A Short and Incomplete Introduction to Python

Part 3: Sequences and `for`-loops

Riccardo Murri <riccardo.murri@uzh.ch>,
Sergio Maffioletti <sergio.maffioletti@uzh.ch>
S3IT: Services and Support for Science IT,
University of Zurich

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Lists and sequences

Sequences

Python provides a few built-in *sequence* classes:

list	*mutable*, possibly heterogeneous
tuple	*immutable*, possibly heterogeneous
str	*immutable*, only holds characters
bytes	*immutable*, only holds bytes

Additional sequence types
are provided by external modules:

array	*mutable*, homogeneous (like C/Fortran arrays, from NumPy)
DataFrame	*mutable*, heterogeneous (like R, from Pandas)

List basics

Lists are by far the most common and used sequence type in Python.

Lists are created and initialized by enclosing values into ‘[’ and ‘]’:

```
>>> L = [ 'U', 'Z' ]
```

List basics, II

You can append and remove items from a list:

```
>>> L = [ ’U’, ’Z’ ]
>>> L.append(’H’)
>>> print (L)
[’U’, ’Z’, ’H’]
```

You can append **any** object to a list:

```
>>> L.append([1, 2])
>>> print(L)
[’U’, ’Z’, ’H’, [1, 2]]
```

List basics, II

You can append and remove items from a list:

```
>>> L = [ ’U’, ’Z’ ]
>>> L.append(’H’)
>>> print (L)
[’U’, ’Z’, ’H’]
```

You can append **any** object to a list:

```
>>> L.append([1, 2])
>>> print(L)
[’U’, ’Z’, ’H’, [1, 2]]
```

Sequences, II

You can access individual items in a sequence using the postfix `[]` operator.

Sequence indices start at 0.

```
>>> L = [’U’, ’Z’, ’H’]
>>> print(L[0], L[1], L[2])
’U’ ’Z’ ’H’
>>> S = ’UZH’
>>> print(S[0], S[1], S[2])
’U’ ’Z’ ’H’
```

Sequence length

The `len()` function returns the number of items in any sequence (not just lists).

```
>>> len(L)
3
```

Built-in functions **`sum`**`()`, **`max`**`()`, **`min`**`()` also work on list arguments.

Exercise 3.A: Write a function `avg()` that takes a list of numbers and returns their mean value.

Slices

The notation `[`n`:`m`]` is used for accessing a *slice* of sequence (the items at positions n, $n+1$, ..., $m-1$).

```
>>> # list numbers from 0 to 9
>>> R = list(range(0,10))
>>> R[1:4]
[1, 2, 3]
```

If n is omitted it defaults to 0, if m is omitted it defaults to the length of the sequence.

A *slice* of a sequence is a sequence *of the same type*.

```
>>> S = 'zurich'
>>> S[0:4]
'zuri'
```

List mutation

You can replace items in a *mutable* sequence by assigning them a new value:

```
>>> L = ['P', 'y', '2']
>>> L[2] = '3'
>>> print(L)
['P', 'y', '3']
```

List mutation

You can also replace an entire slice of a mutable sequence:

```
>>> L[0:2] = [’1’, ’2’]
>>> print(L)
[’1’, ’2’, ’3’]
```

The new slice does not need to have the same length:

```
>>> L[2:] = range(5)
>>> print(L)
[’1’, ’2’, 0, 1, 2, 3, 4]
```

Lists operators

You can concatenate two lists using the + operator:

```
>>> [1, 2] + [3, 4]
[1, 2, 3, 4]
```

You can mutate a list *in place* with the += operator:

```
>>> L = [1, 2]
>>> L += [3, 4]
>>> print(L)
[1, 2, 3, 4]
```

The ⋆ operator also works on lists:

```
>>> L = [1, 2]
>>> print(L*3)
[1, 2, 1, 2, 1, 2 ]
```

Operating on lists

Python provides a number of methods to modify a list `L`:

L.append(x)

Append item `x` to list `L`.

L.insert(n, x)

Insert item `x` at position `n` of list `L`; other items are "shited to the right" to make place.

L.pop(n)

Remove item at position `n` from list `L`.

L.extend(K)

Graft a list `K` to the end of list `L`.

