

Python Essentials 2:

Module 5

Modules, packages string and list methods, and exceptions

In this module, you will learn about:

- Python modules: their rationale, function, how to import them in different ways, and present the content of some standard modules provided by Python;

- the way in which modules are coupled together to make packages.

- the concept of an exception and Python's implementation of it, including the try-except instruction, with its applications, and the raise instruction.

- strings and their specific methods, together with their similarities and differences compared to lists.

(part 2)

Working with standard modules

Before we start going through some standard Python modules, we want to introduce the `dir()` function to you. It has nothing to do with the `dir` command you know from Windows and Unix consoles, as `dir()` doesn't show the contents of a disk directory/folder, but there is no denying that it does something really similar - it is able to reveal all the names provided through a particular module.

There is one condition: the module has to have been previously imported as a whole (i.e., using the `import module` instruction - `from module` is not enough).

The function returns an alphabetically sorted list containing all entities' names available in the module identified by a name passed to the function as an argument:

```
dir(module)
```

Note: if the module's name has been aliased, you must use the alias, not the original name.

Using the function inside a regular script doesn't make much sense, but it is still possible.

For example, you can run the following code to print the names of all entities within the `math` module:

```
import math

for name in dir(math):
    print(name, end="\t")
```

The example code should produce the following output:

```
__doc__      __loader__  __name__    __package__ __spec__    acos  acosh  asin  asinh
      atan  atan2  atanh  ceil  copysign    cos  cosh  degreee  erf  erfc  exp
      expm1  fabs  factorial  floor  fmod  frexp  fsum  gamma  hypot  isfinite  isinf  isnan
      ldexp  lgammalog  log10  log1p  log2  modf  pi  pow  radians  sin  sinh  sqrt  tan
      tanh  trunc
output
```

Have you noticed these strange names beginning with `__` at the top of the list? We'll tell you more about them when we talk about the issues related to writing your own modules.

Some of the names might bring back memories from math lessons, and you probably won't have any problems guessing their meanings.

Using the `dir()` function inside a code may not seem very useful - usually you want to know a particular module's contents before you write and run the code.

Fortunately, you can execute the function directly in the Python console (IDLE), without needing to write and run a separate script.

This is how it can be done:

```
import math
dir(math)
```

Selected functions from the math module

Let's start with a quick preview of some of the functions provided by the math module.

We've chosen them arbitrarily, but that doesn't mean that the functions we haven't mentioned here are any less significant. Dive into the modules' depths yourself - we don't have the space or the time to talk about everything in detail here.

The first group of the math's functions are connected with trigonometry:

```
sin(x) → the sine of x;  
cos(x) → the cosine of x;  
tan(x) → the tangent of x.
```

All these functions take one argument (an angle measurement expressed in radians) and return the appropriate result (be careful with `tan()` - not all arguments are accepted).

Of course, there are also their inversed versions:

```
asin(x) → the arcsine of x;  
acos(x) → the arccosine of x;  
atan(x) → the arctangent of x.
```

These functions take one argument (mind the domains) and return a measure of an angle in radians.

To effectively operate on angle measurements, the math module provides you with the following entities:

```
pi → a constant with a value that is an approximation of  $\pi$ ;  
radians(x) → a function that converts x from degrees to radians;  
degrees(x) → acting in the other direction (from radians to degrees)
```

Now look at the code in the editor.

```
from math import pi, radians, degrees, sin, cos, tan, asin
```

```
ad = 90  
ar = radians(ad)  
ad = degrees(ar)  
  
print(ad == 90.)  
print(ar == pi / 2.)  
print(sin(ar) / cos(ar) == tan(ar))  
print(asin(sin(ar)) == ar)
```

The example program isn't very sophisticated, but can you predict its results?

Apart from the circular functions (listed above) the math module also contains a set of their hyperbolic analogues:

```
sinh(x) → the hyperbolic sine;  
cosh(x) → the hyperbolic cosine;  
tanh(x) → the hyperbolic tangent;  
asinh(x) → the hyperbolic arcsine;  
acosh(x) → the hyperbolic arccosine;  
atanh(x) → the hyperbolic arctangent.
```

Selected functions from the math module: continued

Another group of the math's functions is formed by functions which are connected with exponentiation:

- `e` → a constant with a value that is an approximation of Euler's number (`e`)
- `exp(x)` → finding the value of e^x ;
- `log(x)` → the natural logarithm of x
- `log(x, b)` → the logarithm of x to base b
- `log10(x)` → the decimal logarithm of x (more precise than `log(x, 10)`)
- `log2(x)` → the binary logarithm of x (more precise than `log(x, 2)`)

Note: the `pow()` function:

- `pow(x, y)` → finding the value of x^y (mind the domains)

This is a built-in function, and doesn't have to be imported.

