Python for Finance Lecture Notes

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Chapter 1

Introduction to python

`Python` is one of the most widely used programming languages in the world, and it has been around for more than 28 years now.

First and foremost reason why `python` is much popular because it is highly productive as compared to other programming languages like `C++` and `java`. It is a much more concise and expressive language and requires less time, effort, and lines of code to perform the same operations.

This makes `python` very easy-to-learn programming language even for beginners and newbies. It is also very famous for its simple programming syntax, code readability and English-like commands that make coding in `python` lot easier and efficient. With `python`, the code looks very close to how humans think. For this purpose, it must abstract the details of the computer from you. Hence, it is slower than other "lower-level language" like `C`.

There were times when computer run time was to be the main issue and the most expensive resource. But now, things have changed. Computer, servers and other hardware have become much much cheaper than ever and speed has become a less important factor. Today, development time matters more in most cases rather than execution speed. Reducing the time needed for each project saves companies tons of money.

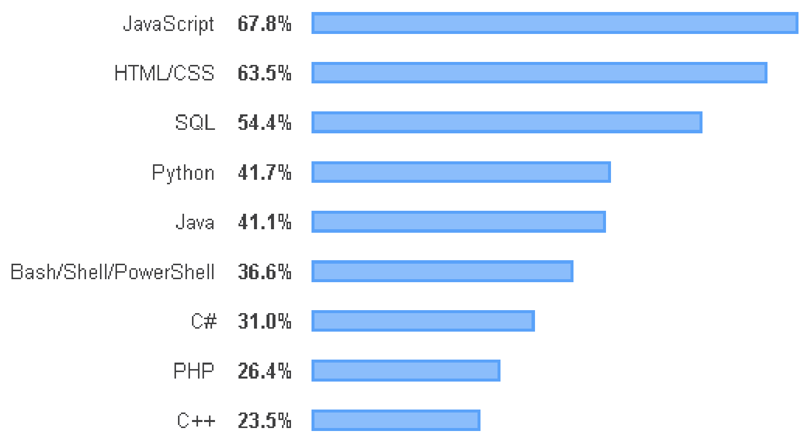
As far as the execution speed or performance of the program is concerned, we can easily manage it by horizontal scaling, meaning that more servers can be used to reach that level of speed or performance.

In short, `python` is widely used even when it is somehow slower than other languages because:

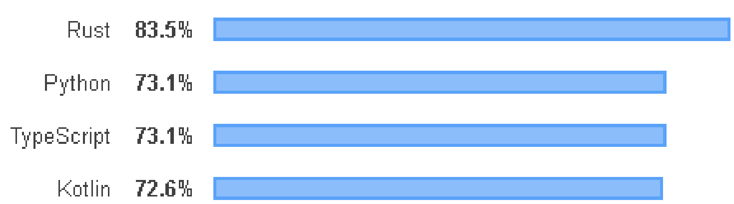
- is more productive;
- companies can optimize their most expensive resource: employees;
- rich set of libraries and frameworks;
- large community.

1.1 What is `python` ?

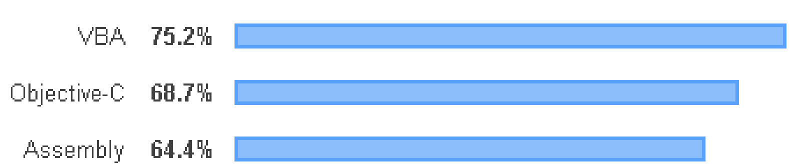
`Python` is a so called *interpreted language*: it takes some code (a sequence of instructions), reads and executes it. This is different from other programming languages like `C` or `C++` which *compile* code



List of most used languages by developers according to Stack Overflow survey in 2019.

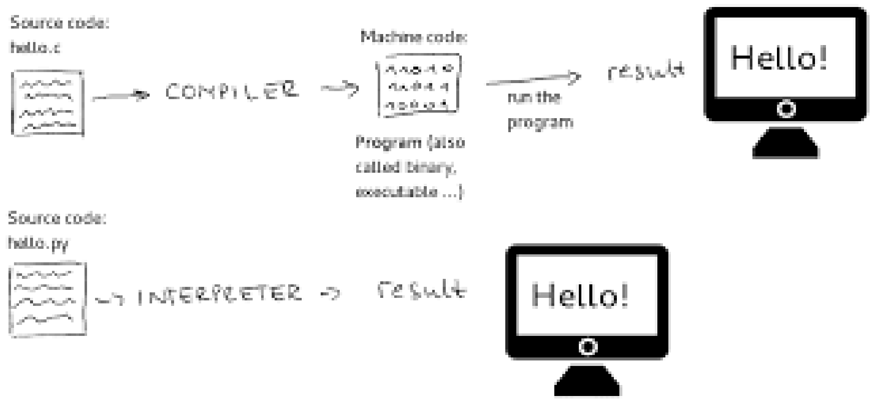


List of most loved languages by developers according to Stack Overflow survey in 2019.



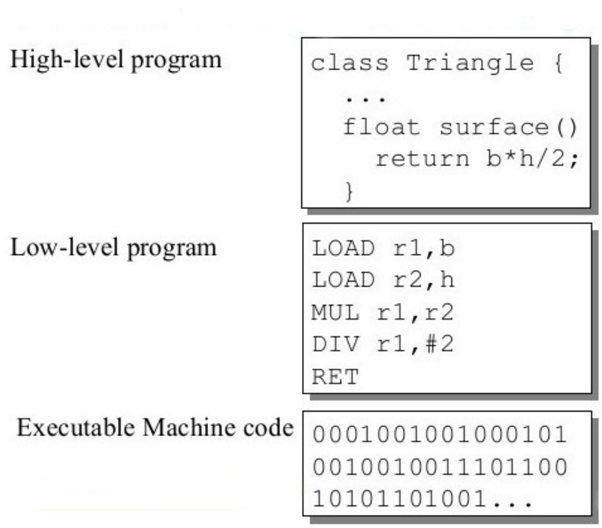
List of most *dreaded* languages by developers according to Stack Overflow survey in 2019.

into a language that the computer can understand directly (*machine language*).



