Python for Everybody

Exploring Data Using Python 3

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```
    I hate you Python!
         ^
SyntaxError: invalid syntax
>>> if you come out of there, I would teach you a lesson
  File "<stdin>", line 1
    if you come out of there, I would teach you a lesson
               ^
SyntaxError: invalid syntax
>>>
```

There is little to be gained by arguing with Python. It is just a tool. It has no emotions and it is happy and ready to serve you whenever you need it. Its error messages sound harsh, but they are just Python's call for help. It has looked at what you typed, and it simply cannot understand what you have entered.

Python is much more like a dog, loving you unconditionally, having a few key words that it understands, looking you with a sweet look on its face (>>>), and waiting for you to say something it understands. When Python says "SyntaxError: invalid syntax", it is simply wagging its tail and saying, "You seemed to say something but I just don't understand what you meant, but please keep talking to me (>>>)."

As your programs become increasingly sophisticated, you will encounter three general types of errors:

Syntax errors These are the first errors you will make and the easiest to fix. A syntax error means that you have violated the "grammar" rules of Python. Python does its best to point right at the line and character where it noticed it was confused. The only tricky bit of syntax errors is that sometimes the mistake that needs fixing is actually earlier in the program than where Python *noticed* it was confused. So the line and character that Python indicates in a syntax error may just be a starting point for your investigation.

Logic errors A logic error is when your program has good syntax but there is a mistake in the order of the statements or perhaps a mistake in how the statements relate to one another. A good example of a logic error might be, "take a drink from your water bottle, put it in your backpack, walk to the library, and then put the top back on the bottle."

Semantic errors A semantic error is when your description of the steps to take is syntactically perfect and in the right order, but there is simply a mistake in the program. The program is perfectly correct but it does not do what you *intended* for it to do. A simple example would be if you were giving a person directions to a restaurant and said, "... when you reach the intersection with the gas station, turn left and go one mile and the restaurant is a red building on your left." Your friend is very late and calls you to tell you that they are on a farm and walking around behind a barn, with no sign of a restaurant. Then you say "did you turn left or right at the gas station?" and they say, "I followed your directions perfectly, I have them written down, it says turn left and go one mile at the gas station." Then you say, "I am very sorry, because while my instructions were syntactically correct, they sadly contained a small but undetected semantic error.".

Again in all three types of errors, Python is merely trying its hardest to do exactly what you have asked.

1.11 The learning journey

As you progress through the rest of the book, don't be afraid if the concepts don't seem to fit together well the first time. When you were learning to speak, it was not a problem for your first few years that you just made cute gurgling noises. And it was OK if it took six months for you to move from simple vocabulary to simple sentences and took 5-6 more years to move from sentences to paragraphs, and a few more years to be able to write an interesting complete short story on your own.

We want you to learn Python much more rapidly, so we teach it all at the same time over the next few chapters. But it is like learning a new language that takes time to absorb and understand before it feels natural. That leads to some confusion as we visit and revisit topics to try to get you to see the big picture while we are defining the tiny fragments that make up that big picture. While the book is written linearly, and if you are taking a course it will progress in a linear fashion, don't hesitate to be very nonlinear in how you approach the material. Look forwards and backwards and read with a light touch. By skimming more advanced material without fully understanding the details, you can get a better understanding of the "why?" of programming. By reviewing previous material and even redoing earlier exercises, you will realize that you actually learned a lot of material even if the material you are currently staring at seems a bit impenetrable.

Usually when you are learning your first programming language, there are a few wonderful "Ah Hah!" moments where you can look up from pounding away at some rock with a hammer and chisel and step away and see that you are indeed building a beautiful sculpture.

If something seems particularly hard, there is usually no value in staying up all night and staring at it. Take a break, take a nap, have a snack, explain what you are having a problem with to someone (or perhaps your dog), and then come back to it with fresh eyes. I assure you that once you learn the programming concepts in the book you will look back and see that it was all really easy and elegant and it simply took you a bit of time to absorb it.

1.12 Glossary

bug An error in a program.

central processing unit The heart of any computer. It is what runs the software that we write; also called "CPU" or "the processor".

compile To translate a program written in a high-level language into a low-level language all at once, in preparation for later execution.

high-level language A programming language like Python that is designed to be easy for humans to read and write.

interactive mode A way of using the Python interpreter by typing commands and expressions at the prompt.

interpret To execute a program in a high-level language by translating it one line at a time.

low-level language A programming language that is designed to be easy for a computer to execute; also called "machine code" or "assembly language".

machine code The lowest-level language for software, which is the language that is directly executed by the central processing unit (CPU).

main memory Stores programs and data. Main memory loses its information when the power is turned off.

parse To examine a program and analyze the syntactic structure.

portability A property of a program that can run on more than one kind of computer.

print function An instruction that causes the Python interpreter to display a value on the screen.

problem solving The process of formulating a problem, finding a solution, and expressing the solution.

program A set of instructions that specifies a computation.

prompt When a program displays a message and pauses for the user to type some input to the program.

secondary memory Stores programs and data and retains its information even when the power is turned off. Generally slower than main memory. Examples of secondary memory include disk drives and flash memory in USB sticks.

semantics The meaning of a program.

semantic error An error in a program that makes it do something other than what the programmer intended.

source code A program in a high-level language.

1.13 Exercises

Exercise 1: What is the function of the secondary memory in a computer?

a) Execute all of the computation and logic of the program
b) Retrieve web pages over the Internet
c) Store information for the long term, even beyond a power cycle
d) Take input from the user

Exercise 2: What is a program?

Exercise 3: What is the difference between a compiler and an interpreter?

Exercise 4: Which of the following contains "machine code"?

a) The Python interpreter
b) The keyboard
c) Python source file
d) A word processing document

Exercise 5: What is wrong with the following code:

