Lab 02 - Python basics

Objectives

- Familiarization with *Python 3.x*
- Understanding core differences between *Python* and *C/C++* or *Bash*
- Writing a neat little script to help solve substitution ciphers

Contents

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Proof of Work

Learning *Python* is not a 2-hour endeavor. Today's lab is barely scratching the surface but we have to start somewhere, right? Leaving today's tasks aside, we suggest you take on a few coding challenges [https://www.hackerrank.com/domains/python?filters%5Bsubdomains%5D%5B%5D=py-introduction] before lab 03, all while keeping the documentation [https://docs.python.org/3.9/index.html] and also, ***the documentation [https://www.google.com/]*** readily available at all times.

The first two exercises this week are tutorials. You don't have to upload any proof of reading them or testing the commands :p. We mostly stuck to the basics, but now and again you will see some long-winded explanations that we considered relevant. If you're already a *Python* expert, feel free to breeze through them. If not, play around in the **python** shell, with *Python* scripts, and ask questions.

Exercise 3 is not a tutorial and will require you to apply some of the concepts learned in this laboratory to break a cipher. The solution can be as simple as a single line of code, but what matters is solving the puzzle, not how optimally you do it. Once again, document your attempt and upload a *.pdf* together with your script to the appropriate moodle [https://curs.upb.ro/2021/course/view.php?id=5793] assignment. The submission cut-off time is 11:55pm, on the same day as the lab. Also, please don't forget the feedback! :D

Tasks

01. [25p] Intro, datatypes and more

Up until now, you should have had some interaction with the *C language* (or even, with *C++*). Normally, you would write your code in a source file, compile it with **gcc** and most likely get a few dozen errors. Eventually, you would end up with a binary executable file (i.e.: an ELF [https://refspecs.linuxfoundation.org/elf/elf.pdf]).

Another language that you've recently started learning is *Bash*. The main difference between the two is that *Bash* is actually an interpreted language, meaning that you have a program (also called **bash**; confusing, I know) that continuously reads your input and has pre-determined routines that it executes for known command patterns.

Python can be seen as a combination of the two. On the one hand, it's an interpreted language, just like *Bash*. Try to run **python3** in your terminal and see for yourself. Notice how the prompt changed? The similarities with *Bash* though, pretty much end there. *Python* is closer to *C/C++* in that it's better structured, implementing concepts from Object-Oriented Programming (OOP) and supporting multiple programming paradigms.

Why should you learn *Python*:

- It's easier to learn than *C/C++*. While these are low-level languages, preferred when you need precise control over certain aspects such as the memory, *Python* is more flexible (e.g.: dynamic typing vs static typing) and lets you prototype ideas faster.
- It's widely used in the industry for writing “glue code”. Compiled languages are, of course, significantly faster than interpreted languages. If you want high performance cryptographic libraries or game engines, you use a compiled language. “So why learn *Python* at all?”, you may think. By providing wrappers for libraries written in other languages, *Python* is meant to help you build a system from multiple pre-existing components with the minimum amount of effort.
- It gives you more control in some cases. In *C++* for example, classes (i.e.: *C* structures but smarter) typically use access specifiers such as **public** or **private** to control what mechanisms you can interact with, as a developer. Sometimes (very rarely) you may actually know what you're doing and you might want to fiddle around with the implementation of a container [https://en.cppreference.com/w/cpp/container], let's say. Unless you are willing to modify and recompile that specific library, you'd be forced to employ some pretty dubious hacks to make the change. *Python* on the other hand, doesn't have access specifiers. By convention, anything within a class that you are not supposed to interact with will be prefixed with a '_' (e.g.: `_do_not_touch_me()`). But if you're keen on it, by all means… do as you wish.

Native data types

In *Python* you don't have to declare variables. You just… use them. By assigning a value to a variable, you create it. If a variable with the same name already exists, you overwrite it. Just because you don't specify a type during declaration (as in *C*), it doesn't mean that the variable doesn't have one. The type of the variable is inferred from the type of the value that is assigned. Naturally, performing operations on variables of different types might create problems. Adding an integer and a float is permitted because both are numeric types. Adding a string and boolean however… At least errors such as this, or dividing by zero [https://www.youtube.com/watch?v=asDlYjJqzWE] don't crash our shell.

```
$ python3
Python 3.9.7 (default, Aug 31 2021, 13:28:12)
[GCC 11.1.0] on linux
Type "help", "copyright", "credits" or "license" for more information.

>>> a = 'ana are mere'
>>> b = 55

>>> type(a)
<class 'str'>
>>> type(b)
<class 'int'>
>>> c = True
>>> type(c)
```

```
<class 'bool'>

>>> a = 3.1415
>>> type(a)
<class 'float'>

>>> 'ana are mere' + c
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: can only concatenate str (not "bool") to str
>>> 1 / 0
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ZeroDivisionError: division by zero
```