Interpreted vs compiled language

As a result, `python` is essentially an *interactive* programming language, you can program and see the results almost at the same time. This is very nice for a faster development since compilation time can be quite long (just to give an idea the compilation of our `C++` financial code takes more than one hour). However there are drawbacks in terms of performance, the *translation* to machine language has to be done in real-time resulting in slower execution times.



Human readable vs machine code

In the next chapters we'll take a quick tour of `python` and see the main features and characteristics of this programming language, later on we will see how it can be useful to solve real-world financial problems.

First of all since `python`, as basically all programs, comes in different version and flavours we need to specify the particular one we are going to use. The latest version (at the time I'm writing this pages) is `3.8.5`, but it is continuously evolving, however it is not difficult to see older versions floating around (e.g. `2.7`). This is because there are some big differences between `python2.X` and `python3.X` which prevent a sizable portion of `python2` users to stick with it (consider that moving to python3 would require a large amount of work to adapt big projects). In conclusion we will concentrate on python 3.7.

1.2 Python basics

Every language has *keywords*, these are reserved words that have a special meaning and tell the computer what to do. The first one we encounter is print: it prints to screen whatever is specified between the parenthesis.

```
print ("Hello world !")

Hello world !
```

```
print ("Welcome")
print ("to")
print ("everybody")

Welcome
to
everybody
```

Good programming practice recommends to document the code you write (you will soon see that it is surprisingly easy to forget what you wanted to do in your code). In python you can add comments to code starting a line with a hash character (#).

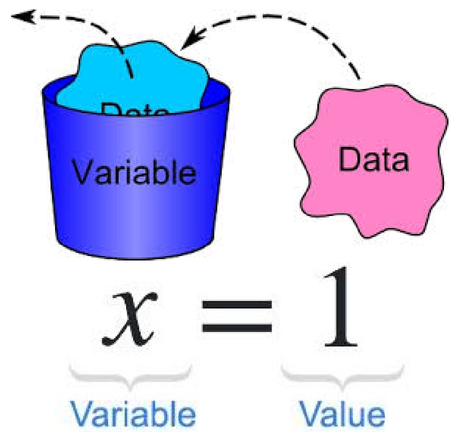
```
print ("Ciao") # this is a comment

Ciao
```

1.2.1 Variables

A variable is a computer memory location paired with a symbolic name, which contains some quantity of information referred to as a *value* (e.g. a number, a string...). Variables and hence data they contain, can be used, referenced and manipulated throughout a program. A value is assigned to a variable with the equal operator (=) and printing a variable shows its content.

```
x = 9
print (x)

9
```

```
myphone = "Huawei P10Lite"
print (myphone)

Huawei P10Lite
```



Graphical representation of a variable.

Another very useful keyword is `type`: it tells which kind of object is stored in a variable.

```
print (type(x))
print (type(myphone))

<class 'int'>
<class 'str'>
```

After their definitions `x` and `myphone` can be used as aliases for a number and a string and their content manipulated, for example:

```
print (x+5)

14
```

There are rules that limit the variable naming possibilities, in particular they must:

- begin with a letter (`myphone`) or underscore (`_myphone`);
- other characters can be letters, numbers or more _;
- variable names are case-sensitive so `myphone` and `myPhone` are two distinct variables;

Keywords, as said, are reserved words and as such cannot be used as variable names (e.g. `print`, `type`, `for`...).

To use **good** variable names (and make your programs clearer and easier to read) always choose meaningful names instead of short names (i.e. `numberOfCakes` is much better than simply `n`), try to be consistent with your conventions (e.g. choose once and for all between `number_of_cakes` or `numberofcakes` or `numberOfCakes`, usually begin a variable name with underscore (_) only for a special case (will see later when this is usually done).

1.2.2 Boolean expressions

Boolean expressions evaluate to `true` or `false` only. This type of expressions usually involve logical or comparison operators like `or`, `and`, > (greater-than), < (less-than),... The equal-to Boolean operator symbol is a double = (==), to not be confused with the assignment operator single = (=), with the first we compare two variables, with the second we associate a value to a variable.

Let's see some example. The following expression answers the question is 1 equal to 2:

```
1 == 2

False
```

Here another example using the not equal operator (!=):

```
1 != 2

True
```

```
2 < 2

False
```

```
2 <= 2  # in this case we allow the numbers to be equal too

True
```

```
print (x)
15 <= x and x <= 20 # this expression could also be written as 15 <= x <= 20

11
False
```

```
15 <= x or x <= 20

True
```

```
not (x > 20) # the not keyword negates the following expression

True
```

1.2.3 String expressions

A "string" is a sequence of characters (letters, digits, spaces, punctuation,...). There are many operations that can be performed on strings, like for example concatenate (with + operator), truncate, replace characters,...

```
mystring = "some text with punctuation, spaces and digits 10"
mystring.replace("s", "z")

'zome text with punctuation, zpacez and digitz 10'
```

```
"abc" + "def" # it is possible to concatenate strings with +

'abcdef'
```

```
"The number " + 4 + " is my favourite number"
# this causes an error since we are trying to concatenate a string
# with a number so two different kind of objects
```

```
---------------------------------------------------------------------------

TypeError                                 Traceback (most recent call last)

<ipython-input-33-b9f65c5a45f7> in <module>()
----> 1 "The number " + 4 + " is my favourite number"
      2 # this causes an error since we are trying to concatenate a string
      3 # with a number so two different kind of objects

TypeError: can only concatenate str (not "int") to str
```

To avoid this error is possible to **cast** an object to a different type which means to convert an object to a different type. In this case we can *force* the number four to be represented as a string with the `str()` function:

```
"The number " + str(4) + " is my favourite number"

'The number 4 is my favourite number'
```

```
print (type(3.4))
print (type(str(3.4)))

<class 'float'>
<class 'str'>
```

In this simple case everything worked fine but type casting is not always possible: for example a number can be converted to a string (e.g. from the integer 4 to the actual symbol "4") but the opposite is not possible (e.g. cannot convert the string "matteo" to a meaningful number). In this second case we can try to use the function `int()` to convert a string to an integer.

```
int("matteo")

---------------------------------------------------------------------------

ValueError                                Traceback (most recent call last)

<ipython-input-17-979283bb65e4> in <module>
----> 1 int("matteo")

ValueError: invalid literal for int() with base 10: 'matteo'
```

```
int("4")

4
```

Pretty string formatting

In order to get prettier strings than those obtained just concatenating with the + operator, `python` allows to format text using the following syntax `"text {} other text {}".format(var1, var2)`. With this notation, each `{}` is mapped to the variables listed in the `format` statement, the optional characters inside the curly brackets can determine the resulting format, for example in the following code `{:.1f}` means that this variable is a float number and that has to be printed with only one digit only after the decimal separator.

```
"The speed of light is about {:.1f} {}".format(299792.458, "km/s")

'The speed of light is about 299792.5 km/s'
```

In addition `format` allows for 0-padding of numbers, left or right alignment of text columns and so on.

