
    """
    return sum([1 for a, b in zip(a, b) if a == b])
```

Exercise: List of lists

```
def list_o_lists(n):
    """Assuming N >= 0, return the list consisting of N lists:
    [1], [1, 2], [1, 2, 3], ... [1, 2, ... N].
    >>> list_o_lists(0)
    []
    >>> list_o_lists(1)
    [[1]]
    >>> list_o_lists(5)
    [[1], [1, 2], [1, 2, 3], [1, 2, 3, 4], [1, 2, 3, 4, 5]]
    """
```

Exercise: List of lists (solution)

```
def list_o_lists(n):
    """Assuming N >= 0, return the list consisting of N lists:
    [1], [1, 2], [1, 2, 3], ... [1, 2, ... N].
    >>> list_o_lists(0)
    []
    >>> list_o_lists(1)
    [[1]]
    >>> list_o_lists(5)
    [[1], [1, 2], [1, 2, 3], [1, 2, 3, 4], [1, 2, 3, 4, 5]]
    """
    return [list(range(1, i + 1)) for i in range(1, n+1)]
```

Exercise: Palindrome

```python
def palindrome(s):
    """Return whether s is the same sequence backward and forward.

    >>> palindrome([3, 1, 4, 1, 5])
    False
    >>> palindrome([3, 1, 4, 1, 3])
    True
    >>> palindrome('seveneves')
    True
    >>> palindrome('seven eves')
    False
    """
```

Exercise: Palindrome (solution)

```python
def palindrome(s):
    """Return whether s is the same sequence backward and forward.

    >>> palindrome([3, 1, 4, 1, 5])
    False
    >>> palindrome([3, 1, 4, 1, 3])
    True
    >>> palindrome('seveneves')
    True
    >>> palindrome('seven eves')
    False
    """
    return all([a == b for a, b in zip(s, reversed(s))])
    # OR
    return list(s) == list(reversed(s))
```

Use cases for iterators

Reasons for using iterators

A code that processes an iterator using `iter()` or `next()` **makes few assumptions about the data itself**.

- Changing the data storage from a list to a tuple, map, or dict doesn't require rewriting code.
- Others are more likely to be able to use your code on their data.

An iterator **bundles together a sequence and a position** with the sequence in a single object.

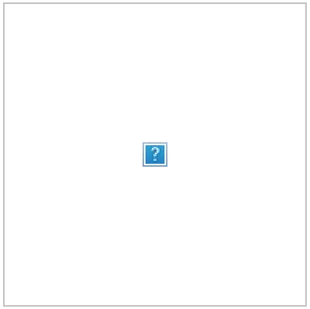
- Passing that object to another function always retains its position.
- Ensures that each element of the sequence is only processed once.
- Limits the operations that can be performed to only calling `next()`.

Blackjack demo!

Python Project of The Day!

Mathematical Animation Engine

Manim: An open-source Python animation engine for explanatory math videos, first created by Grant Sanderson



for 3Blue1Brown videos.

Check out the examples gallery, oooo!