Let's take a look at each of the more common types in *Python*:

Numbers

As you probably noticed in the snippet above, *Python* makes a distinction between different numeric types, such as *float* or *integer*. It, however, is not limited to only these two types. *Complex* numbers are also natively supported:

```
>>> a = 3
>>> b = 5
>>> c = 1 - 8j

>>> isinstance(c, complex)
True
>>> c.real
1.0
>>> c.imag
-8.0

>>> a *= 1j
>>> a
3j
>>> c * a - b
(19+3j)
```

Notice how we accessed the real and imaginary parts of the complex number `c`? Being able to do this should immediately remind of structures in *C*, or classes in *C++*. We should investigate this further…

```
>>> help(c)
>>> # use the arrows or PageUp / PageDown to navigate the help window
>>> # press 'q' to exit back to the shell prompt
>>> # yes, these are all comments
>>> # no, you don't have to copy them :p
```

The **help()** function is an interpreter built-in that accesses the documentation of a specific type, module, etc. The output might be a bit too… complete. But if you scroll all the way down, you will find what we're interested in:

```
 |  conjugate(...)
 |      complex.conjugate() -> complex
 |
 |      Return the complex conjugate of its argument. (3-4j).conjugate() == 3+4j.
 |
 |  ----------------------------------------------------------------------
 |  Data descriptors defined here:
 |
 |  imag
 |      the imaginary part of a complex number
 |
 |  real
 |      the real part of a complex number
```

So the *complex* type has two internal variables that hold the real and imaginary parts of the number. But what's this? It also has a method (i.e.: function) defined. Try to invoke **conjugate()** for `C`. Does it work? Does it change the **imag** and **real** internal variables?

Well, that was an interesting detour. But let's get back to our numbers. As you might imagine, all the basic arithmetic operators work in *Python* pretty much like they would in *C*; even the modulus operator. There are, however, two extra ones that might be useful: *exponentiation* and *floor division*:

```
>>> 5 ** 3
125

>>> # regular division can produce a float even if the operands are integers
>>> 9 / 4
2.25
>>> # floor division acts like regular division on integers in C
>>> 9 // 4
2
```

“What about bitwise operators?” Of course they're supported ;)
Here is a reminder [https://mathstats.uncg.edu/sites/pauli/112/HTML/secbinary.html] if you forgot how the binary representation of numbers works.

```
>>> x = 8
>>> bin(x)
'0b1000'

>>> bin(x << 1)
'0b10000'
>>> bin(x >> 2)
'0b10'
>>> bin(x | 0b0010)
'0b1010'
>>> bin(x ^ 0b1010)
'0b10'
>>> bin(x & 0b0111)
'0b0'
```

Strings

Strings in *Python* are more similar to the std::string [https://en.cppreference.com/w/cpp/string/basic_string] in *C++* than with those in *C*. Just a heads up, but this will be a running theme while you learn *Python*. Knowing about OOP [https://en.wikipedia.org/wiki/Object-oriented_programming#:~:text=Object%2Doriented%20programming%20(OOP),(often%20known%20as%20methods).] and *C++* is not necessary to understand the basic concepts in *Python* but it does help somewhat. Anyway, a string declaration works pretty much as you'd expect. Note that you can use both single and double quotes in their declaration. It doesn't matter which you prefer.

While the choice of single / double quotes is irrelevant in *Python*, the same cannot be said for **Bash**. Single quotes [https://www.gnu.org/software/bash/manual/html_node/Single-Quotes.html] inhibit the expansion of character sequences (e.g.: referencing a variable, like `${MY_VAR}`). Double quotes [https://www.gnu.org/software/bash/manual/html_node/Double-Quotes.html] do not. Make sure you don't mix up these concepts.

```
>>> # here, we use the + operator to concatenate four strings into one
>>> # we use \ to break the current line and continue our command on the next
>>> # do not copy the ... at the start; that's the multiline prompt
>>> # bonus point if you recognize the quote ;)
>>> s = "'I was there,' he would say afterwards, until afterwards "  + \
...     "became a time quite devoid of laughter. 'I was there, the " + \
...     "day Horus slew the Emperor.' It was a delicious conceit, "  + \
...     "and his comrades would chuckle at the sheer treason of it."

>>> # the length of the string can be obtained using len()
>>> len(s)
230

>>> # we can access a single character from the string, but it's still a string
>>> s[3]
'w'
>>> type(s[3])
<class 'str'>

>>> # we can also extract a substring
>>> # if we specify [x:y], it starts from the letter indexed x, but stops at y-1
>>> # if we avoid specifying x, it will consider it to be 0 implicitly
>>> # if we avoid specifying y, it will consider it to be len(s) implicitly
>>> s[0:38]
"'I was there,' he would say afterwards"
>>> s[:38]
"'I was there,' he would say afterwards"
>>> s[210:]
'sheer treason of it.'

>>> # here, things get funky
>>> # you can use a *negative* index to count *backwards* from the end
>>> s[-20:]
'sheer treason of it.'
```

