Introduction to Python

Sicurezza (CT0539) 2024-25
Università Ca' Foscari Venezia

Riccardo Focardi
www.unive.it/data/persone/5590470
secgroup.dais.unive.it

Why Python?

Standard in the **IT security** industry, many tools are written in Python or support plugins/bindings in Python

Flexible: supports multiple **paradigms** (imperative, object-oriented, functional)

Highly supported: huge **library**

Interpreted: quick **prototyping**

Extensible: add **built-in modules** in C

Dynamic typing: no static types but strong **dynamic types**. Forbids non well-typed operations at runtime: no subtle errors such as in **PHP** or **JS**

Simple syntax: easy to read, easy to write: no semicolons “;”, no curly braces “{”

Warning: indentation matters!

Python interpreter

The interpreter, with no arguments, starts in **interactive mode**

⇒ Useful for simple experiments and getting used with data types and commands

We will use **python3** (`python` will run python 2.7 so use `python3`)

```
$ python3
Python 3.6.9 (default, Nov  7 2019, 10:44:02)
[GCC 8.3.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> print('Hello, World!')
Hello, World!
>>>
```

Numbers

```
>>> 3+4
7
>>> 4-2
2
>>> 3*4
12
>>> 3/4    # float division
0.75
>>> 3//4   # integer division
0
>>> 4%3    # modulo
1
>>> 3**4   # exponentiation
81
```

Dynamic typing

```
>>> 3/1
3.0
>>> 3//1
3
>>> type(3)
<class 'int'>
>>> type(1)
<class 'int'>
>>> type(3/1)
<class 'float'>
>>> type(3//1)
<class 'int'>
```

Variables

Variables do not need to be declared and are just assigned

```
>>> a = 3+2
>>> a
5
>>> a = a*2
>>> a
10

>>> print(a)  # works with any type
10
```

Dynamic typing

```
>>> type(a)
<class 'int'>
>>> a = 3.0
>>> type(a)
<class 'float'>

>>> a = 3       # integer
>>> a = a/2
>>> type(a)
<class 'float'>
```

Strings

Delimiters: strings are delimited by either `'` or `"`

```
>>> 'ciao'
'ciao'
>>> "ciao"
'ciao'
>>> '"ciao"'   # nested
'"ciao"'
>>> "'ciao'"   # nested
"'ciao'"
>>> '\'ciao\''   # escaped
"'ciao'"
```

Multiline: strings delimited by `"""` or `'''` are multiline

```
>>> """
... hello
... this
... is
... multiline
... """
'\nhello\nthis\nis\nmultiline\n'
```

Strings: basic functions

len: returns the length of a string

```
>>> a = 'ciao'
>>> len(a)
4
>>> print(a)
ciao
```

+: concatenates two strings

```
>>> print(a + ' ' + a)
ciao ciao
```

format: takes a format string and replaces arguments (like printf in C)

{ [field] [**!** conv] [**:** format] **}**

field: name or position

conv: s (str), r (repr), a (ascii), useful with objects

format: specifies the format (fill, alignment, width, precision, type). See the documentation for detail

Format string examples:

```
>>> 'ciao {0} {1}'.format('Riccardo','Focardi')    # position of args
'ciao Riccardo Focardi'

>>> 'Coordinates: {lat}, {long}'.format(lat='37.24N', long='-115.81W')
'Coordinates: 37.24N, -115.81W'                    # name of args

>>> '{:>30}'.format('right aligned')  # no position/name takes the first
'                 right aligned'      # format specification after :

>>> 'int: {0:d};  hex: {0:x};  oct: {0:o};  bin: {0:b}'.format(42)
'int: 42;  hex: 2a;  oct: 52;  bin: 101010'    # arg 0 in various formats

>>> n = 42
>>> f'int: {n:d};  hex: {n:x};  oct: {n:o};  bin: {n:b}'
'int: 42;  hex: 2a;  oct: 52;  bin: 101010'    # f-string f'...'
```

Strings slicing

Stings can be accessed:

s[i] with the **index** as arrays: returns a single char

s[i:j] slicing to obtain another string: returns the substring from i to j-1

s[i:j:s] slicing with step s (one char every s)

Note: index starts from 0

```
>>> 'ciao'[2]
'a'               # third char
>>> 'ciao'[2:4]
'ao'              # 2 to 3
>>> 'ciao'[-1]
'o'               # 4-1 = 3
>>> 'ciao'[-2:-4]
''                # empty! (no err)
>>> 'ciao'[-2:-4:-1] # OK!
'ai'              # -2 to -3
>>> 'ciao'[::-1]  # correct?
'oaic'            # reverse!
>>> 'ciao'[::]
'ciao'            # the full string
```

str class

Positions in Python strings:

```
+---+---+---+---+---+---+
| P | y | t | h | o | n |
+---+---+---+---+---+---+
  0   1   2   3   4   5
 -6  -5  -4  -3  -2  -1
```