Look at the code in the editor.

```
from math import e, exp, log

print(pow(e, 1) == exp(log(e)))
print(pow(2, 2) == exp(2 * log(2)))
print(log(e, e) == exp(0))
```

Can you predict its output?

Selected functions from the math module: continued

The last group consists of some general-purpose functions like:

`ceil(x)` → the ceiling of `x` (the smallest integer greater than or equal to `x`)
`floor(x)` → the floor of `x` (the largest integer less than or equal to `x`)
`trunc(x)` → the value of `x` truncated to an integer (be careful - it's not an equivalent either of `ceil` or `floor`)
`factorial(x)` → returns `x!` (`x` has to be an integral and not a negative)
`hypot(x, y)` → returns the length of the hypotenuse of a right-angle triangle with the leg lengths equal to `x` and `y` (the same as `sqrt(pow(x, 2) + pow(y, 2))` but more precise)

Look at the code in the editor. Analyze the program carefully.

It demonstrates the fundamental differences between `ceil()`, `floor()` and `trunc()`.

Run the program and check its output.

```
from math import ceil, floor, trunc

x = 1.4
y = 2.6

print(floor(x), floor(y))
print(floor(-x), floor(-y))
print(ceil(x), ceil(y))
print(ceil(-x), ceil(-y))
print(trunc(x), trunc(y))
print(trunc(-x), trunc(-y))
```

Is there real randomness in computers?

Another module worth mentioning is the one named random.

It delivers some mechanisms allowing you to operate with pseudorandom numbers.

Note the prefix pseudo - the numbers generated by the modules may look random in the sense that you cannot predict their subsequent values, but don't forget that they all are calculated using very refined algorithms.

The algorithms aren't random - they are deterministic and predictable. Only those physical processes which run completely out of our control (like the intensity of cosmic radiation) may be used as a source of actual random data. Data produced by deterministic computers cannot be random in any way.

A random number generator takes a value called a seed, treats it as an input value, calculates a "random" number based on it (the method depends on a chosen algorithm) and produces a new seed value.

The length of a cycle in which all seed values are unique may be very long, but it isn't infinite - sooner or later the seed values will start repeating, and the generating values will repeat, too. This is normal. It's a feature, not a mistake, or a bug.

The initial seed value, set during the program start, determines the order in which the generated values will appear.

The random factor of the process may be augmented by setting the seed with a number taken from the current time - this may ensure that each program launch will start from a different seed value (ergo, it will use different random numbers).

Fortunately, such an initialization is done by Python during module import.

Selected functions from the random module

The random function

The most general function named `random()` (not to be confused with the module's name) produces a float number x coming from the range (0.0, 1.0) - in other words: $(0.0 \leq x < 1.0)$.

The example program below will produce five pseudorandom values - as their values are determined by the current (rather unpredictable) seed value, you can't guess them:

```
from random import random

for i in range(5):
    print(random())
```

Run the program. This is what we've got:

```
0.9535768927411208
0.5312710096244534
0.8737691983477731
0.5896799172452125
0.02116716297022092
sample output
```

The seed function

The `seed()` function is able to directly set the generator's seed. We'll show you two of its variants:

`seed()` - sets the seed with the current time;

`seed(int_value)` - sets the seed with the integer value `int_value`.

We've modified the previous program - in effect, we've removed any trace of randomness from the code:

```
from random import random, seed

seed(0)

for i in range(5):
    print(random())
```

Due to the fact that the seed is always set with the same value, the sequence of generated values always looks the same.

Run the program. This is what we've got:

```
0.844421851525
0.75795440294
0.420571580831
0.258916750293
0.511274721369
sample output
```

And you?

Note: your values may be slightly different than ours if your system uses more precise or less precise floating-point arithmetic, but the difference will be seen quite far from the decimal point.

Selected functions from the random module: continued

The randrange and randint functions

If you want integer random values, one of the following functions would fit better:

```
randrange(end)
randrange(beg, end)
randrange(beg, end, step)
randint(left, right)
```

The first three invocations will generate an integer taken (pseudorandomly) from the range (respectively):

```
range(end)
range(beg, end)
range(beg, end, step)
```

Note the implicit right-sided exclusion!

The last function is an equivalent of `randrange(left, right+1)` - it generates the integer value `i`, which falls in the range `[left, right]` (no exclusion on the right side).

Look at the code in the editor. This sample program will consequently output a line consisting of three zeros and either a zero or one at the fourth place.

```
from random import randrange, randint

print(randrange(1), end=' ')
print(randrange(0, 1), end=' ')
print(randrange(0, 1, 1), end=' ')
print(randint(0, 1))
```


Selected functions from the random module: continued

The previous functions have one important disadvantage - they may produce repeating values even if the number of subsequent invocations is not greater than the width of the specified range.

