Politecnico di Torino

Data Science Lab

Python programming

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Summary

- **Python language**
  - Python data types
  - Controlling program flow
  - Functions
  - Lambda functions
  - List comprehensions
  - Classes
- **Structuring Python programs**

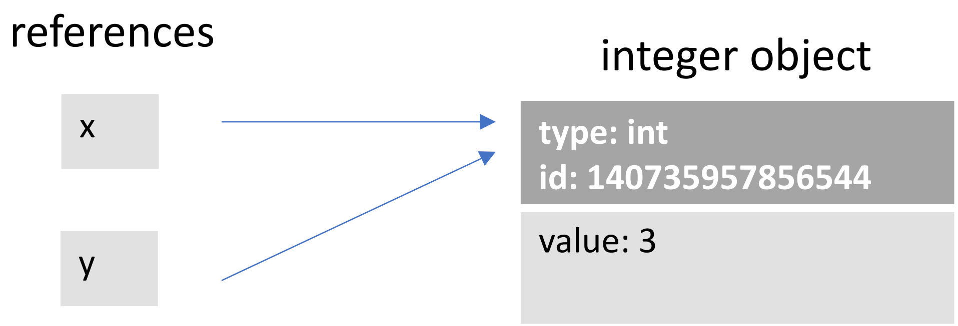
Python data types

- Python is an **object-oriented** language
- Every piece of data in the program is an **Object**
  - Objects have **properties** and **functionalities**
  - Even a simple **integer** number is a Python **object**

Example of an integer object

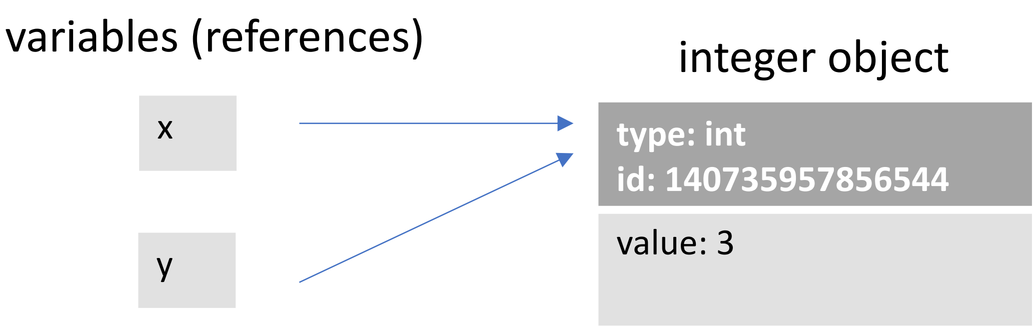
type: int **id: 140735957856544**
value: 3

- **Reference** = **symbol** in a program that refers to a particular **object**
- A single Python object can have **multiple references (alias)**



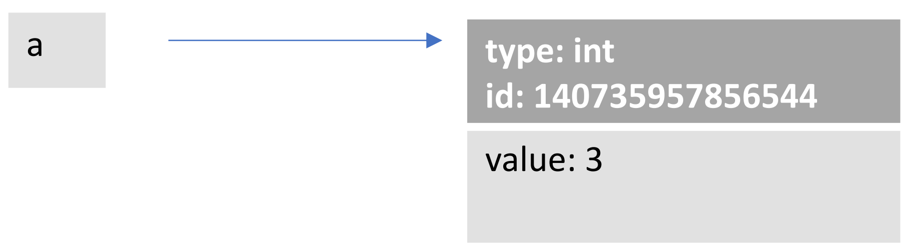
- In Python
  - **Variable** = **reference** to an object

- When you **assign** an object to a variable it becomes a **reference** to that object



- **Defining a variable**
  - **No need** to specify its data type
  - **Just assign** a value to a new variable name