Immutable: cannot **modify** elements, need to create a new string

No overflow: **limits** are checked at runtime (dynamic types)

```
>>> s = 'Python'
>>> s[0] = 'p'
TypeError: 'str' object does not
support item assignment

>>> s = 'p' + s[1:]
>>> s
'python'     # this is a new string

>>> s[6]
IndexError: string index out of range
>>> s[-7]
IndexError: string index out of range
```

Lists

Versatile data type supporting **indexing**, **slicing**, **modification** (mutable), append (**+**)

Can contain items of **different types**

```
>>> l = [1,2,3]
>>> m = ['a','b','c']

>>> l + m
[1, 2, 3, 'a', 'b', 'c']
```

Slicing

```
>>> l[1:]
[2, 3]

>>> m[1:3]
['b', 'c']
```

Modification (mutable):

```
>>> l[0] = 0
>>> l
[0, 2, 3]
```

Lists: assignment to slices

Slicing can also be used for modifying a substring

```
>>> m
['a', 'b', 'c']

>>> m[1:3]
['b', 'c']

>>> m[1:3] = ['B','C']
>>> m
['a', 'B', 'C']
```

Single index returns an **element** while a slice returns a **list**

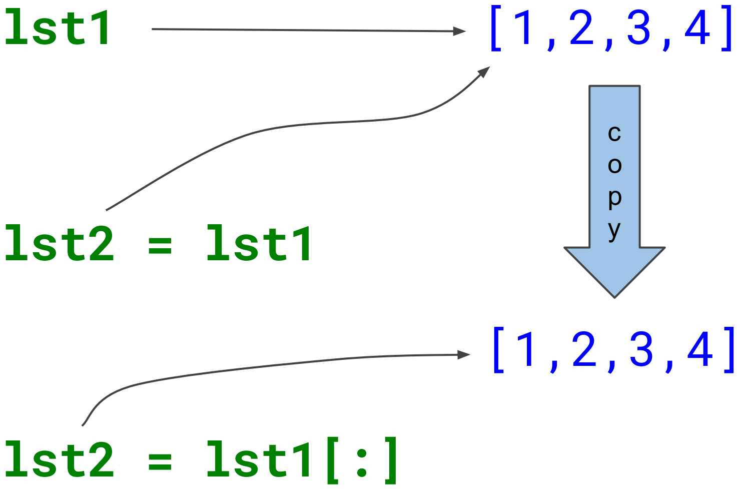
```
>>> m[1]
'B'
>>> m[1:2]
['B']

>>> m[1] = [1,2,3,4,5]
>>> m
['a', [1, 2, 3, 4, 5], 'C']
>>> m[1:2] = [1,2,3,4,5]
>>> m
['a', 1, 2, 3, 4, 5, 'C']
```

Reference vs. copy

Lists are references, assignment does not copy the list!

`lst2 = lst1` copies the **reference**: any change to `lst2` will also affect `lst1` and vice-versa

`lst2 = lst1[:]` copies the **list**: any change to `lst2` will only affect `lst2`'s copy and vice-versa



Exercise 1: Reverse word order

Print the words found in a given string in reverse order

INPUT: `'This is a test in which we revert the order of words'`

OUTPUT: `'words of order the revert we which in test a is This'`

Useful links: split, join

Control flow (indentation matters!)

if-then-else

```
if a == b:
    print('a equal b')
elif a == c:
    print('a equal c')
else:
    print('different')
```

for loop

```
for a in R:
    print(a)
```

while loop

```
a = 0
while True:
    if a%2 != 0:
        a += 1
        continue
    try:
        print(a, 10/a)
    except:
        pass
    if a == 10:
        break
    a += 1
```

Functions

Definition

```
def sum(x,y):
    return x+y
```

Keyword arguments

```
def sum(x=0,y=0):
    return x+y
```

Keyword arguments have default values

```
>>> sum()
0
>>> sum(1)
1
>>> sum(1,2)
3
>>> sum(y=3)
3
>>> sum(y=3,x=1)
4
>>> sum(1,y=3,x=1)
TypeError: sum() got multiple values
for argument 'x'
```

Python programs and modules

Shebang (hashbang): tells how to execute the interpreter:

```
#!/usr/bin/env python3
```

Encoding: what encoding to use

```
# -*- coding: utf-8 -*-
```

Python executes any code which is not in a function, even when you import it. “Isolate” main as:

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

Modules: sys contains functions related to execution:

```
import sys
```

Example: `sys.argv` command line arguments

It is possible to include python programs in other programs and use them as modules

Exercise 2: Caesar cipher

Decrypt a given ciphertext encrypted with Caesar cipher (letters are shifted 3 position ahead in the alphabet)

```
ABCDEFGHIJKLMNOPQRSTUVWXYZ
DEFGHIJKLMNOPQRSTUVWXYZABC
```