1.2.4 Mathematical expressions

Below few examples of the basic mathematical expressions available in `python`.

```
1 + 2

3
```

```
40 - 5

35
```

```
x * 20 # remember that we set x equal to 9

180
```

```
x / 4

2.25
```

```
print (type(2.25))

<class 'float'>
```

```
x // 4 # integer division - result will be truncated to the
       # corresponding integer (no rounding)
       # 11 / 3 = 3.666666 -> 11 // 3 = 3


2
```

```
y = 3
x ** y # x to the power of y

729
```

```
3 * (x + y)

36
```

As an example of variable manipulation let's try to increment `x` by 1 and save the result again in `x`.

```
print (x)
x = x + 1
print (x)

15
16
```

Sometimes the increment of a variable plus the assignment to the same variable is written with a more compact syntax `x += 1` (this is also true for other operators e.g. `x *= 2`).

More complex mathematical functions are not directly available, let's see for example the logarithm:

```
log(3)

---------------------------------------------------------------------------

NameError                                 Traceback (most recent call last)

<ipython-input-17-ffde4d60496a> in <module>()
    ----> 1 log(3) # causes an error because the logarithm function
          2        # is not available by default


NameError: name 'log' is not defined
```

1.3 Modules

One very important feature of each language is the ability to reuse code among different programs, e.g. imagine how awful would be if you had to re-implement every time you need it a function to compute the logarithm. Usually there are mechanisms that allow to collect useful routines in *packages* (or *libraries*, or *modules*) so that later they can be called and used by any program may need them.

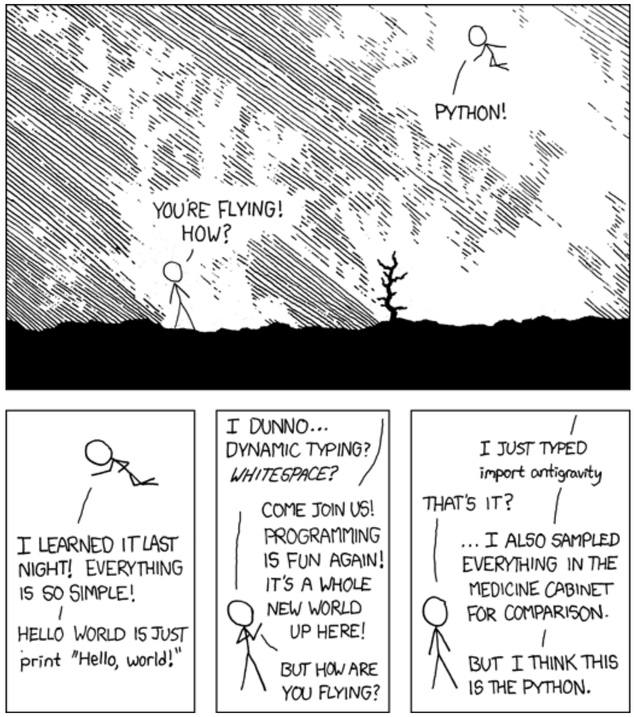
These collections of utilities in `python` are called *modules* and each installation of this language brings with it a standard set of them. If you need more functionality, you can download more modules from the web (there are zillions out there) or if you are not satisfied with what you found you can write your own (which is one the goal of this course in the end).

Some examples of useful modules we will use are:

- Numpy - which provides matrix algebra functionality and much more;
- Scipy - which provides a whole series of scientific computing functions;
- Pandas - which provides tools for manipulating time series or data-set in general;
- Matplotlib - for plotting graphs;
- Jupyter - for notebooks like this one.

Later we will take a closer look at three modules which are quite useful in financial analysis.

In order to load a module in a `python` program you can use the `import` keyword. To inspect a module (to understand which are its functionalities) it can be used the `help` and `dir` keywords:



`Python` has many modules for download on the web...

the first write a help message which usually describes the functionalities of a module, the latter list all the available functions of a module. **In order to access a function of a module you have to use the . (dot) operator:** `module-name.function-name`**.**

Let's see an example dealing with the `math` module which implements the most common mathematical functions.

```
import math
dir(math)

Out[18]: ['__doc__',
          '__loader__',
          '__name__',
          '__package__',
          '__spec__',
          'acos',
          'acosh',
          'asin',
          'asinh',
          'atan',
          'atan2',
          'atanh',
          'ceil',
          'copysign',
          'cos',
          'cosh',
```

```
...
```

```
help(math)

Help on module math:

NAME
    math

MODULE REFERENCE
    https://docs.python.org/3.6/library/math

    The following documentation is automatically generated from the Python
    source files.  It may be incomplete, incorrect or include features that
    are considered implementation detail and may vary between Python
    implementations.  When in doubt, consult the module reference at the
    location listed above.

DESCRIPTION
    This module is always available.  It provides access to the
    mathematical functions defined by the C standard.

FUNCTIONS
    acos(...)
        acos(x)

        Return the arc cosine (measured in radians) of x.
...
```

```
math.log(3)

1.0986122886681098
```

```
math.exp(3)

20.085536923187668
```

```
print (type(math.log)) # yet another type: builtin function
print (type(math.log(3)))

<class 'builtin_function_or_method'>
<class 'float'>
```