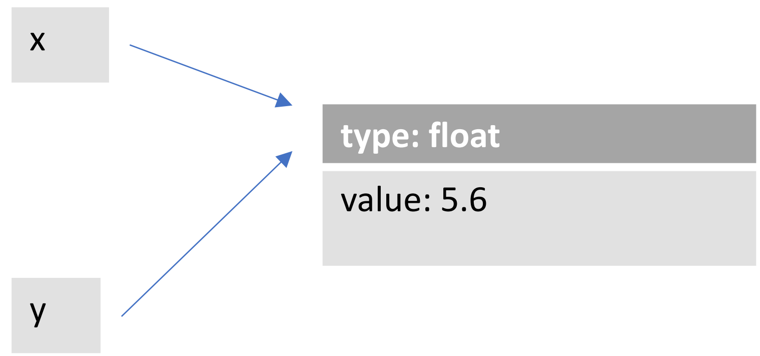
```
a = 3
```



Python data types

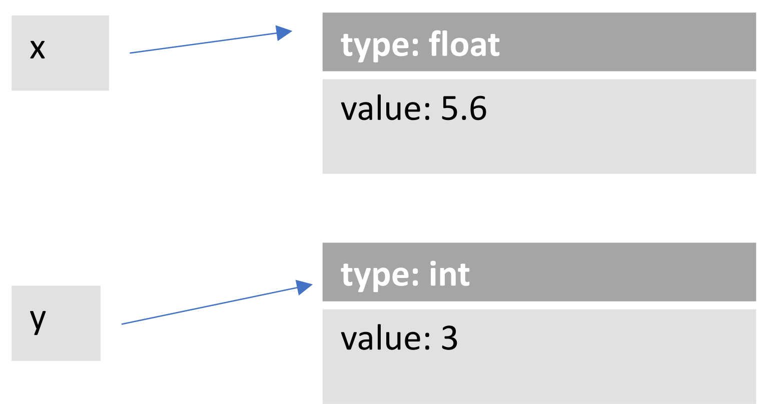
- Example

```
x = 5.6
y = x
```



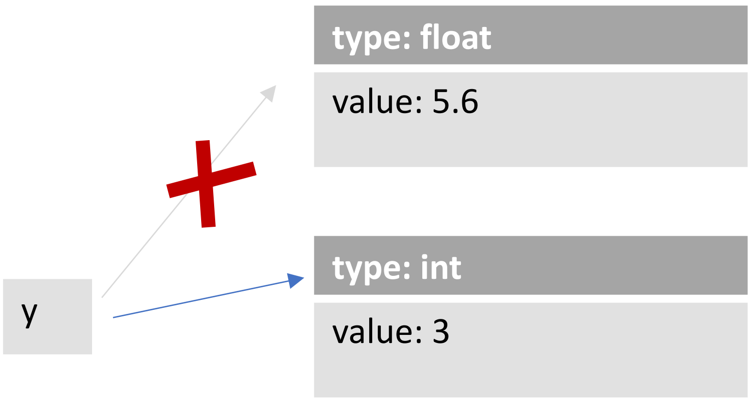
- If you assign y to a new value…

```
y = 3
```

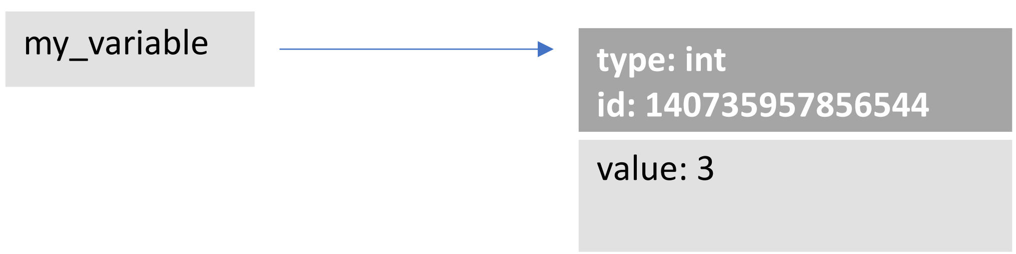


- From the previous example we learn that:
  - Basic data types, such as integer and float variables are **immutable**:
    - Assigning a new number will not change the value inside the object by rather create a new one

```
y = 5.6
y = 3
```



- Verify this reasoning with id()
  - **id(my_variable)** returns the **identifier** of the object that the variable is referencing



Python data types

Jupyter example

- Type in your code

In [1]:

```
x = 1
y = x
print(id(x))
print(id(y))
```

- Press CTRL+ENTER to run and obtain a result

Out[1]:

```
140735957856544
140735957856544
```

Python data types

- **Basic data types**
  - *int, float, bool, str*
  - *None*
  - All of these objects are **immutable**
- **Composite data types**
  - *tuple* (**immutable** collections of objects)
  - *list, set, dict* (**mutable** collections of objects)