Look at the code below - the program very likely outputs a set of numbers in which some elements are not unique:

```
from random import randint

for i in range(10):
    print(randint(1, 10), end=',')
```

This is what we got in one of the launches:

```
9,4,5,4,5,8,9,4,8,4,
sample output
```

The choice and sample functions

As you can see, this is not a good tool for generating numbers in a lottery. Fortunately, there is a better solution than writing your own code to check the uniqueness of the "drawn" numbers.

It's a function named in a very suggestive way - choice:

```
choice(sequence)
sample(sequence, elements_to_choose)
```

The first variant chooses a "random" element from the input sequence and returns it.

The second one builds a list (a sample) consisting of the elements_to_choose element "drawn" from the input sequence.

In other words, the function chooses some of the input elements, returning a list with the choice. The elements in the sample are placed in random order. Note: the elements_to_choose must not be greater than the length of the input sequence.

Look at the code below:

```
from random import choice, sample

my_list = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]

print(choice(my_list))
print(sample(my_list, 5))
print(sample(my_list, 10))
```

Again, the output of the program is not predictable. Our results looked like this:

```
4
[3, 1, 8, 9, 10]
[10, 8, 5, 1, 6, 4, 3, 9, 7, 2]
```

How to know where you are?

Sometimes, it may be necessary to find out information unrelated to Python. For example, you may need to know the location of your program within the greater environment of the computer.

Imagine your program's environment as a pyramid consisting of a number of layers or platforms.

The layers are:

- your (running) code is located at the top of it;

- Python (more precisely - its runtime environment) lies directly below it;

- the next layer of the pyramid is filled with the OS (operating system) - Python's environment provides some of its functionalities using the operating system's services; Python, although very powerful, isn't omnipotent - it's forced to use many helpers if it's going to process files or communicate with physical devices;

- the bottom-most layer is hardware - the processor (or processors), network interfaces, human interface devices (mice, keyboards, etc.) and all other machinery needed to make the computer run; the OS knows how to drive it, and uses lots of tricks to conduct all parts in a consistent rhythm.

This means that some of your (or rather your program's) actions have to travel a long way to be successfully performed - imagine that:

- your code wants to create a file, so it invokes one of Python's functions;

- Python accepts the order, rearranges it to meet local OS requirements (it's like putting the stamp "approved" on your request) and sends it down (this may remind you of a chain of command)

- the OS checks if the request is reasonable and valid (e.g., whether the file name conforms to some syntax rules) and tries to create the file; such an operation, seemingly very simple, isn't atomic - it consists of many minor steps taken by...

- the hardware, which is responsible for activating storage devices (hard disk, solid state devices, etc.) to satisfy the OS's needs.

Usually, you're not aware of all that fuss - you want the file to be created and that's that.

But sometimes you want to know more - for example, the name of the OS which hosts Python, and some characteristics describing the hardware that hosts the OS.

There is a module providing some means to allow you to know where you are and what components work for you. The module is named `platform`. We'll show you some of the functions it provides to you.

Selected functions from the platform module

The platform function

The platform module lets you access the underlying platform's data, i.e., hardware, operating system, and interpreter version information.

There is a function that can show you all the underlying layers in one glance, named platform, too. It just returns a string describing the environment; thus, its output is rather addressed to humans than to automated processing (you'll see it soon).

This is how you can invoke it:

```
platform(aliased = False, terse = False)
```

And now:

aliased → when set to True (or any non-zero value) it may cause the function to present the alternative underlying layer names instead of the common ones;

terse → when set to True (or any non-zero value) it may convince the function to present a briefer form of the result (if possible)

We ran our sample program using three different platforms - this is what we got:

Intel x86 + Windows ® Vista (32 bit):

Windows-Vista-6.0.6002-SP2

Windows-Vista-6.0.6002-SP2

Windows-Vista

output

Intel x86 + Gentoo Linux (64 bit):

Linux-3.18.62-g6-x86_64-Intel-R-_Core-TM-_i3-2330M_CPU_@_2.20GHz-with-gentoo-2.3

Linux-3.18.62-g6-x86_64-Intel-R-_Core-TM-_i3-2330M_CPU_@_2.20GHz-with-gentoo-2.3

Linux-3.18.62-g6-x86_64-Intel-R-_Core-TM-_i3-2330M_CPU_@_2.20GHz-with-glibc2.3.4

output

Raspberry PI2 + Raspbian Linux (32 bit):

Linux-4.4.0-1-rpi2-armv7l-with-debian-9.0

Linux-4.4.0-1-rpi2-armv7l-with-debian-9.0

Linux-4.4.0-1-rpi2-armv7l-with-glibc2.9

output

You can also run the sample program in IDLE on your local machine to check what output you will have.

```
from platform import platform
```

```
print(platform())
```

```
print(platform(1))
```

```
print(platform(0, 1))
```