If we want to avoid to type `math.` every time we compute a logarithm or an exponential, we can just import only the needed functions from a module using the following syntax:

```
from math import log, exp
print (log(3))
print (exp(3))

1.0986122886681098
```

```
20.085536923187668
```

As an example let's compute the interest rate r that produces a return R of 11000 Euro when investing 10000 Euro for 2 years:

$$R = Ne^{r\tau} \rightarrow r = \frac{1}{\tau}\log(\frac{R}{N})$$

```
rate = (1/2)*log(11000/10000)
print (rate)

0.04765508990216247
```

1.4 Indented blocks and the `if/elif/else` statement

Unlike other languages which uses parenthesis to isolate blocks of code `python` uses *indentation*. A first example of this peculiarity is given by `if/elif/else` statements. Such commands allow to dynamically run different blocks of code based on certain conditions. For example in the following we print different statements according to the value of `x`, note that the block of code to be run according each condition is shifted (i.e. indented) with respect to the rest of the code:

```
print (x)
if x == 1:
    print ("This will not be printed")
    # the block of code that is run if the first condition is met is indented
elif x == 15:
    print ("This will not be printed either")
    # again the block of code that is run here is indented
    # to be "isolated" by the rest
else:
    print ("This *will* be printed")

16
This *will* be printed
```

If by mistake the indentation of a block is missing an error is raised:

```
if x == 1:
print ("This will not be printed")
elif x == 15:
    print ("This will not be printed either")
else:
    print ("This *will* be printed")

File "<ipython-input-38-4535a45a6419>", line 3
  print ("This will not be printed")
    ^
IndentationError: expected an indented block
```

Below another example:

```
if x != 1:
   print ("x does not equal to 1")

x does not equal to 1
```

Just for comparison this is the same code written in `C`++:

```
if (x == 1) {
 print ("This will not be printed");
}
else if (x == 15) {
  print ("This will not be printed either");
}
else {
print ("This *will* be printed");
}
```

N.B. Notice how indentation doesn't matter at all here since the blocks are enclosed and defined by the brackets.

1.5 Loops

Another very important feature of a language is the ability to repeatedly run the same block of code many times. These is called looping and in `python` can be done with `for` or `while` keywords.

1.5.1 `for`

In a `for` loop we specify the set (or interval) over which we want to loop and a variable will assume all the values in that set (or interval). For example let's assume we want to print all the numbers between 25 and 30 excluded (here the keyword `range` returns the list of integers between the specified limits, if the first limit is not specified 0 is assumed):

```
for i in range(25, 30):
     print (i)

25
26
27
28
29
```

At each cycle of the loop the variable `i` takes one of the values between 25 and 31. With `range` it is also possible to specify the step, so that the loop can jump every 2 units or to go in descending order:

```
for i in range (30, 25, -1):
    print (i)
```

```
30
29
28
27
26
```

If it is needed to skip values in the loop the `continue` keyword can be used; in the code below 5 is actually missing from the list in the printout since it has been skipped by the `continue`:

```
for i in range(10):
    if i == 5:
        continue
    print (i)

0
1
2
3
4
6
7
8
9
```

Instead of using `range` it is possible to specify directly the set of looping values:

```
for i in (4, 6, 10, 20): # here we loop directly on a list of numbers
   print (i)

4
6
10
20
```

Finally looping on a string actually means to loop on each single character:

```
phrase = 'how to loop over a string'
for c in phrase:
   print (c)

h
o
w

t
o

l
o
o
p
```

```
o
v
e
r

a

s
t
r
i
n
g
```

1.5.2 `while`

In a `for` loop we go through all the elements of a list of objects, the `while` statement instead repeats the same block of code until a condition is met. The following block of code is run if `x` squared is less than 50, so we first set `x=1` and at each iteration we increment it by 1 until the condition is `True` (8 squared is 64 which is greater than 50):

```
x = 1
while x ** 2 < 50:
   print (x)
   x += 1

1
2
3
4
5
6
7
```

It is possible to exit prematurely from a `while` loop using the `break` keyword. In this case the while-condition is simply `True` so the code would run forever unless we set an exit strategy.

```
x = 1
while True:
  if (x ** 2 > 50):
      break
  print (x)
  x += 1

1
2
3
4
5
```

```
6
7
```

Chapter 2

Data Containers

In this chapter the container types available in python are reviewed.

2.1 Lists

A list in python is a container that is a *mutable*, ordered sequence of elements. Each element or value that is inside of a list is called an *item*. Each item can be accessed using square brackets notation (very important, list indexing is zero-based so the first element has index 0 actually). A list is considered mutable since you can add, remove or update the items in it. Ordered instead means that items are kept in the same order they have been added. Lists can be created by enclosing in square brackets the comma-separated list of the items or using the list() operator.

```
mylist = list([21, 32, 15])
mylist = [21, 32, 15]
print(mylist)
print (type(mylist))

[21, 32, 15]
<class 'list'>
```

```
print(mylist[0])

21
```

If you have a list of lists (i.e. a 2-dimensional list) you can use the square brackets multiple times to access the inner elements:

```
alist = [[1,2], [3,4], [5,6]]
print (alist[1][1]) # first [1] returns [3,4], second returns 4
```

The number of elements in a list is counted using the keyword len():

```
print(len(mylist))

3
```

Looping on list items can be achieved in two ways: using directly the list or by index:

```
print ("Loop using the list itself:")
for i in mylist:
    print (i)

print ("Loop by index:")
for i in range(len(mylist)): # len() returns the number of items in a list
    print (mylist[i])

Loop using the list itself:
21
32
15

Loop by index:
21
32
15
```

With the `enumerate` function is actually possible to do both at the same time since it returns two values, the index of the item and its value, so in the example below, `i` will take the item index values while `item` the item value itself:

```
for i, item in enumerate(mylist):
    print (i, item)

0 21
1 74
2 85
3 15
4 188
```

Since a list is mutable we can dynamically change its items:

```
mylist[1] = 74 # we can change list items since it's *mutable*
print (mylist)

[21, 74, 15]
```

With `append` an item is added at the end, while with `insert` an item can be added in a specified position:

```
mylist.append(188) # append add an item at the end of the list
print (mylist)

[21, 74, 15, 188]

mylist.insert(2, 85) # insert an item in the desired position
                     # (2 in this example)
print (mylist)

[21, 74, 85, 15, 188]
```

To append multiple values at once to a list a loop can be used but `python` offers a single line way of doing it: `[i*2 for i in range(10)]`. This syntax is called *list comprehension*.