- **int, float**
  - No theoretical size limit
    - Effectively limited by memory available
  - Available operations
    - +, -, *, /, // (integer division), % remainder, ** (exponentiation)
    - Example

In [1]:
```
x = 9
y = 5
r1 = x // y        # r1 = 1
r2 = x % y         # r2 = 4
r3 = x / y         # r3 = 1.8
r4 = x ** 2        # r4 = 81
```

- Note that dividing 2 **integers** yields a **float**

Python data types

- **bool**
  - Can assume the values True, False
  - Boolean operators: **and, or, not**
    - Example

In [1]:
```python
is_sunny = True
is_hot = False
is_rainy = not is_sunny                  # is_rainy = False
bad_weather = not (is_sunny or is_hot)  # bad_weather = False

temperature1 = 30
temperature2 = 35
raising = temperature2 > temperature1    # raising = True
```

Python data types

String

In [1]:

```
string1 = "Python's nice"          # with double quotes
string2 = 'He said "yes"'          # with single quotes
print(string1)
print(string2)
```

Out[1]:

```
Python's nice
He said "yes"
```

- Definition with single or double quotes is equivalent

Python data types

- **Conversion** between types
  - Example

In [1]:

```
x = 9.8
y = 4
r1 = int(x)                  # r1 = 9
r2 = float(y)                # r2 = 4.0
r3 = str(x)                  # r3 = '9.8'
r4 = float("6.7")            # r4 = 6.7
r5 = bool("True")            # r5 = True
r6 = bool("False")           # r6 = True :(
r7 = bool(0)                 # r7 = False
```

- Only `0`, `""`, `[]`, `{}`, `set()`, `()` convert to `False` through bool()

Python data types

Working with strings

- **string[i]:** get i-th character of string (0-indexed)
- **len:** get string length
- **strip:** remove leading and trailing spaces (tabs or newlines)
- **upper/lower**: convert uppercase/lowercase
- Full list → https://docs.python.org/3/library/stdtypes.html#text-sequence-type-str

In [1]:

```
s1 = ' My string '
length = len(s1)              # length = 11
s2 = s1.strip()               # s2 = 'My string'
s3 = s1.upper()               # s3 = ' MY STRING '
s4 = s1.lower()               # s4 = ' my string '
```

- **Sub-strings**
  - **string[start:stop]**
    - The start index is **included**, while stop index is **excluded**
    - Index of characters starts **from 0**
    - We can optionally specify a step string[start:stop:step] (∗)

```
0   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
T   h   i   s       i   s       a       s   t   r   i   n   g
```

[1:14]

[0:2]

[14:16]

start (0)
included

stop (2)
excluded

(∗) see details in the upcoming “list” explanation

- **Shortcuts**
  - **Omit start** if you want to start from the beginning
  - **Omit stop** if you want to go until the end of the string

In [1]:

```
s1 = "Hello"
charact = s1[0]          # charact = 'H'
s2 = s1[0:3]             # s2 = 'Hel'
s3 = s1[1:]              # s3 = 'ello'
s4 = s1[:3]              # s4 = 'Hell’
s5 = s1[:]               # s4 = 'Hello'
```

- **Sub-strings**
  - **Negative indices:**
    - count characters **from the end**
    - **-1 = last character**

```
-16 -15 -14 -13 -12 -11 -10 -9  -8  -7  -6  -5  -4  -3  -2  -1
 0   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
 T   h   i   s       i   s       a       s   t   r   i   n   g
```

[-15:-2]

[0:-14]

[-2:16]

[:-1]

- **Sub-strings**
  - **Negative indices:**
    - count characters **from the end**
    - **-1 = last character**

In [1]:
```
s1 = "MyFile.txt"

s2 = s1[:-1]            # s2 = 'MyFile.tx'
s3 = s1[:-2]            # s3 = 'MyFile.t'
s4 = s1[-3:]            # s4 = 'txt'
```

- **Strings: concatenation**
  - Use the **+** operator

In [1]:

```python
string1 = 'Value of '
sensor_id = 'sensor 1.'
print(string1 + sensor_id)              # concatenation
val = 0.75
print('Value: ' + str(val))             # float to str
```

Out[1]:

```
Value of sensor 1.
Value: 0.75
```

Python data types

- **Strings are immutable**

In [1]:

```
str1 = "example"
str1[0] = "E"                # will cause an error
```