As you can see, we access individual characters and substrings just like how you'd expect to access elements in an array. The fact is, everything we've just seen here applies identically to generic arrays. We'll see that, and more, in the next section. For now, look in `help(str)`; identify a function to convert all characters to lowercase, and another to find a substring in a string. Apply both of them to `s` in one command in order to find the string *'emperor'* (all lower case).

One final thing about strings: formatting. There are multiple ways of doing this, but this is most similar to the formatting in **printf()** and honestly, it's the one I prefer :p

```
>>> '%-10s are %.2f mere' % ('Ana', 15)
'Ana        are 15.00 mere'
```

Lists

When you think “list”, you might be reminded of the constant-sized arrays in *C*. But lists in *Python* are closer in design to the std::vector [https://en.cppreference.com/w/cpp/container/vector] container from *C++*, in that they can be arbitrarily resized at runtime. One difference, however, is that the elements contained in a list do not have to be of the same type (although it would be preferable if they were).

```
# notice how we don't need \ to split the command
# the interpreter expects that we may want to extend the declaration on multiple lines
>>> months = [ 'January', 'February', 'March',
...            'April',   'May',      'June',
...            'July',    'August',   'September',
...            'October', 'November', 'December' ]

>>> # most of what we tested in the Strings section also applies here
>>> len(months)
12
>>> months[0]
'January'
>>> months[-1]
'December'

# here, we extract all months starting with the one indexed 3rd, up until the 3rd from the end
# obtaining a subset of a list is called slicing
>>> months[3:-3]
['April', 'May', 'June', 'July', 'August', 'September']

# here, we extract every second month starting with January
# the z in [x:y:z] is the iteration step
# in this case, x and y didn't need to be explicitly stated
>>> months[0:12:2]
['January', 'March', 'May', 'July', 'September', 'November']
>>> months[::2]
['January', 'March', 'May', 'July', 'September', 'November']

# here, we extract months ranging from the one indexed 6th to the one indexed 0th (excluding it), in reverse order
>>> months[6:0:-1]
['July', 'June', 'May', 'April', 'March', 'February']
```

Next, let's look at a neat little trick called **list comprehension**. We haven't looked at control structures (i.e.: **for**, **if**, etc.) yet, but the following use cases are more or less self contained. Note that the **range()** function does not generate a list, by itself. What it does, it creates a number generator that can be interrogated to continuously get the next number in the range. The reason for this is not to overload the memory when working with larger values.

```
>>> # list() consumes all values that range() can offer
>>> list(range(10))
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]

>>> # we create an array for every element (we call it "it") in the range
>>> # in stead of list(), the for structure consumes the input itself
>>> [ it for it in range(10) ]
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]

>>> # initialize the array with the cubes of the elements
>>> [ it ** 3 for it in range(10) ]
[0, 1, 8, 27, 64, 125, 216, 343, 512, 729]

>>> # do the same, but only for even elements in range
>>> # odd elements are in stead replaced with None
>>> # None is a special type that represents a NULL object
>>> [ it ** 3 if it % 2 == 0 else None for it in range(10) ]
[0, None, 8, None, 64, None, 216, None, 512, None]

>>> # include the cubes only of the odd elements
>>> # even elements are completely ignored
>>> [ it ** 3 for it in range(10) if it % 2 == 1 ]
[1, 27, 125, 343, 729]
```

Let's take a closer look at the final two examples. In the first, we used the *Python* equivalent of the *C* ternary operator: `it ** 3 if it % 2 == 0 else None`. This would roughly translate to `(it % 2 == 0) ? pow(it, 3) : None`. Notice that in this example, we either have to have `it ** 3` or `None`. In other words, we can't drop the `else`. Otherwise, we would get an invalid syntax error. For a similar outcome however, we have the second example. Here, the use of `if it % 2 == 1` at the end is specific to this type of array initialization and will most likely generate an error in any other context.