Accessing items outside the list range gives an error:

```
mylist[10] # error ! it doesn't exists, the list has only 3
           # elements, so the last is item 2


---------------------------------------------------------------------------


IndexError                                Traceback (most recent call last)

<ipython-input-36-ed1e5e6c3e46> in <module>
----> 1 mylist[10] # error ! it doesn't exists, the list has only 3
      2            # elements, so the last is item 2


IndexError: list index out of range
```

Read carefully the error messages usually they are very explicative and can help a lot in *debugging* (i.e. finding mistakes) in your programs.

There are two more nice features of `python` indexing:

- negative indices are like positive ones except that they starts from the last element;
- *slicing* which allows to specify a range of indices to select more items at once (if the first or last limits are missing slicing will start from the first or end with last index respectively).

```
print ("negative index -1 returns the last element:", mylist[-1])
print ("slice [1:3] returns items 1st and 2nd:", mylist[0:3])
print ("slice [:2] returns items 0th and 1st:", mylist[:2])
print ("slice [2:] returns items between the 2nd and the last:", mylist[2:])

negative index -1 returns the last element: 188
slice [1:3] returns items 1st and 2nd: [21, 74, 85]
slice [:2] returns items 0th and 1st: [21, 74]
slice [2:] returns items between the 2nd and the last: [85, 15, 188]
```

Needless to say that slicing with `[:]` returns the entire list.

It is worth mentioning that a list doesn't have to be populated with the same kind of objects (list indices are instead always integers).

```
mixedlist = [1, 2, "b", math.sqrt]
print (mixedlist)

[1, 2, 'b', <built-in function sqrt>]
```

```
print (mixedlist['k'])


---------------------------------------------------------------------------


TypeError                                 Traceback (most recent call last)
```

```
<ipython-input-72-aea4c7f9789e> in <module>()
----> 1 print (mixedlist['k'])

TypeError: list indices must be integers or slices, not str
```

A complete list of the commands available for a list can be shown with the `dir` statement:

```
dir(list)

[...
 'append',
 'clear',
 'copy',
 'count',
 'extend',
 'index',
 'insert',
 'pop',
 'remove',
 'reverse',
 'sort']
```

Their meaning is pretty clear, so for example `sort` re-order the items according to a custom criteria or `index(item)` return the index of the specified item.

2.2 Dictionaries

A we have seen lists are ordered collections of elements and as such we can say that map integers (the index of each item) to values (any kind of `python` object). *Dictionaries* generalize such a concept being containers which map *keys* (**almost** any kind of `python` object) to values (any kind of `python` object).

In our previous section we had:

$$0\ (\text{0th item}) \rightarrow 21$$
$$1\ (\text{1st item}) \rightarrow 74$$
$$2\ (\text{2nd item}) \rightarrow 85$$
$$...$$

With a dictionary we can have something like this:

$$''apple''(\text{key}) \rightarrow 4$$
$$''banana''(\text{key}) \rightarrow 5$$

As we will see dictionaries are very flexible and will be very useful to represent complex data structures.

Dictionaries can be created by enclosing in curly brackets the comma-separated list of key-value pairs (key and value are separated by a :), or using the `dict()` operator. In lists we could access items by index, here we do it by key still using the square brackets. Trying to access not existing keys results in error, but we can check if a key exists with the `in` operator. As before, if a dictionary contains other dictionaries or lists, the square brackets can be applied repeatedly to access the inner items.

```
adict = {"apple": 4, "banana": 5}
print (adict["apple"])

4
```

```
adict["pear"] # error !

---------------------------------------------------------------------------

KeyError                                  Traceback (most recent call last)

<ipython-input-41-9d051ebd10de> in <module>
----> 1 adict["pear"] # error ! this key doesn't exists

KeyError: 'pear'
```

```
"pear" in adict # indeed

False
```

The items can be dynamically created or updated with the assignment = operator, while again `len()` returns the number of items in a dictionary.

```
adict["banana"] = 2
adict["pear"] = 10
print (len(adict))
print (adict)

3
{'apple': 4, 'banana': 2, 'pear': 10}
```

Dictionaries can be made of more complicated types than simple string and integers:

```
adict[math.log] = math.exp
```

Also dictionaries can be created with the *comprehension* syntax: `{i:v for i, v in enumerate(["a", "b", "c"])}`.

Looping over dictionary items can be done by key, by value or by both: `.keys()` returns a list of keys, `.values()` returns a list of values and `.items()` a list of pairs key-value.

```
print ("All keys: ", adict.keys())
for key in adict.keys():
    print (key)

print ("All values: ", adict.values())
for value in adict.values():
    print (value)
```

```
print ("All key-value pairs: ", adict.items())
for key, value in adict.items():
    print (key, value)

All keys:  dict_keys(['apple', 'banana', 'pear', <built-in function log>])
apple
banana
pear
<built-in function log>

All values:  dict_values([4, 2, 10, <built-in function exp>])
4
2
10
<built-in function exp>

All key-value pairs:  dict_items([('apple', 4), ('banana', 2), ('pear', 10),
(<built-in function log>, <built-in function exp>)])
apple 4
banana 2
pear 10
<built-in function log> <built-in function exp>
```

To merge two dictionaries the function `update()` can be used, while with `del` it is possible to remove a key-value pair.