- Use instead:

In [1]:

```
str1 = "example"
str1 = 'E' + str1[1:]
```

- **Formatted string literals (or f-strings)**
  - Introduced in Python 3.6
  - Useful pattern to build a string from one or more variables
  - E.g. suppose you want to build the string:

	var1		var2
My float is	17.5	and my int is	5

  - Syntax:
    - **f**"My float is **{var1}** and my int is **{var2}**"

- **Formatting strings (older versions)**
  - Syntax:
    - "My float is **%f** and my int is **%d**" % (17.5, 5)

float placeholder

int placeholder

values to be replaced

My float is | 17.5 | and my int is | 5

- "My float is **{0}** and my int is **{1}**".format(17.5, 5)

index of variable that
will replace the braces

- **Example (>= Python 3.6)**

In [1]:

```
city = 'London'
temp = 19.23456
str1 = f"Temperature in {city} is {temp} degrees."
str2 = f"Temperature with 2 decimals: {temp:.2f}"
str3 = f"Temperature + 10: {temp+10}"
print(str1)
print(str2)
print(str3)
```

Out[1]:

```
Temperature in London is 19.23456 degrees.
Temperature with 2 decimals: 19.23
Temperature + 10: 29.23456
```

- **None type**
  - Specifies that a reference does not contain data

In [1]:
```python
my_var = None

if my_var is None:
    my_var = 10
```

  - Useful to:
    - Represent "missing data" in a list or a table
    - Initialize an empty variable that will be assigned later on
      - (e.g. when computing min/max)

Python data types

- **Tuple**
  - **Immutable** sequence of *heterogeneous* variables
  - Definition:

In [1]:
```python
t1 = ('Turin', 'Italy')      # City and State
t2 = 'Paris', 'France'       # optional parentheses

t3 = ('Rome', 2, 25.6)       # can contain different types
t4 = ('London',)             # tuple with single element
```

- **Tuple unpacking**
  - **Assigning** a tuple to a set of variables

In [1]:

```
city_data = ('Turin', 'Italy', 12)
city, state, temperature = city_data

print(city)        # Turin
print(state)       # Italy
print(temperature) # 12
```

Python data types

- **Swapping** elements with tuples
  - This is an interesting case of unpacking

In [1]:
```
a = 1
b = 2
a, b = b, a
print(a)
print(b)
```

Out[1]:
```
2
1
```

Python data types

- **Tuple**
  - Tuples can be **concatenated**
  - A new tuple is generated upon concatenation

In [1]:

```python
city = 'Turin', 'Italy'
temperatures = 6, 15
city_data = city + temperatures
print(city_data)
```

Out[1]:

```
('Turin', 'Italy', 6, 15)
```

Python data types

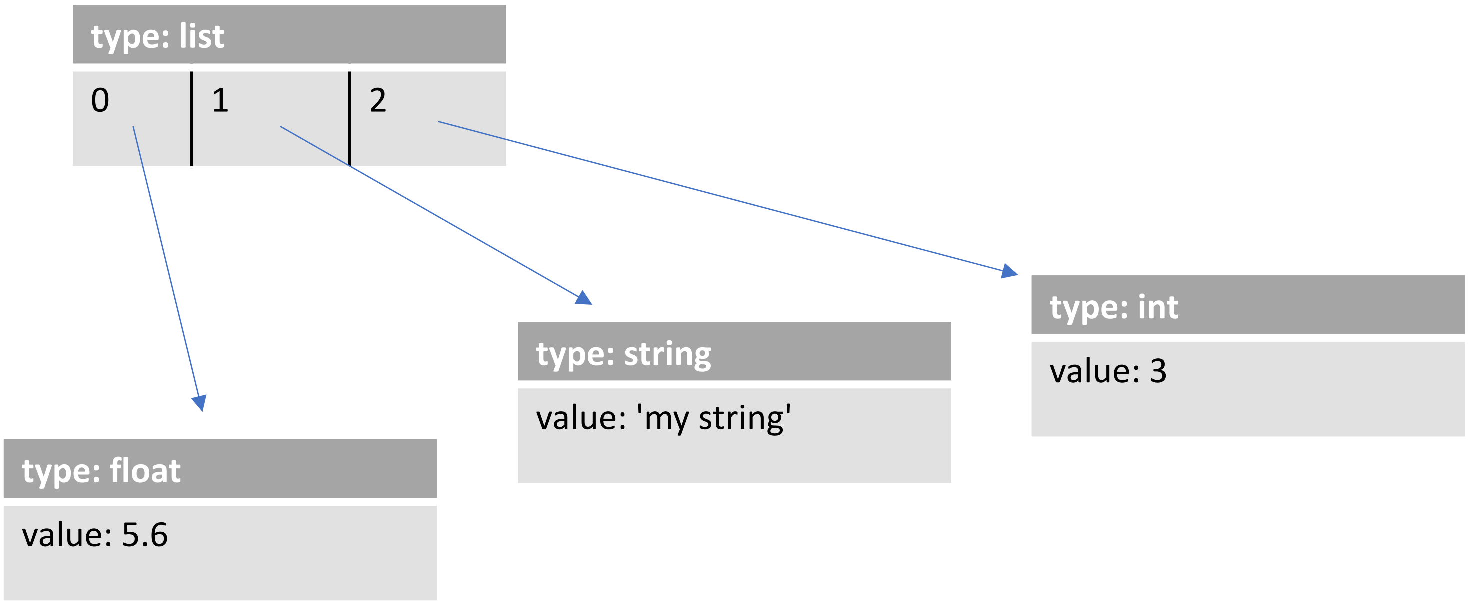
- **Tuple**
  - Accessing elements of a tuple
    - t [start:stop]
    - We can optionally specify a step str[start:stop:step] (∗)