Since we know how to initialize an array, and access elements of an array, all that's left is manipulating an array.

```
>>> # first, create a simple list
>>> v = list(range(0, 20, 2))
>>> v
[0, 2, 4, 6, 8, 10, 12, 14, 16, 18]

>>> # delete the element with the index 4
>>> # del is a Python built-in keyword and can delete more than just list elements
>>> del(v[4])
>>> v
[0, 2, 4, 6, 10, 12, 14, 16, 18]

>>> # delete a whole range of values
>>> del(v[4:8])
>>> v
[0, 2, 4, 6, 18]

# delete the first occurrence of the element 4
>>> v.remove(4)
>>> v
[0, 2, 6, 18]

>>> # append a new element
>>> v.append(99)
>>> v
[0, 2, 6, 18, 99]

>>> # insert a new element on the first position
>>> v.insert(0, -99)
```

```
>>> v
[-99, 0, 2, 6, 18, 99]

>>> # extend the list with a few more numbers from a range()
>>> v.extend(range(-5, 5, 4))
>>> v
[-99, 0, 2, 6, 18, 99, -5, -1, 3]

>>> # concatenate v with another list, then overwrite v
>>> v += [ -10, 0, 10 ]
>>> v
[-99, 0, 2, 6, 18, 99, -5, -1, 3, -10, 0, 10]

>>> # sort all elements using the default criterion (i.e.: ascending order)
>>> v.sort()
>>> v
[-99, -10, -5, -1, 0, 0, 2, 3, 6, 10, 18, 99]
```

Tuples

While lists are variable-sized and any element can be changed, tuples are immutable. Meaning that they can't be changed in any way once they are created. Similarly to arrays, though, slicing still works. Because slicing creates a new tuple (or array) from an existing object, you are not really *changing* anything. We already used a tuple when doing string formatting earlier. They are defined exactly like a list, but using parentheses in stead of brackets. So why should we use tuples if we already have lists? For once, tuples are faster to iterate over than lists. Moreover, sometimes you might want your data to be read-only. For example, when you use the same tuple object as a dictionary key and expect it never to change.

```
>>> # this is how you declare a tuple
>>> t = ( 'pi', 3.1415, True )
>>> t
('pi', 3.1415, True)

>>> # splicing still works, and we get another tuple
>>> t[:2]
('pi', 3.1415)

>>> # a list can be generated from the content of a tuple
>>> list(t)
['pi', 3.1415, True]
>>> list(t) + [ 'e', .5772, True ]
['pi', 3.1415, True, 'e', 0.5772, True]

>>> # similarly, a tuple can be generated from a list
>>> tuple(list(t) + [ 'e', .5772, True ])
('pi', 3.1415, True, 'e', 0.5772, True)

>>> # tuples can be used as a shortcut to assign multiple values at once
>>> # many functions in Python return multiple values (how would you do this in C?)
>>> # by convention, you use _ to signify that you want to ignore a certain value
>>> t = ('c', 4, False)
>>> (x, y, _) = t
>>> x
'c'
```

```
>>> y
4
```

Dictionaries

These are unordered sets of key-value pairs. Each key must have a corresponding value. Also, each key is unique. Dictionaries work pretty much like an array, only that you don't *have* to use numeric indexes, but objects of your choice:

```
>>> # this is how you declare a dictionary (can also be empty)
>>> ip_addrs = { 'ocw.cs.pub.ro' : '141.85.227.65',
...              'google.com'    : '142.250.180.206',
...              'filelist.io'   : '104.21.16.66' }

>>> # blindly accessing elements is usually a bad idea
>>> ip_addrs['ocw.cs.pub.ro']
'141.85.227.65'
>>> ip_addrs['curs.upb.ro']
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'curs.upb.ro'

>>> # better to first check if the key exists in the dictionary
>>> 'curs.upb.ro' in ip_addrs
False
>>> ip_addrs['curs.upb.ro'] = '141.85.241.61'
>>> ip_addrs['curs.upb.ro']
'141.85.241.61'

>>> # dictionaries also have specific methods, viewable with help()
>>> # these are a few self-explanatory examples
>>> ip_addrs.keys()
['google.com', 'filelist.io', 'curs.upb.ro', 'ocw.cs.pub.ro']
>>> ip_addrs.values()
['142.250.180.206', '104.21.16.66', '141.85.241.61', '141.85.227.65']
>>> ip_addrs.items()
[('google.com', '142.250.180.206'), ('filelist.io', '104.21.16.66'), ('curs.upb.ro', '141.85.241.61'), ('ocw.cs.pub.ro', '141.85.227.65')]
```

02. [25p] Scripting, control structures and functions

Scripting

In essence, *Python* is still a scripting language. Writing a *Python* script is very similar to writing a *Bash* script. After all, both use a specific interpreter. So let's take a look at how we might start:

my_first_script.py

```
#!/usr/bin/python3

import sys      # gives access to cli arguments
```

```
def main():
    print('Hello world!\nReceived %d arguments are: %s' % \
        (len(sys.argv), str(sys.argv)))

if __name__ == '__main__':
    main()
```