Reference: https://docs.python.org/2/library/stdtypes.html#typesseq

Operating on lists, II

L.index(x)
Return position of first item in `L` having value `x`.

L.count(x)
Return number of items in `L` having value `x`.

L.remove(x)
Remove first occurence of item having value `x` from list `L`.

Reference: https://docs.python.org/2/library/stdtypes.html#typesseq

Operating on lists, III

sorted(L)

Return a copy of `L` with items sorted in ascending order.

L.sort()

Modify list `L`, sorting it in ascending order in-place.

reversed(L)

Return a copy of `L` with items in reverse order as they occur in `L`.

L.reverse()

Modify list `L`, reversing the order of its items in-place.

Reference: https://docs.python.org/2/library/stdtypes.html#typesseq

Exercise 3.B: Write a function `median(L)` that takes a list `L` of numbers and returns the median value.

`for`-loops

for-loops

With the for statement, you can **loop over the items of a sequence**:

```
for i in range(0, 4):
  # loop block
  print (i*i)
```

To break out of a for loop, use the break statement.

To jump to the next iteration of a for loop, use the continue statement.

The `for` statement can be used to loop over elements in *any sequence*.

```
>>> for val in [1,2,3] :
...   print(val)
1
2
3
```

Loop over lists

The `for` statement can be used to loop over elements in *any sequence*.

```
>>> for val in 'abc':
...   print(val)
'a'
'b'
'c'
```

Loop over strings

If you want to loop over a *sorted* sequence you can use the function `sorted()` :

```
>>> for val in sorted([1,3,2]):
...  print(val)
1
2
3
```

and to loop over a sequence in *inverted* order you can use the `reversed()` function:

```
>>> for val in reversed('abc'):
...     print(val)
'c'
'b'
'a'
```

Exercise 3.C: Write a function `odd` that takes a list of integers and returns a list of all the odd ones.

Exercise 3.D: Write a function `deviation(L, m)` that takes a list `L` of numbers and a single value `m` returns a list with the difference of `m` and each element `x` of `L`.

Exercise 3.E: Write a function `randlist(N)` that returns a list of `N` random numbers, each sampled uniformly from the real interval [0.0, 1.0).

Python's standard module `random` provides functions to generate (pseudo-)random numbers.

map, reduce, filter (1)

Constructing a new list by looping over a given list and applying a function on all elements is so common that there are specialized functions for that:

map(fn, L)

Return a new list formed by applying function `fn(x)` to every element `x` of list `L`

filter(fn, L)

Return a new list formed by elements `x` of list `L` for which `fn(x)` evaluates to a “True” value.

map, reduce, filter (2)

reduce(fn2, L)

Apply function `fn2(x,y)` to the first two items `x` and `y` of list `L`, then apply `fn2` to the result and the third element of `L`, and so on until all elements have been processed — return the final result.

See also: http://www.python-course.eu/lambda.php and https://docs.python.org/3/howto/functional.html (more advanced)

This is how you could rewrite Exercises 7 and 8 using `map` and `filter`.

```
# *** Exercise 3.B ***
def is_odd(x):
  return (x % 2 == 1)

def odd(L):
  return filter(is_odd, L)
```

```
# *** Exercise 3.C ***
def deviation(L, m):
  # note:  can define
  # func’s in func’s!
  def delta(x):
    return abs(x-m)
  return map(delta, L)
```

Generators and Iterators

Iterators

An **Iterator** is a generalization of a sequence: you can read items out of an iterator, *one at a time*. (This can be used e.g. to implement unbounded sequences.)

Iterators are *read-only*: you cannot set or alter items in an iterator!

There are multiple ways to create iterators in Python. **Generators** are special functions that implement an iterator.

Generators

A **Generator** is a function that uses the **`yield`** keyword.

```
def until_quit():
    reply = input()
    while reply != ’quit’:
      yield (’->’ + reply)
      reply = input()
    return
```

Every time **`yield`** is executed, an item is returned to the caller.

Generators, II

A **Generator** is a function that uses the **`yield`** keyword.

```
def until_quit():
    reply = input()
    while reply != 'quit':
      yield ('->' + reply)}
      reply = input()
    return
```

When execution hits a `return` (or the end of the function), iteration stops.