In [1]:

```
t1 = ('a', 'b', 'c', 'd')

val1 = t1[0]                # val1 = 'a'
t2 = t1[1:]                 # t2 = ('b', 'c', 'd')
t3 = t1[:-1]                # t3 = ('a', 'b', 'c')

t1[0] = 2                   # will cause an error
                            # (a tuple is immutable)
```


(∗) see details in the upcoming “list” explanation

- **List**
  - **Mutable** sequence of heterogeneous elements
  - Each element is a **reference** to a Python object



- **List**
  - Definition

In [1]:
```python
l1 = []                            # empty list
l2 = [1, 'str', 5.6, None]         # can contain different types

a, b, c, d = l2                    # can be assigned to variables
                                   # a=1, b='str', c=5.6, d=None
```

Python data types

- **List**
  - **Adding** elements and **concatenating** lists

In [1]:
```python
l1 = [2, 4, 6]
l2 = [10, 12]
l1.append(8)                 # append an element to l1
l3 = l1 + l2                 # concatenate 2 lists
print(l1)
print(l3)
```

Out[1]:
```
[2, 4, 6, 8]
[2, 4, 6, 8, 10, 12]
```

- **List**
  - **Other methods:**
    - `list.count(element)`
      - Number of occurrences of element
    - `list1.extend(list2):`
      - Extend list1 with another list list2
    - `list.insert(index, element):`
      - Insert element at position
    - `list.pop(index):`
      - Remove element by position
    - `list.index(element):`
      - Returns position of *first* occurrence of element

https://docs.python.org/3/tutorial/datastructures.html#more-on-lists

- **List**
  - **Accessing** elements:
    - Same syntax as tuples, but this time assigment is allowed

In [1]:
```
l1 = [0, 2, 4, 6]
val1 = l1[0]                # val1 = 0
a, b = l1[1:-1]             # a=2, b=4
l1[0] = 'a'
print(l1)
```

Out[1]:
```
['a', 2, 4, 6]
```

- **List**
  - **Accessing** elements
    - Can also specify a **step**: [start:stop:step]
      - **step = 2** skips 1 element
      - **step = -1** reads the list in reverse order
      - **step = -2** reverse order, skip 1 element

In [1]:
```
l1 = [0, 1, 2, 3, 4]
l2 = l1[::2]                 # l2 = [0, 2, 4]
l3 = l1[::-1]                # l3 = [4, 3, 2, 1, 0]
l4 = l1[::-2]                # l3 = [4, 2, 0]
```

- **List**
  - **Assigning** multiple elements

In [1]:
```
l1 = [0, 1, 2, 3, 4]
l1[1:4] = ['a', 'b', 'c']   # l1 = [0, 'a', 'b', 'c', 4]
```