Quick reminder: you need to give the script executable permissions if you want to run it.

```
$ chmod +x my_first_script.py
$ ./my_first_script.py these are some arguments
```

First of all, you can download this file directly by clicking on the name at the top of the snippet. Next, let's take it step by step and understand what is going on:

- On the first line, we have a shebang (i.e.: `#!`); this specifies the path to the interpreter that the operating system should use to run this script. You can try to identify the location of **python3** in your system using `$ whereis python3`, but it should be the same.
- The `import sys` is new, but you should at least intuit what it does. Functionally, it works pretty much like a *C* `#include`. Practically, there are differences:
  - an `#include` directive takes the code in the specified header file and just copy-pastes it before proceeding with the compilation.
  - a *C* header file does not (usually) contain the actual code. Only definitions that your program should use without having access to the implementation. Once the compilation is finished, more often than not the actual code that is executed by invoking the functions in the included header resides in a shared library (e.g.: */usr/lib/libcrypt.so*). Some of these libraries are linked by default (e.g.: */usr/lib/libc.so*). For others, you may need to specify a linker flag (e.g.: `-lcrypt`).
  - in *Python*, when you import a module, the interpreter basically executes all the code in the module. After that, it returns to the same `import` line but now, all functions have been defined and variables have been declared. The only difference from *C* is that you must access them through the module name (e.g.: `sys.argv`).
- `def main():` declares the start of a function (shocker). Note that this function did not have to be named *"main"*. There is no such convention in *Python*, but this name makes it familiar and immediately obvious what its purpose should be. Also, the script execution entry point is not this function!
- looking at the `print()` function, there are a few things to discuss:
  - *Python* does not have curly brackets like *C/C++*. In stead, it uses indentation as a way to differentiate blocks of code. For example, if we want to specify the body of the **main()** function, all instructions in said body must be indented by exactly one *tab*. If one of these instructions is an **if** statement, its body must be indented by two *tabs*. Note that these tabs can either be the *'\t'* character, or four spaces. However, if you combine the two in the same source file, the interpreter will throw an error!
  - remember that when using the **python** shell earlier, we could just punch in a variable name or an expression and the result would be shown? This does not work inside a script. Simply writing `sys.argv` has the same effect as in *C*. The expression is evaluated. The interpreter determines that it is a variable. It returns the content of the variable but there's nothing more to the statement. The obtained content is lost and the interpreter moves on… This is why we must use the **print()** function.
- Here, we meet our first real **if** statement: `if __name__ == '__main__':`. If we ignore function declarations, this is the first command that is actually executed. In fact, we could skip this **if** and just leave **main()** in stead. Nothing would be visibly different. The key word here is *visibly*. You see, the variable __**name**__ is a *Python* built-in that is set to the name of the current module. If our script is imported in another script (or a **python** shell), the __**name**__ variable would hold the

name of the script (i.e.: *my_first_script*). However, if we run this script directly from **bash**, it's value would be set to *"__main__"*. In other words, without this **if**, whenever we would import this script as a module just to have access to the **main()** function, the invocation of main would be executed implicitly.

This may have been a lot to unpack. Take a moment and if you have any questions, ask away. If not, let's move on!

Control Structures

Conditional statements

Up until this point we've already seen the **if** statement used a few times. It should hold no mysteries :p

At the moment, there is no equivalent to the **switch case** from *C/C++*. A similar feature called **match** will be introduced in *Python 3.10*. Functionally, the two will be the same. The main differences would be the lack of a **default** clause keyword, and that of a need to use **break** with every **case** statement. For now, we won't bother with this.

```
>>> # get the current time
>>> import time
>>> lt = time.localtime()
>>> lt
time.struct_time(tm_year=2021, tm_mon=11, tm_mday=7, tm_hour=18, tm_min=23, tm_sec=58, tm_wday=6, tm_yday=311, tm_isdst=0)

>>> # let's print different messages based on the time interval
>>> hour = lt.tm_hour
>>> hour
18

>>> # notice how we use elif
>>> if hour < 7:
...     print('night')
... elif hour < 12:
...     print('morning')
... elif hour == 12:
...     print('noon')
... elif hour < 17:
...     print('afternoon')
... else:
...     print('evening')
...
evening

>>> # in Python we use "not", "or", "and" in stead of "!", "||", "&&"
>>> import random
>>> r = random.randint(0, 100)

>>> if (r % 2 == 0 and r < 50) or not (r % 2 == 1 and r > 50):
...     print("was there a point?")
...
was there a point?

>>> # again, remember to perform checks before accessing dictionary items
>>> d = { }
>>> if r not in d:
...     d[r] = 0
```

```
...
>>> d[r] += 1
>>> d[r]
1
>>> d[r + 1] += 1
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
```

While statement

Again, the **while** in *Python* is not that different than the **while** in C/C++.

```
>>> r = random.randint(0, 100)
>>> guess = -1

>>> # continue and break work just like in C/C++
>>> while guess != r:
...     guess = int(input('take a guess: '))
...     if guess % 12 == 0:
...         continue
...     elif guess % 3 == 0:
...         break
...
>>> print('good job, I guess...')
```

For statement

This is probably different from what you may be used to from other programming languages. The **for** in *Python* does not iterate until a certain condition is satisfied. Nor does it let you specify the iteration step. As a result, it's not immediately replaceable with a **while** loop. In stead, **for** iterates over a sequence of items.