Selected functions from the platform module: continued

The machine function

Sometimes, you may just want to know the generic name of the processor which runs your OS together with Python and your code - a function named `machine()` will tell you that. As previously, the function returns a string.

```
from platform import machine

print(machine())
```

Again, we ran the sample program on three different platforms:

Intel x86 + Windows ® Vista (32 bit):

```
x86
output
```

Intel x86 + Gentoo Linux (64 bit):

```
x86_64
output
```

Raspberry PI2 + Raspbian Linux (32 bit):

```
armv7l
output
```

Selected functions from the platform module: continued

The processor function

The `processor()` function returns a string filled with the real processor name (if possible).

```
from platform import processor  
  
print(processor())
```

Once again, we ran the sample program on three different platforms:

Intel x86 + Windows ® Vista (32 bit):

```
x86  
output
```

Intel x86 + Gentoo Linux (64 bit):

```
Intel(R) Core(TM) i3-2330M CPU @ 2.20GHz  
output
```

Raspberry PI2 + Raspbian Linux (32 bit):

```
armv7l  
output
```

Test this on your local machine.

Selected functions from the platform module: continued

The system function

A function named `system()` returns the generic OS name as a string.

```
from platform import system  
  
print(system())
```

Our example platforms presented themselves like this:

Intel x86 + Windows ® Vista (32 bit):

Windows
output

Intel x86 + Gentoo Linux (64 bit):

Linux
output

Raspberry PI2 + Raspbian Linux (32 bit):

Linux
output

Selected functions from the platform module: continued

The version function

The OS version is provided as a string by the version() function.

```
from platform import version  
  
print(version())
```

Run the code and check its output. This is what we got:

Intel x86 + Windows ® Vista (32 bit):

```
6.0.6002  
output
```

Intel x86 + Gentoo Linux (64 bit):

```
#1 SMP PREEMPT Fri Jul 21 22:44:37 CEST 2017  
output
```

Raspberry PI2 + Raspbian Linux (32 bit):

```
#1 SMP Debian 4.4.6-1+rpi14 (2016-05-05)  
output
```

Selected functions from the platform module: continued

The `python_implementation` and the `python_version_tuple` functions

If you need to know what version of Python is running your code, you can check it using a number of dedicated functions - here are two of them:

`python_implementation()` → returns a string denoting the Python implementation (expect CPython here, unless you decide to use any non-canonical Python branch)

`python_version_tuple()` → returns a three-element tuple filled with:
the major part of Python's version;
the minor part;
the patch level number.

```
from platform import python_implementation, python_version_tuple

print(python_implementation())

for atr in python_version_tuple():
    print(atr)
```

Our example program produced the following output:

```
CPython
3
7
7
sample output
```

It's very likely that your version of Python will be different.

Python Module Index

We have only covered the basics of Python modules here. Python's modules make up their own universe, in which Python itself is only a galaxy, and we would venture to say that exploring the depths of these modules can take significantly more time than getting acquainted with "pure" Python.

Moreover, the Python community all over the world creates and maintains hundreds of additional modules used in very niche applications like genetics, psychology, or even astrology.

These modules aren't (and won't be) distributed along with Python, or through official channels, which makes the Python universe broader - almost infinite.

You can read about all standard Python modules here: <https://docs.python.org/3/py-modindex.html>.

Don't worry - you won't need all these modules. Many of them are very specific.

All you need to do is find the modules you want, and teach yourself how to use them. It's easy.

Key takeaways

1. A function named `dir()` can show you a list of the entities contained inside an imported module. For example:

```
import os
dir(os)
```

prints out the list of all the `os` module's facilities you can use in your code.

2. The `math` module couples more than 50 symbols (functions and constants) that perform mathematical operations (like `sine()`, `pow()`, `factorial()`) or providing important values (like π and the Euler symbol e).

3. The `random` module groups more than 60 entities designed to help you use pseudo-random numbers. Don't forget the prefix "random", as there is no such thing as a real random number when it comes to generating them using the computer's algorithms.

4. The `platform` module contains about 70 functions which let you dive into the underlying layers of the OS and hardware. Using them allows you to get to know more about the environment in which your code is executed.

5. Python Module Index (<https://docs.python.org/3/py-modindex.html>) is a community-driven directory of modules available in the Python universe. If you want to find a module fitting your needs, start your search there.

Exercise 1

What is the expected value of the `result` variable after the following code is executed?

```
import math
result = math.e == math.exp(1)
```

Exercise 2

(Complete the sentence) Setting the generator's seed with the same value each time your program is run guarantees that...

Exercise 3

Which of the `platform` module's functions will you use to determine the name of the CPU running inside your computer?

Exercise 4

What is the expected output of the following snippet?

```
import platform

print(len(platform.python_version_tuple()))
```