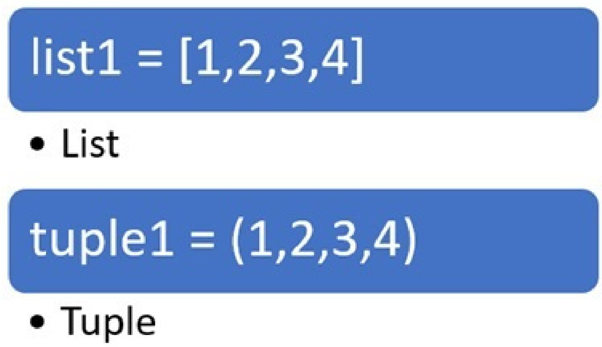
```
del adict[math.log]
seconddict = {"watermelon": 0, "strawberry": 1}
adict.update(seconddict)
print (adict)

{'apple': 4, 'banana': 2, 'pear': 10, 'watermelon': 0, 'strawberry': 1}
```

Again the complete list of dictionary functions can be shown with `dir`:

```
dir(dict)

[...
 'clear',
 'copy',
 'fromkeys',
 'get',
 'items',
 'keys',
 'pop',
 'popitem',
 'setdefault',
 'update',
 'values']
```

2.3 Tuples

Tuples create a bit of confusion for beginners because they are very similar to lists but they have some subtle conceptual differences. Nonetheless, tuples do appear when programming in `python` so it's important to know about them.



At first glance list and tuples look very similar, but they are not...

Like lists, tuples are containers of any type of object. Unlike lists though they are *immutable* which means that once they have been created the content cannot be changed (i.e. no append, insert or delete of the elements). Furthermore since they are immutable they can be used as dictionary keys (lists cannot). To create a tuple the comma-separated list of items has to be enclosed in brackets, or the `tuple()` operator can be used. Accessing tuple items is done in exactly the same way as lists.

```
atuple = (1, 2, 3)
print ("Length: {}".format(len(atuple)))
print ("First element: {}".format(atuple[0]))
print ("Last element: {}".format(atuple[-1]))

Length: 3
First element: 1
Last element: 3
```

In the next snippet of code it is shown the so called unpacking which is another way to assign tuple values to variables.

```
x, y, z = (10, 5, 12)
print ("coord: x={} y={} z={}".format(x, y, z))

coord: x=10 y=5 z=12
```

If an ntuple has just one element don't forget the comma at the end otherwise it will be treated as a single number.

```
tuple2 = (1,)
print(type(tuple2))
tuple2 = (1)
print(type(tuple2))
```

```
<class 'tuple'>
<class 'int'>
```

Since a tuple is immutable to add new elements it is necessary to create a new object:

```
tuple1 = (1, 2, 3)
tuple2 = tuple1 + (4, 5)
print(tuple2)

(1,2,3,4,5)
```

Finally, as already said tuples can be used as dictionary keys:

```
d = {
   ('Finance', 1): 'Room 8',
    ('Finance', 2): 'Room 3',
    ('Math', 1): 'Room 6',
    ('Programming', 1): 'IT room'
    }
```

Below the full list of tuple functions:

```
dir(dict)

[...
 'count',
 'index']
```

Chapter 3

Date and Time

In this chapter we will take a little break and concentrate on a topic that it is not usually covered in this type of courses. However given its importance for financial computation the next paragraphs will be devoted to a close look up on the `datetime` module, whose usage will help in manipulating dates.

3.1 Dates

As said dates are not usually included in a standard `python` tutorials, however since they are pretty essential for finance we are going to cover this topic in some detail. In `python` the date utilities mainly lives in the `datetime` module. We are also going to show `relativedelta` from the `dateutil` module, which allows to add/subtract days/months/years to dates, in other words to make operations on them.

In this first example the today's date is defined and with `relativedelta` two more dates are created adding two months and three days to the first one.

```
from datetime import date, datetime
from dateutil.relativedelta import relativedelta

date1 = date.today()
print (date1)
date2 = date.today() + relativedelta(months=2)
print (date2)
date3 = date.today() - relativedelta(days=3)
print (date3)

2020-08-03
2020-10-03
2020-07-31
```

Here instead another way of computing a new date is shown: in particular a one day delta is stored in a variable and today's date is moved by three days multiplying the defined delta by three.

```
one_day = relativedelta(days=1)
date.today() - 3 * one_day

datetime.date(2020, 7, 31)
```

Next, given two dates their difference is computed (and expressed in days).

```
date1 = date(2019, 7, 2)
date2 = date(2019, 8, 16)
(date2 - date1).days

45
```

Dates can be converted to and from strings and a large variety of formats can be specified in this conversions. The format is determined by a string in which each character starting with % represent an element of the date, e.g. %Y year, %d day, %s seconds, etc...

Below dates to string conversion:

```
date1 = date(2019, 7, 2)
date1.strftime("%Y-%b-%d (%a)") # dates can formatted in many ways
                                # check the docs for more details

'2019-Jul-02 (Tue)'
```

And here, a string is converted to `datetime` object:

```
# a string can be converted to dates too
datetime.strptime('25 Aug 2019', "%d %b %Y").date()

datetime.date(2019, 8, 25)
```

Finally a last example showing how to get the week-day from a date:

```
date1.weekday() # 0 = Monday, ..., 6 = Sunday

1
```

Chapter 4

Python's Object Oriented Programming

In this chapter the main characteristics that makes `python` an *object oriented programming* language will be reviewed. Before going to OOP however the concepts of function and variable scope will be outlined.

4.1 Functions

A function is a block of organized, reusable code that is used to perform a single action. Functions provide better modularity for your application and high degree of code reusing. To define a function the keyword `def` is used, followed by the name of the function and by the required parameters in parenthesis. Functions are called by name passing the necessary parameters if any.

```
# sum up all the integers between 1 and n
def my_function(n): # this function take one input only (n)
    x = 0
    for i in range(1, n+1):
        x += i
    return x # the function returns a number

my_function(5) # 5 + 4 + 3 + 2 + 1
```

Functions can return any kind of objects (numbers, strings, lists, complex objects...) but it is not mandatory to have a return value, so you can have functions **without** a `return` statement (e.g. a function that simply take a string as input and print it to screen with a particular format). In addition the syntax of the `return` is different from other languages like `Visual Basic`, the returned object doesn't have to have the same name as the function. Indeed above the variable `x` is returned and not the variable `my_function`.

```
def printing(mystring):
    print((myString).upper())
```

Functions can call other functions (once a function has been defined it can be accessed from everyone withing the same file or notebook): here my$_f$unction$_2$ calls my$_f$unction

```
def my_function_2(n, x):
    return "The result is : {}".format(str(my_function(n)*x))
    # returns x * result of my_function(n)
    # so function of function

my_function_2(5, 10)
```

Functions can also call themselves too (i.e *recursion*). In the next example we will see a function that computes the factorial exploiting the following relationship:

$$\begin{cases} n! = n \times (n-1)! & (\forall n > 1) \\ n! = 1 & (\forall n \leq 1) \end{cases}$$

```
def factorial(n):
    if n <= 1:
        return 1
    else:
        return n * factorial(n-1)

factorial(10)
```

In this example the function `factorial` is initially called with the input corresponding to the factorial we want to compute, it then call itself each time with $\texttt{n} - \texttt{1}$, multypling together all the results.