Remember using **for** to iterate over the items generated by the **range()** function? In that case, the iteration step should be established via **range()**, not the built-in constructs of the **for** statement.

Modifying elements of an iterable object (like a list or dictionary) with **for** may be prone to errors when the modified element is the iterator itself. Sometimes it's better to work with copies or create new objects entirely.

```
>>> # iteration step is given by range()
>>> for it in range(0, 10, 2):
...     print(it)

>>> # this is also a good method of iterating over available dictionary keys
>>> # NOTE: using the ip_addrs dictionary from earlier; not redeclaring it here...
>>> for key in ip_addrs:
...     print(key)
...
ocw.cs.pub.ro
google.com
filelist.io
```

This may be a bit random, but **for** and **while** loops can have **else** statements. The **else** block is executed if the **for** reaches the end of the iterable object or if the **while** statement's condition becomes *False*. If the loop is otherwise broken, the **else** block will not be executed.

```
>>> for key in ip_addrs:
...     if key == 'lwn.net':
...         print('good for you!')
...         break
... else:
...     print(':(')
...
:(
```

Functions

Defining functions is done using the **def** keyword, followed by its name and a parenthesized list of parameters, with a **:** at the end, for good measure. The body of the function starts on the next line.

Each function has its own local context. You can still access global variables from functions for read-only operations. However, if you want to modify a global variable, you need to mark it as such with the keyword **global**:

```
>>> x = 10
>>> def increment_x(value):
...     global x
...     x += value
...
>>> increment_x(5)
>>> x
15
```

Functions, of course, can have arguments. *Python* uses a system named *"Call by Object Reference"*. If you pass immutable objects (e.g.: numbers, strings, tuples) as arguments and overwrite them in the invoked function, the originals in the calling function will remain untouched and you will be working with a copy. This is known as *"Call by value"*. If your argument is mutable (e.g.: lists, dictionaries), the changes that you make will be reflected in the caller's environment. This is known as *"Call by reference"*.

```
>>> def modify_string(s):
...     s = 'a new string'
...     print(s)
...
>>> def modify_list(l):
...     l.append(99)
...     print(l)
...
>>> original_s = 'original string'
>>> original_l = [1, 2, 3]

>>> # call by value
>>> modify_string(original_s)
a new string
>>> print(original_s)
```

```
original string

>>> # call by reference
>>> modify_list(original_l)
[1, 2, 3, 99]
>>> print(original_l)
[1, 2, 3, 99]
```