  - **Removing** multiple elements

In [1]:
```
l1 = [0, 1, 2, 3, 4]
del l1[1:-1]        # l1 = [0, 4]
```

- **“in” operator**
  - **Check** if element belongs to a list

In [1]:
```
l1 = [0, 1, 2, 3, 4]
myval = 2
myval in l1 # True, since 2 is in l1
```

  - **Iterate** over list elements

In [1]:
```
l1 = [0, 1, 2, 3, 4]
for el in l1:
    print(el)
```

List

Sum, min, max of elements

In [1]:
```
l1 = [0, 1, 2, 3, 4]
min_val = min(l1)           # min_val = 0
max_val = max(l1)           # max_val = 4
sum_val = sum(l1)           # sum_val = 10
```

Sort list elements

- `reverse=True` for descending order

In [1]:
```
l1 = [3, 2, 5, 7]
l2 = sorted(l1)                  # l2 = [2, 3, 5, 7]
l3 = sorted(l1, reverse=True) # l3 = [7, 5, 3, 2]
```

- **Set**
  - **Unordered** collection of **unique** elements
  - Definition:

In [1]:
```
s0 = set()                  # empty set
s1 = {1, 2, 3}
s2 = {3, 3, 'b', 'b'}       # s2 = {3, 'b'}
s3 = set([3, 3, 1, 2])      # from list: s3 = {1,2,3}
```

Python data types

- **Set**
  - **Operators between two sets**
    - | union (∪)
    - & intersection (∩)
    - - difference (\)
    - <= subset (⊆)
    - < proper subset (⊂)
    - >= superset (⊇)
    - > proper superset (⊃)

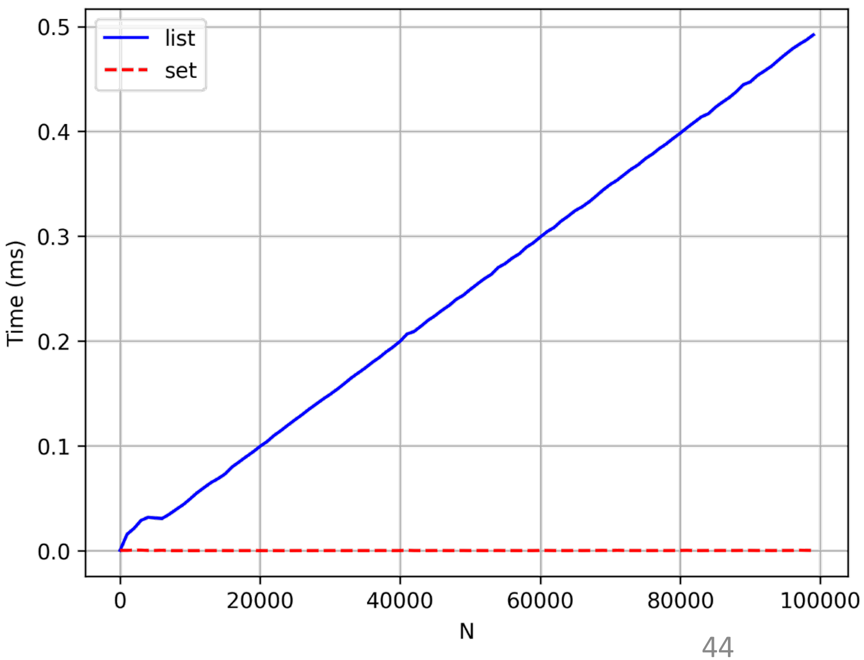
```
s1 = {1, 2, 3}
s2 = {3, 'b'}
union = s1 | s2             # {1, 2, 3, 'b'}
intersection = s1 & s2      # {3}
difference = s1 - s2        # {1, 2}

{1,2} <= s1      # True
{1,2,3} < s1     # False (not a proper subset)
{1,2,3} <= s1    # True (same set)
```

- **Set**
  - **Add/remove elements**

In [1]:
```
s1 = {1,2,3}
s1.add('4')                 # s1 = {1, 2, 3, '4'}
s1.remove(3)                # s1 = {1, 2, '4'}
```

- **"in" operator**
  - **Check** whether element belongs to a set
  - O(1) operation
    - **!** Note that lists are O(n)

`el in list` vs `el in set` (execution time)



In [1]:
```
s1 = set([0, 1, 2, 3, 4])
myval = 2
myval in s1 # True, since 2 is in s1
```