Lq fubswrjudskb, d Fdhvdu flskhu, dovr nqrzq dv Fdhvdu'v flskhu, wkh vkliw flskhu, Fdhvdu'v frgh ru Fdhvdu vkliw, lv rqh ri wkh vlpsohvw dqg prvw zlghob nqrzq hqfubswlrq whfkqltxhv. Lw lv d wbsh ri vxevwlwxwlrq flskhu lq zklfk hdfk ohwwhu lq wkh sodlqwhaw lv uhsodfhg eb d ohwwhu vrph ilahg qxpehu ri srvlwlrqv grzq wkh doskdehw. Iru hadpsoh, zlwk d ohiw vkliw ri 3, G zrxog eh uhsodfhg eb D, H zrxog ehfrph E, dqg vr rq. Wkh phwkrg lv qdphg diwhu Mxolxv Fdhvdu, zkr xvhg lw lq klv sulydwh fruuhvsrqghqfh

Useful links: chr, ord, join, string methods (ciphertext: /home/rookie/Python)

Functional programming

Iterators are objects representing **streams of data**

`next(iterator)`: generates the next element of the stream
⇒ the element is **removed**!

Note: iterators generate elements on-the-fly and update the state

`iter(iterable)`: generates an iter-**ator** from any *iter-**able***

```
>>> i = iter([1,2,3])
>>> i
<list_iterator object at 0x7f693...>
>>> next(i)
1
>>> next(i)
2
>>> next(i)
3
>>> next(i)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

Functional programming

`filter``(f, iterable)`: returns an iterator such that `f(item)` is true

`map``(f, iterable)`: returns iterator of transformed items `f(item)`

`map``(f, i1, i2, ...)`: returns iterator of items `f(e1,e2, ...)` where `e1, e2, ...` are from `i1, i2, ...`

`range``(n)`: iterable yielding numbers from 0 to n-1

```
>>> list( filter(lambda x:x%2==0, range(10)) )
[0, 2, 4, 6, 8]
>>> list( map(lambda x,y:x*y, range(10), range(10)) )
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
>>> list( map(lambda x:x*x, range(10)) )
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

List comprehensions

Create a list using iterables

Can use many **for** and **if** constructs

Can be nested

```
[(x,y,...) for x in i1
           for y in i2 … ]
```

Note: list is len(i1)*len(i2)* … long

```
[(x,y,...) for x in i1 if c1
           for y in i2 if c2 … ]
```

Conditions c1, c2, … should hold

Pairs (even,odd) numbers

```
>>> [ (x,y) for x in range(4) if x%2==0
...         for y in range(4) if y%2==1 ]
[(0, 1), (0, 3), (2, 1), (2, 3)]
```

Nested comprehension:

```
>>> [ x*x for x in
...    [ y for y in range(10) if y%2==0 ]
... ]
[0, 4, 16, 36, 64]
```

if-then-else in list comprehensions

If you need to use **else** in list comprehensions the **for** should go **after** the conditional:

```
[ e1 if conditional else e2 for item in list ]
```

```
[ e1 if c1 else
  e2 if c2 else e3 …
  for item in list ]
```

Exercise 2: try to solve exercise 2 using list comprehensions

Sets, tuples, dictionaries

Sets: unique elements, no ordering

in: membership testing: 1 in {1,2,3}

| : set union {1,2,3}|{4} is {1,2,3,4}

&: set intersection {1,2,3}&{3,4} is {3}

Tuples: immutable sequences

packing : x = (1,2,3) or x = 1,2,3

unpacking : y,z,w = x

singleton: x = (1,)   **empty**: x=()

Dictionaries: associative arrays indexed by (unique) keys

in: membership, 'a' in {'a': 2, 'b': 5}

Add element: `d['z'] = 6`

Del element: `del d['z']`

`d.keys()`: view of d’s keys

`d.values()`: view of d’s values

`d.items()`: view of d’s pairs

Exercise 3: Frequency analysis

Print the list of pairs (character, number of occurrences) found in a given string, sorted by the number of occurrences

```
exercise.frequency('This is a test in which we count the frequency of
letters. Guess what? Blank space is the most frequent!')
```

```
OUTPUT: [(' ', 19), ('e', 12), ('t', 10), ('s', 9), ('h', 6), ('i', 5),
('n', 5), ('a', 4), ('c', 4), ('u', 4), ('w', 3), ('o', 3), ('f', 3), ('r',
3), ('q', 2), ('l', 2), ('T', 1), ('y', 1), ('.', 1), ('G', 1), ('?', 1),
('B', 1), ('k', 1), ('p', 1), ('m', 1), ('!', 1)]
```

Useful links: dictionaries, sorted