The previous example is quite simple but recursion can be tricky sometimes so apply it with caution.

Functions input parameters also accept default values, which means that a function that works with some input values can be called with less parameters provided their default values have been specified.

In the following example the function `powers` takes three inputs: a list of numbers, an exponent (`n`) and a constant (`c`). The code loops through the provided list of numbers and process them according to the formula $item^n + c$, it puts the results in a new list which will be finally returned.

```
def powers(l, n=2, c=0):
    return [item**n+c for item in l]

print (powers([5, 11, 6], 3, 4))
print (powers([5, 11, 6]))

[129, 1335, 220]
[25, 121, 36]
```

As you can see in the example the function is called twice with two different set of parameters: in the first case we pass to it the list of numbers, the exponent and the costant, in the second only just the same list of numbers. In the latter case, being defined the default values for `n` and `c`, the function works as well, fewer inputs are provided and the missing ones will be replaced by their defaults.

When calling a function paramenters can be passed also by name for clarity, in this case of course the order doesn't matter. Compare the two results below:

```
def func(a, b, c):
    return a + b * c

print (func(c=4, b=2, a=1))
print (func(4, 2, 1))

9
6
```

In the first case the function is called by name, in the second case the parameter are implicitly assinged according to thier position.

Another nice feature of `pyhton` functions is that we can associate an help message to them so that we can easily check what a function is for by simply asking `help(functioName)`:

```
def powers(l, n=2, c=0):
    """
a shifted power function example
    """
    return [item**n+c for item in l]

help(powers)

Help on function powers in module __main__:

powers(l, n=2, c=0)
    a shifted power function example
```

Remember it is always very important to document your code !

4.2 Variable scope

Not all variables are accessible from all parts of our program, and not all variables exist for the entire lifetime of the program. The part of a program where a variable is accessible is called its *scope*.

A variable which is defined in the main body, sometimes referred to as global namesapce i.e. the code block which is not indented at all, of a file is called a *global variable*. It will be visible throughout the file, and also inside any file which imports that file. Global variables can have unintended consequences because of their wide-ranging effects, that is why we should almost never use them and they are usually represented by an uppercase name. Only objects which are intended to be used globally, like functions and classes (which will be introduced in the next section), should be put in the global namespace.

Global variables can be accessed directly inside but before doing that they have to be specified in a special statement starting with the keyword `global`. Essentially `global` tells `python` that in the following function we want to use the listed global variable.

Imagine a global variable `AGLOBALPARAM` has been defined at the beginning of a program, in the example below it is shown:

- a function that read the value of `AGLOBALPARAM` without modifying it;

- a function that read and modify `AGLOBALPARAM`;
- and a function that throws an exception (i.e. an error in technical language) because it has been badly coded.

```
AGLOBALPARAM = 10

# Here you just use AGLOBALPARAM value, but do not modify it
# param is just a local copy of AGLOBALPARAM
def multiplyParam(param):
    param = param * 10
    return (param)

# Here you actually use AGLOBALPARAM
# you modify it directly with the global command
def divideParam():
    global AGLOBALPARAM
    AGLOBALPARAM = AGLOBALPARAM / 10
    return (AGLOBALPARAM)

# Here you try to use AGLOBALPARAM but gives you an error
# AGLOBALPARAM is not defined in the function body
# and the global command has not been used neither
def sumParam():
    AGLOBALPARAM = AGLOBALPARAM + 10
    return (AGLOBALPARAM + x)

print ("AGLOBALPARAM is {} to start.".format(AGLOBALPARAM))
print ("Let's multiply it by 10.")
multiplyParam(AGLOBALPARAM)
print ("AGLOBALPARAM is still {}".format(AGLOBALPARAM))
print ("Let's divide it by 10")
divideParam()
print ("Now AGLOBALPARAM is {}".format(AGLOBALPARAM))
print ("Let's sum it to 10")
sumParam()
```

A variable which is defined in a block of code is said to be local to that block. Examples of local scopes are: functions, `for` or `while` loops, `if` blocks, ... In the case of a fucntion it means that a local variable will be accessible from the point at which it is defined until the end of the function itself (e.g. function parameters are examples of local variables).

```
# functions are not evaluated untill their are not called
def test_scope(max_val):
    for i in range(max_val):
        print (i)
    print ("max_val in 'test_scope' function is {}".format(max_val))

# the Python interpreter starts evaluating the code from here
```

```
max_val = 10
test_scope(5)
print ("max_val in global scope is {}".format(max_val))
print (i)
```

In the previous example we have defined two `max_val` variables, one which is global and it has been initially set to 10, another one which is local to the `test_scope` function. Try as much as possible to use different names for each variable you are going to use in a program to avoid possible confusion and mistakes which may lead to unexpected behaviour of your code.