Example: Generators

The `for` statement can be used to loop over elements in *any iterator*.

```
>>> for val in until_quit():
...   print(val)
foo
’->foo’
bar
’->bar’
quit
```

Iterate over user input until `quit` is entered.

Exercise 3.F: The Collatz sequence is defined recursively as follows: given a number x, the next item x' in the sequence is given by:

- $x' = x/2$ if x is even,
- $x' = 3x + 1$ if x is odd.

Write a function `collatz` that takes a single starting integer x, and iterates the Collatz sequence starting at x. If 1 is reached, iteration should stop.

Generators, III

You can pull items out of a generator (more generally, *iterator*) using the **next** built-in function.

```
>>> def square(x):
...   return x*x
>>> g = map(square, [2, 7])
>>> next(g)
4
>>> next(g)
49
>>> next(g)  # error!
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

Plotting basics

Plotting libraries

Matplotlib is the most-used plotting library in the Python community: it provides a large array of (mostly low level) facilities for making plots, and a more high-level interface largely inspired by MATLAB plotting system.
Seaborn is an add-on library that provides:

- better default visual styles
- easier plotting functions for many commonly-used types of plots

Enabling plotting in code

To use Matplotlib and Seaborn in a Jupyter notebook to *embed* graphics in the notebook, run this code in a cell:

```
%matplotlib inline

import matplotlib.pyplot as plt
import seaborn as sea
```

The same code (minus the `%matplotlib inline` "magic") can be used in any Python script. By default, graphics will appear in a separate pop-up window.

Line plots, I

The `plt.plot(`x`, `y`)` function can be used to make a $2D$ line plot.

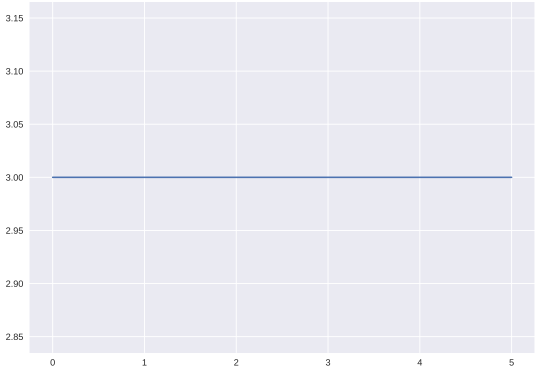
Arguments x and y are sequences: corresponding items in the two sequences give the $2D$ coordinates of points in the plot.

Note that:

- x must be *sorted*!
- x and y must have the same length.

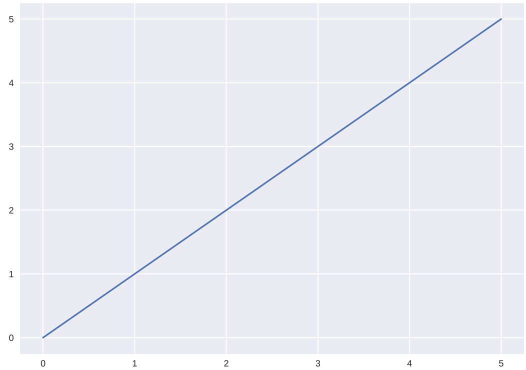
Line plots, II

```
In [1]:  x = [0, 1, 2, 3, 4, 5]
In [2]:  y = [3, 3, 3, 3, 3, 3]
In [3]: plt.plot(x, y)
Out[3]:  [<matplotlib.lines.Line2D at 0x7fe8a3454750>]
```



Line plots, III

```
In [4]:  x = [0, 1, 2, 3, 4, 5]
In [5]: y = x
In [6]: plt.plot(x, y)
Out[6]: [<matplotlib.lines.Line2D at 0x7fe8a3454750>]
```



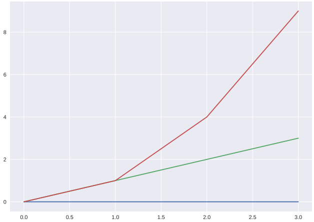
Line plots, IV

Plotting different series of data in the same figure requires a bit more work.