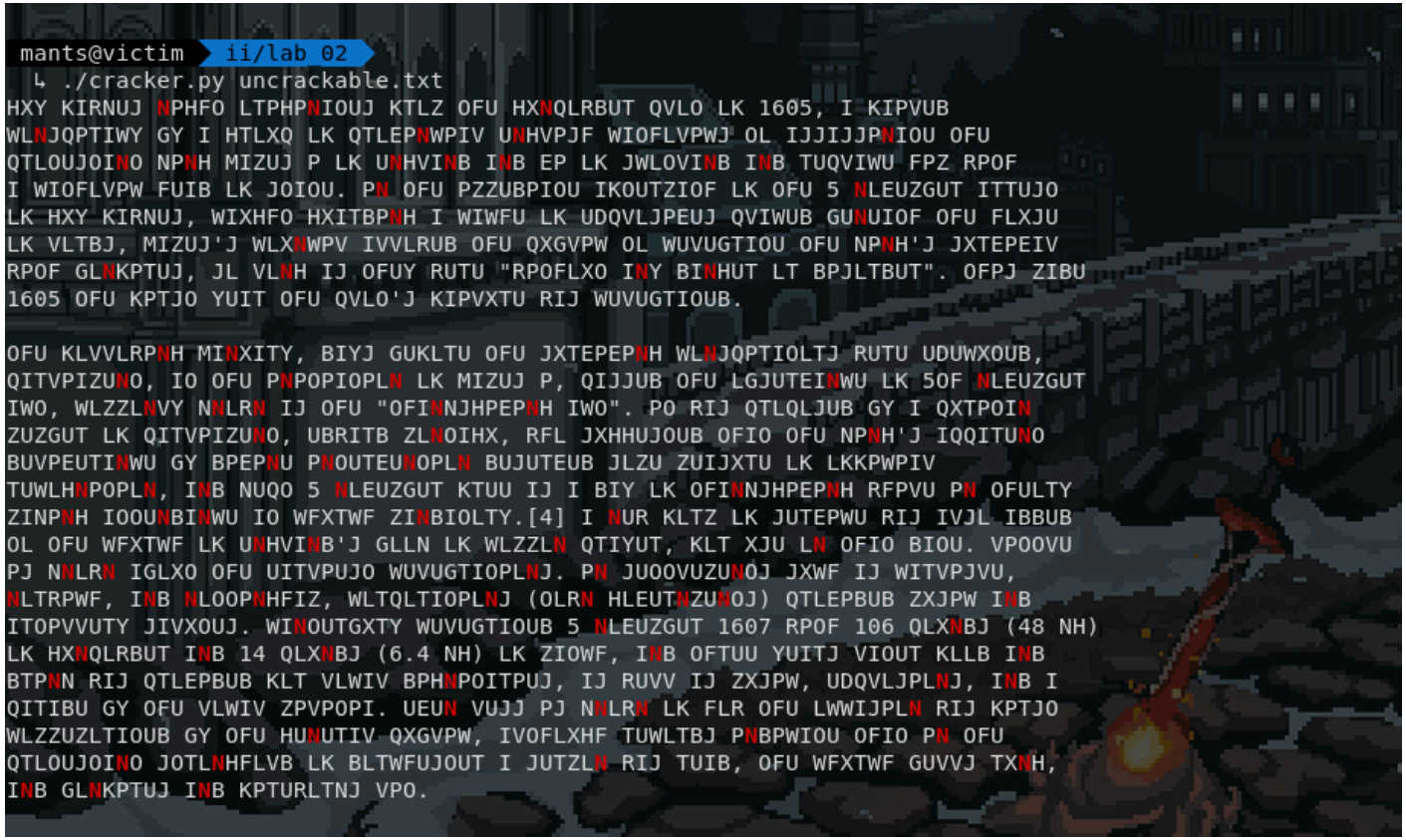
This can get confusing… I know. On the upside, *Python* is very flexible in how you define your arguments. For example, this is how you can assign default values:

```
# defining a function with default argument values
>>> def prompt_user(prompt, expected='student', retries=3):
...     while retries != 0:
...         user = input(prompt)
...         if user == expected:
...             return True
...         retries -= 1
...     return False

>>> # only specifying the required argument
>>> prompt_user('Who are you? ')
Who are you? user
Who are you? student
True

>>> # overwriting default argument values
>>> prompt_user('*What* are you? ', 'I aM sPeCiAl', 0)
False

>>> # using keyword arguments to overwrite only specific arguments
>>> prompt_user('Who are you? ', retries=0)
False
```

A word of caution. The default initialization of arguments happens only once! If we use immutable objects (like numbers or strings) we won't have any surprises. But when using mutable objects (like lists), the default value can change over subsequent calls:

```
>>> # I mean... you _could_ still want this...
>>> def append_to_default(l=[ 0 ]):
...     l.append(l[-1] + 1)
...     print(l)
...

>>> append_to_default()
[0, 1]
>>> append_to_default()
[0, 1, 2]
>>> append_to_default()
[0, 1, 2, 3]
```