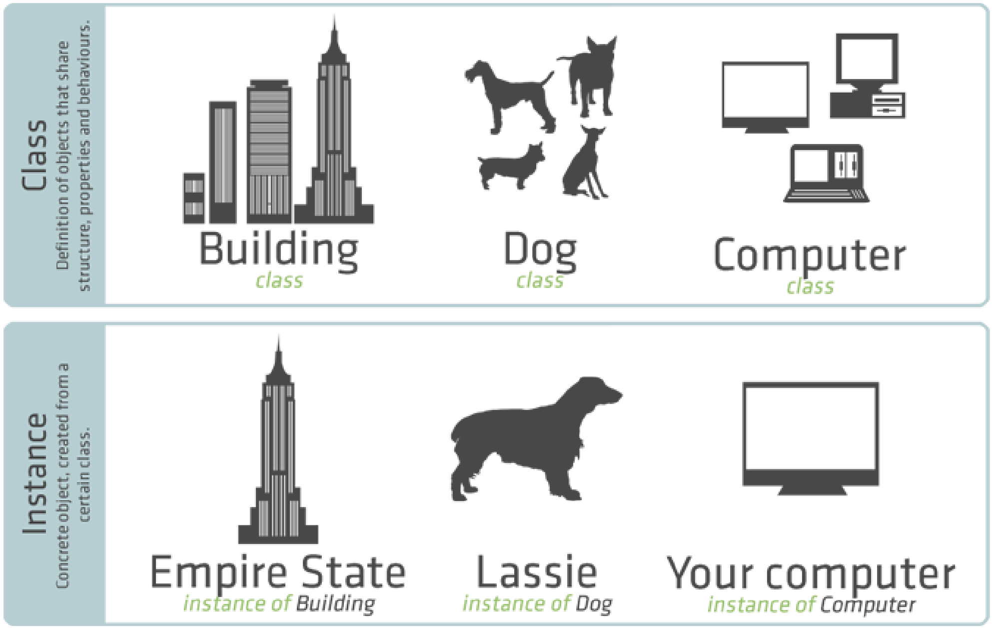
As a last example compare the following `for` loops; the first one correctly written loops with tha variables `i` and `j`, in the second one `j` has been replaced by `i`, note how this is perfectly legal but the result changes dramatically:

```
a = [["a", "b", "c"],["d", "e", "f"],["g", "h", "i"]]
for i in range(3):
    for j in range(3):
        print (a[i][j])

a
b
c
d
e
f
g
h
i
```

```
a = [["a", "b", "c"],["d", "e", "f"],["g", "h", "i"]]
for i in range(3):
    for i in range(3):
        print (a[i][i])

a
e
i
a
e
i
a
e
i
```

4.3 Classes

Classes are a key ingredient of *Object Oriented Programming* (OOP) and their concept is implemented in many languages like `python`, `Java` and `C++`. OOP is a programming model in which



Graphical representation of a class instance.

programs are organized around data, or objects, rather than functions and logic. **An object can be thought of a dataset with unique attributes and behaviour** (examples can range from physical entities, such as a human being that is described by properties like name and birthday, down to abstract concepts as a discount curve). This opposes the historical approach to programming where emphasis was placed on how the logic was written rather than how to define the data within the logic. In this framework classes are a mean for creating objects (a particular data structure), providing initial values for state (member variables or attributes), and implementations of behavior (member functions or methods).

Let's summarize here some terminology:

- a class is a collection of related functions, and these are called the *methods* of the class;
- methods act on *instances* of the class, which are classes initialized with some data;
- each data item has a name, and those names are called the *attributes* of the class.

In other words classes are collections of functions that operate on a dataset, and instances of that class represent individual datasets (or in other words a specialization of that class).

Examples of class are: a class representing a generic building (with number of entrances, number of floors, a flag to know if there is a garden...), a generic dog (with age, fur color...) or a generic computer (with manifacturer, RAM size, CPU type,...).

Examples of corresponding instances are: the Empire State Building (a specific building), Lassie (a very particular dog), or your computer.

To see how they can be defined let's try to code a class representing a person:

```
from datetime import date
# this is the class definition
# usually classes use camel naming convention
class Person:
```

```
    # the special method __init__ allows to instanciate a class
    # with an initial dataset (in this example a name and a birthday)
    def __init__(self, name, date_of_birth):
        # attribute of the class Person
        # name and self.name are different variable !!!
        # name will be destroyed once __init__ is processed
        # self.name lives with every particualar instance of Person
        self.name = name
        # attribute of the class Person
        self.date_of_birth = date_of_birth

    # this normal method computes the current age of the
    # "instanciated" person
    def age(self):
        today = date.today()
        age = today.year - self.date_of_birth.year
        if today.month < self.date_of_birth.month or \
            today.day < self.date_of_birth.day:
            age -= 1
        return age
```

First of all the necessary modules are imported, in this case the `datetime` module is used to managed the person age. Then the `class` keyword followed by the class name is used to start the actual class definition. In a sepate block of code all the class methods are defined like normal functions, you can see `__init__` and `age` here. These are examples of two kind of methods:

- normal methods which use or modify the instance attributes;
- special methods, which define the class behaviour: you can spot these because they start and end with two underscores (__).

`__init__` is the simplest example of special methods, it is called every time a class is instanciated (e.g. when you write me = Person(...)) and initializes the attributes of the class, in our example assign values to the `name` and `date_of_birth` attributes.

Another peculiarity of class methods with respect to standard functions is that they always take as first argument `self`. The `self` keyword is very important since allows a method to use the class attributes. Basically if you need to use the `name` attribute you have to type `self.name`.

There are lots of other things you can do with classes, but this is enough for now. So let's try to play a bit with our example:

```
# here we instanciate (create an instance of) the class
# in other words we "specialize" a generic Person with some data

me = Person("Matteo", date(1974, 10, 20))
  print (type(me))
```

Once we have create an instance of a class its methods and attributes can be accessed again with the dot notazion: `instance_name.method_name`.

```
# to access class attributes you have to use .
me.name

me.date_of_birth

# to call a class method you have to use .
# passing the parameters if needed
me.age()
```

Let's try to add more functionality to our class, adding a method that simply prints the age of the person in nice format. So complete the `Person` class with the following code:

```
    # methods in a class are just functions which can work
    # with the class attributes
    # Remember I told you functions can have no return ?
    def print_age(self):
        print ("{} is {} years old right now"\
               .format(self.name, self.age()))
```

Then try to test the new method by instanciating a new "person" and print her age.

```
her = Person("Francesca", date(1986, 1, 27))
print (her.print_age())
```

```
34
```