```
fig, ax = plt.subplots(1, 1, figsize=[10, 7])

# common x-axis items
x = [0, 1, 2, 3]

# three lines
ax.plot(x, [0, 0, 0, 0])
ax.plot(x, [0, 1, 2, 3])
ax.plot(x, [0, 1, 4, 9])
```



```
# save to file
fig.savefig('fig/lineplot2.pdf')
```

Line plots, V

Plotting different series of data in the same figure requires a bit more work.

1. First use the `plt.subplots` function to create *figure* and an *axes* object
2. An *axes* object is a "frame" for a single plot – use methods `.plot()` to lay a graph onto the canvas. Each invocation of `.plot()` *adds* a plot onto the canvas.
3. The *figure* object contains all the axes can be used for saving the final output with `.savefig()`

Exercise 3.G:
Write a function `plotfn(xs, f)` that takes two arguments:

- a sequence of numbers `xs`, and
- a function `f`, which takes one single argument (a number) and returns a number. Function `plotfn()` should display a line plot of the mathematical function `f` over the set of numbers `xs`.

  Bonus points: Change the `plotfn()` function so to take an additional argument (a file name) and save the figure into that file.

  More bonus points: Change the `plotfn` function so to take a *list* of mathematical functions `fs` and plot all of them.

Scatter plots

Use the `plt.scatter(x, y)` function.

Everything else works as in line plots.

Bar plots

Use Seaborn's `sea.barplot(x, y)` function.

Everything else works *almost* as in line plots; when you need to plot onto an axis (the `ax` object of previous examples), then you need to pass the axis as an additional parameter:

```
sea.barplot(x, y, ax=ax)
```

Appendix

Sets (1)

The `set` type implements an **unordered** container that holds exactly one object per equivalence class:

```
>>> S = set()
>>> S.add(1)
>>> S.add('two')
>>> S.add(1)
>>> S
set([1, 'two'])
```

Sets (2)

You can create a set and add elements to it in one go:

```
>>> S2 = set([1, 2, 3, 4])
```

and remove elements:

```
>>> S2.remove(2)
>>> S2.pop()
1
>>> S2
set([3,4])
```

Sets (3)

Sets are often used to get unique values from a list:

```
>>> L = [1, 1, 2, 2, 3, 3]
>>> set(L)
set([1, 2, 3])
```

Of course, you can also create a list from a set:

```
>>> S = set((1,2,3))
>>> list(S)
[1, 2, 3]
```

Q: In what order will the set items appear in the resulting list?

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set([1, 2, 3])
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Of course, you can also create a list from a set:

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>>> S = set((1,2,3))
>>> list(S)
[1, 2, 3]
```

Q: *In what order will the set items appear in the resulting list?*

Tuples

Tuples are like lists

```
>>> T = (1, 2, 3)
>>> T[0]
1
>>> T[0:1]
(1,)
```

but they are *immutable*

```
>>> T[0] = ’a’
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: ’tuple’ object does not support item assignment
```

Multiple assignment

You can assing multiple variables at the same time

```
>>> a, b, c = (1, 2, 3)
>>> print(a)
1
>>> print(b)
2
```

It works with any sequence:

```
>>> a, b, c = ’UZH’
>>> print(a)
U
```

Q: *Can you think of a way to swap the values of two variables using this?*

Multiple assignment

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```
>>> a, b, c = (1, 2, 3)
>>> print(a)
1
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1
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2
```

It works with any sequence:

```
>>> a, b, c = ’UZH’
>>> print(a)
U
```

Q: *Can you think of a way to swap the values of two variables using this?*

```
>>> a, b = b, a
```

Multiple assignment (2)

Multiple assignment can be used in `for` statements as well.

```
>>> L = [(1,’a’), (2,’b’), (3, ’c’)]
>>> for x, y in L:
...     print ("first is " + str(x)
...            + ’ and second is ’ + y)
```

This is particularly useful with functions that return a tuple. For instance the `enumerate()` function (look it up with `help()`!).

Data structures recap

mutable	**immutable**	
`set`	`frozenset`	unordered container of unique elements
`list`	`tuple`	ordered sequence
`dict`	—	key/values mapping
—	`str`	ordered sequence of characters