03. [50p] Solving a substitution cipher



Time to get your hands dirty! Below, you have a ciphertext [https://en.wikipedia.org/wiki/Ciphertext]. Specifically, this output is the result of a substitution cipher [https://en.wikipedia.org/wiki/Substitution_cipher], meaning that every letter in the English alphabet has been assigned a random, unique correspondent. As you may have noticed, digits and special characters remain unchanged.

```
HXY KIRNUJ SPHFO LTPHPSIOUJ KTLZ OFU HXSQLRBUT QVLO LK 1605, I KIPVUB
WLSJQPTIWY GY I HTLXQ LK QTLEPSWPIV USHVPJF WIOFLVPWJ OL IJJIJJPSIOU OFU
QTLOUJOISO NPSH MIZUJ P LK USHVISB ISB EP LK JWLOVISB ISB TUQVIWU FPZ RPOF
I WIOFLVPW FUIB LK JOIOU. PS OFU PZZUBPIOU IKOUTZIOF LK OFU 5 SLEUZGUT ITTUJO
LK HXY KIRNUJ, WIXHFO HXITBPSH I WIWFU LK UDQVLJPEUJ QVIWUB GUSUIOF OFU FLXJU
LK VLTBJ, MIZUJ'J WLXSWPV IVVLRUB OFU QXGVPW OL WUVUGTIOU OFU NPSH'J JXTEPEIV
RPOF GLSKPTUJ, JL VLSH IJ OFUY RUTU "RPOFLXO ISY BISHUT LT BPJLTBUT". OFPJ ZIBU
1605 OFU KPTJO YUIT OFU QVLO'J KIPVXTU RIJ WUVUGTIOUB.

OFU KLVVLRPSH MISXITY, BIYJ GUKLTU OFU JXTEPEPSH WLSJQPTIOLTJ RUTU UDUWXOUB,
QITVPIZUSO, IO OFU PSPOPIOPLS LK MIZUJ P, QIJJUB OFU LGJUTEISWU LK 5OF SLEUZGUT
IWO, WLZZLSVY NSLRS IJ OFU "OFISNJHPEPSH IWO". PO RIJ QTLQLJUB GY I QXTPOIS
ZUZGUT LK QITVPIZUSO, UBRITB ZLSOIHX, RFL JXHHUJOUB OFIO OFU NPSH'J IQQITUSO
BUVPEUTISWU GY BPEPSU PSOUTEUSOPLS BUJUTEUB JLZU ZUIJXTU LK LKKPWPIV
TUWLHSPOPLS, ISB NUQO 5 SLEUZGUT KTUU IJ I BIY LK OFISNJHPEPSH RFPVU PS OFULTY
ZINPSH IOOUSBISWU IO WFXTWF ZISBIOLTY.[4] I SUR KLTZ LK JUTEPWU RIJ IVJL IBBUB
```

```
OL OFU WFXTWF LK USHVISB'J GLLN LK WLZZLS QTIYUT, KLT XJU LS OFIO BIOU. VPOOVU
PJ NSLRS IGLXO OFU UITVPUJO WUVUGTIOPLSJ. PS JUOOVUZUSOJ JXWF IJ WITVPJVU,
SLTRPWF, ISB SLOOPSHFIZ, WLTQLTIOPLSJ (OLRS HLEUTSZUSOJ) QTLEPBUB ZXJPW ISB
ITOPVVUTY JIVXOUJ. WISOUTGXTY WUVUGTIOUB 5 SLEUZGUT 1607 RPOF 106 QLXSBJ (48 NH)
LK HXSQLRBUT ISB 14 QLXSBJ (6.4 NH) LK ZIOWF, ISB OFTUU YUITJ VIOUT KLLB ISB
BTPSN RIJ QTLEPBUB KLT VLWIV BPHSPOITPUJ, IJ RUVV IJ ZXJPW, UDQVLJPLSJ, ISB I
QITIBU GY OFU VLWIV ZPVPOPI. UEUS VUJJ PJ NSLRS LK FLR OFU LWWIJPLS RIJ KPTJO
WLZZUZLTIOUB GY OFU HUSUTIV QXGVPW, IVOFLXHF TUWLTBJ PSBPWIOU OFIO PS OFU
QTLOUJOISO JOTLSHFLVB LK BLTWFUJOUT I JUTZLS RIJ TUIB, OFU WFXTWF GUVVJ TXSH,
ISB GLSKPTUJ ISB KPTURLTNJ VPO.
```

Your task is to write a *Python* script that will help you break the cipher and decode the original text:

- read [https://www.pythontutorial.net/python-basics/python-read-text-file/] the ciphertext from a file specified as a command line argument
- use a dictionary to map each encoded character back to it's original value
- manually populate this dictionary as you progress in your attempt and reveal new characters
- whenever you run the script, it should print the text to the screen, with a few minor changes:
  - any character that exists as a key in the dictionary should be replaced with what you think the correspondent is.
  - any replaced character should be highlighted in bold red.

Remember ANSI codes?

```
$ echo "\033[1;34m I'm blue, da ba dee, dabba daa-ee, dabba dee-a dabba da \033[0m"
```

In breaking a short substitution cipher like this while also knowing the original language, you need to look at bigrams and trigrams. Small groups of letters that have a limited amount of possible values that make sense: *“to”*, *“and”*, *“the”*, etc. As you reveal more and more of the original text, words will begin to form, making everything progressively easier.

If you need an extra hint:

> *“5 SLEUZGUT”* looks like a date. Hmm… ***“SLEUZGUT”***…

Already done? Try this challenge [https://ctflearn.com/challenge/238] as well.

There are a lot more out there for you to find!

04. [10p] Feedback

Please take a minute to fill in the feedback form [https://forms.office.com/Pages/ResponsePage.aspx?id=usiMLdqNNEOeXPrCCS6brJoxNMaLqNZHpd8YaA7IhDNUNVVLQ0lQV0tJRzBaRjhOQzdNOVhYWklBVC4u] for this lab.