```
>>> primt 'Hello world!'
  File "<stdin>", line 1
    primt 'Hello world!'
                       ^
SyntaxError: invalid syntax
>>>
```

Exercise 6: Where in the computer is a variable such as "X" stored after the following Python line finishes?

```
x = 123
```

a) Central processing unit
b) Main Memory
c) Secondary Memory
d) Input Devices
e) Output Devices

Exercise 7: What will the following program print out:

```
x = 43
x = x + 1
print(x)
```

a) 43
b) 44
c) x + 1
d) Error because x = x + 1 is not possible mathematically

Exercise 8: Explain each of the following using an example of a human capability: (1) Central processing unit, (2) Main Memory, (3) Secondary Memory, (4) Input

Device, and (5) Output Device. For example, “What is the human equivalent to a Central Processing Unit”?

Exercise 9: How do you fix a “Syntax Error”?

Chapter 2

Variables, expressions, and statements

2.1 Values and types

A *value* is one of the basic things a program works with, like a letter or a number. The values we have seen so far are `1`, `2`, and "Hello, World!"

These values belong to different *types*: `2` is an integer, and "Hello, World!" is a *string*, so called because it contains a "string" of letters. You (and the interpreter) can identify strings because they are enclosed in quotation marks.

The `print` statement also works for integers. We use the `python` command to start the interpreter.

```
python
>>> print(4)
4
```

If you are not sure what type a value has, the interpreter can tell you.

```
>>> type('Hello, World!')
<class 'str'>
>>> type(17)
<class 'int'>
```

Not surprisingly, strings belong to the type `str` and integers belong to the type `int`. Less obviously, numbers with a decimal point belong to a type called `float`, because these numbers are represented in a format called *floating point*.

```
>>> type(3.2)
<class 'float'>
```

What about values like "17" and "3.2"? They look like numbers, but they are in quotation marks like strings.

```
>>> type('17')
<class 'str'>
>>> type('3.2')
<class 'str'>
```

They're strings.

When you type a large integer, you might be tempted to use commas between groups of three digits, as in `1,000,000`. This is not a legal integer in Python, but it is legal:

```
>>> print(1,000,000)
1 0 0
```

Well, that's not what we expected at all! Python interprets `1,000,000` as a comma-separated sequence of integers, which it prints with spaces between.

This is the first example we have seen of a semantic error: the code runs without producing an error message, but it doesn't do the "right" thing.

2.2 Variables

One of the most powerful features of a programming language is the ability to manipulate *variables*. A variable is a name that refers to a value.

An *assignment statement* creates new variables and gives them values:

```
>>> message = 'And now for something completely different'
>>> n = 17
>>> pi = 3.1415926535897931
```

This example makes three assignments. The first assigns a string to a new variable named `message`; the second assigns the integer `17` to `n`; the third assigns the (approximate) value of π to `pi`.

To display the value of a variable, you can use a print statement:

```
>>> print(n)
17
>>> print(pi)
3.141592653589793
```

The type of a variable is the type of the value it refers to.

```
>>> type(message)
<class 'str'>
>>> type(n)
<class 'int'>
>>> type(pi)
<class 'float'>
```

2.3 Variable names and keywords

Programmers generally choose names for their variables that are meaningful and document what the variable is used for.

Variable names can be arbitrarily long. They can contain both letters and numbers, but they cannot start with a number. It is legal to use uppercase letters, but it is a good idea to begin variable names with a lowercase letter (you'll see why later).

The underscore character (_) can appear in a name. It is often used in names with multiple words, such as `my_name` or `airspeed_of_unladen_swallow`. Variable names can start with an underscore character, but we generally avoid doing this unless we are writing library code for others to use.

If you give a variable an illegal name, you get a syntax error:

```
>>> 76trombones = 'big parade'
SyntaxError: invalid syntax
>>> more@ = 1000000
SyntaxError: invalid syntax
>>> class = 'Advanced Theoretical Zymurgy'
SyntaxError: invalid syntax
```

`76trombones` is illegal because it begins with a number. `more@` is illegal because it contains an illegal character, `@`. But what's wrong with `class`?

It turns out that `class` is one of Python's *keywords*. The interpreter uses keywords to recognize the structure of the program, and they cannot be used as variable names.

Python reserves 33 keywords:

```
and       del       from      None      True
as        elif      global    nonlocal  try
assert    else      if        not       while
break     except    import    or        with
class     False     in        pass      yield
continue  finally   is        raise
def       for       lambda    return
```

You might want to keep this list handy. If the interpreter complains about one of your variable names and you don't know why, see if it is on this list.

2.4 Statements

A *statement* is a unit of code that the Python interpreter can execute. We have seen two kinds of statements: print being an expression statement and assignment.

When you type a statement in interactive mode, the interpreter executes it and displays the result, if there is one.

A script usually contains a sequence of statements. If there is more than one statement, the results appear one at a time as the statements execute.

For example, the script

```
print(1)
x = 2
print(x)
```

produces the output

```
1
2
```

The assignment statement produces no output.

2.5 Operators and operands

Operators are special symbols that represent computations like addition and multiplication. The values the operator is applied to are called *operands*.

The operators `+`, `-`, `*`, `/`, and `**` perform addition, subtraction, multiplication, division, and exponentiation, as in the following examples:

```
20+32   hour-1   hour*60+minute   minute/60   5**2   (5+9)*(15-7)
```

There has been a change in the division operator between Python 2.x and Python 3.x. In Python 3.x, the result of this division is a floating point result:

```
>>> minute = 59
>>> minute/60
0.9833333333333333
```

The division operator in Python 2.0 would divide two integers and truncate the result to an integer:

```
>>> minute = 59
>>> minute/60
0
```

To obtain the same answer in Python 3.0 use floored (// integer) division.

```
>>> minute = 59
>>> minute//60
0
```

In Python 3.0 integer division functions much more as you would expect if you entered the expression on a calculator.

2.6 Expressions

An *expression* is a combination of values, variables, and operators. A value all by itself is considered an expression, and so is a variable, so the following are all legal expressions (assuming that the variable `x` has been assigned a value):

```
17
x
x + 17
```

If you type an expression in interactive mode, the interpreter *evaluates* it and displays the result:

```
>>> 1 + 1
2
```

But in a script, an expression all by itself doesn't do anything! This is a common source of confusion for beginners.

Exercise 1: Type the following statements in the Python interpreter to see what they do:

```
5
x = 5
x + 1
```

2.7 Order of operations

When more than one operator appears in an expression, the order of evaluation depends on the *rules of precedence*. For mathematical operators, Python follows mathematical convention. The acronym *PEMDAS* is a useful way to remember the rules:

- *P*arentheses have the highest precedence and can be used to force an expression to evaluate in the order you want. Since expressions in parentheses are evaluated first, `2 * (3-1)` is 4, and `(1+1)**(5-2)` is 8. You can also use parentheses to make an expression easier to read, as in `(minute * 100) / 60`, even if it doesn't change the result.
- *E*xponentiation has the next highest precedence, so `2**1+1` is 3, not 4, and `3*1**3` is 3, not 27.
- *M*ultiplication and *D*ivision have the same precedence, which is higher than *A*ddition and *S*ubtraction, which also have the same precedence. So `2*3-1` is 5, not 4, and `6+4/2` is 8.0, not 5.
- Operators with the same precedence are evaluated from left to right. So the expression `5-3-1` is 1, not 3, because the `5-3` happens first and then `1` is subtracted from `2`.

When in doubt, always put parentheses in your expressions to make sure the computations are performed in the order you intend.

2.8 Modulus operator

The *modulus operator* works on integers and yields the remainder when the first operand is divided by the second. In Python, the modulus operator is a percent sign (%). The syntax is the same as for other operators:

```
>>> quotient = 7 // 3
>>> print(quotient)
2
>>> remainder = 7 % 3
>>> print(remainder)
1
```

So 7 divided by 3 is 2 with 1 left over.

The modulus operator turns out to be surprisingly useful. For example, you can check whether one number is divisible by another: if `x % y` is zero, then `x` is divisible by `y`.

You can also extract the right-most digit or digits from a number. For example, `x % 10` yields the right-most digit of `x` (in base 10). Similarly, `x % 100` yields the last two digits.

2.9 String operations

The `+` operator works with strings, but it is not addition in the mathematical sense. Instead it performs *concatenation*, which means joining the strings by linking them end to end. For example:

```
>>> first = 10
>>> second = 15
>>> print(first+second)
25
>>> first = '100'
>>> second = '150'
>>> print(first + second)
100150
```

The output of this program is `100150`.

2.10 Asking the user for input

Sometimes we would like to take the value for a variable from the user via their keyboard. Python provides a built-in function called `input` that gets input from the keyboard[1]. When this function is called, the program stops and waits for the user to type something. When the user presses `Return` or `Enter`, the program resumes and `input` returns what the user typed as a string.

[1] In Python 2.0, this function was named `raw_input`.