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- **“in” operator**
  - **Iterate** over set elements
    - Note: sets are unordered
      - The order during iterations is not well-defined

```
In [1]: s1 = set([0, 1, 2, 3, 4])
        for el in s1:
            print(el)
```

```
In [1]: {1,2,3} == {3,2,1}
Out[1]: True

In [2]: for i in {1,2,3}:
   ...:     print(i)
   ...:
1
2
3

In [3]: for i in {3,2,1}:
   ...:     print(i)
   ...:
1
2
3
```

Set example: removing list duplicates

In [1]:
```
input_list = [1, 5, 5, 4, 2, 8, 3, 3]
out_list = list(set(input_list))


print(out_list)
```

- **Note:** order of original elements is not preserved

Out [1]:
```
[1, 2, 3, 4, 5, 8]
```

Notebook Examples

- **1-Python Examples.ipynb**
  - **1) Removing list duplicates**

Python data types

- **Dictionary**
  - Collection of key-value pairs
  - Allows fast **access** of elements **by key**
    - Keys are **unique**
  - **Definition:**

In [1]:
```
d1 = {'Name' : 'John', 'Age' : 25}
d0 = {}                                   # empty dictionary
```

- **Dictionary keys**
  - Must be **hashable** types
    - E.g. int, float, string, bool, **tuple**
    - Note: lists and dictionaries are not hashable
    - Hashable types are hashed with the hash() function
  - Example: itemsets and their support

```
In [1]: d1 = {('a','b') : 120, ('c','d','e') : 1000}
```

  - Note: the same applies for elements of sets!
- **Dictionary values**
  - Any Python object is allowed

- **Dictionary**
  - **Access** by key:

In [1]:
```
images = {10 : 'plane.png', 25 : 'flower.png'}
img10 = images[10]          # img10 = 'plane.png'
img8 = images[8]            # Get an error if key does not exist
img8 = images.get(8)        # .get() returns None if the key does not exist
img8 = images.get(8, 'notfound.ong') # we can optionally specify a default value
```

  - Reading **keys** and **values**:
    - Note: keys() and values() return **views on original data**

In [2]:
```
occurrences = {'Car' : 33, 'Truck' : 55}
keys = list(occurrences.keys())       # keys = ['Car', 'Truck']
values = list(occurrences.values())   # values = [33, 55]
```

Python data types

- **Dictionary**
  - **Adding/updating** values:

In [1]:
```
occur = {'Car' : 33, 'Truck' : 55}
occur ['Car'] = 56          # Update existing value
occur ['Road'] = 3          # Add a new key
```

  - **Deleting** a key:

In [2]:
```
occur = {'Car' : 33, 'Truck' : 55}
del d2['Truck']             # occur = {'Car':33}
```

Python data types

- **Dictionary**
  - **Check** whether a key exists:

In [1]:
```
occur = {'Car' : 33, 'Truck' : 55}
'Truck' in occur # True since “Truck” is in occur
```

Python data types

- **Dictionary**
  - **Iterating** keys and values
    - Note: Previous Python versions had no order guarantee
    - However, Python 3.7+ officially preserves insertion order (*)
  - E.g. get the cumulative price of items in a market basket

In [1]:

```
basket = {'Cola' : 0.99, 'Apples' : 1.5, 'Salt' : 0.4}
price = 0
for k, v in basket.items():
    price += v
    print(f"{k}: {price}")
```

Out [1]:

```
Cola: 0.99
Apples: 2.49
Salt: 2.89
```

(*) https://docs.python.org/3/whatsnew/3.7.html

- **Default dictionary**
  - Access by key with **default value**:

In [1]:
```
from collections import defaultdict

experience = defaultdict(lambda: 1)
experience['Mario']=3
experience['Elena']+=1        # Even if key 'Elena' not defined
```

  - Instead of writing:

In [2]:
```
if 'Elena' in experience:
    experience['Elena']+=1
else:
    experience['Elena']=2
```

tuple vs list vs set vs dict

	tuple	list	set	dict
Mutable	No	Yes	Yes	Yes
Ordered	Yes	Yes	No*	No*
Unique values	No	No	Yes	Yes (keys)
Constraints on values	No	No	Must be hashable	Keys must be hashable
Search cost	O(n)	O(n)	O(1)	O(1)

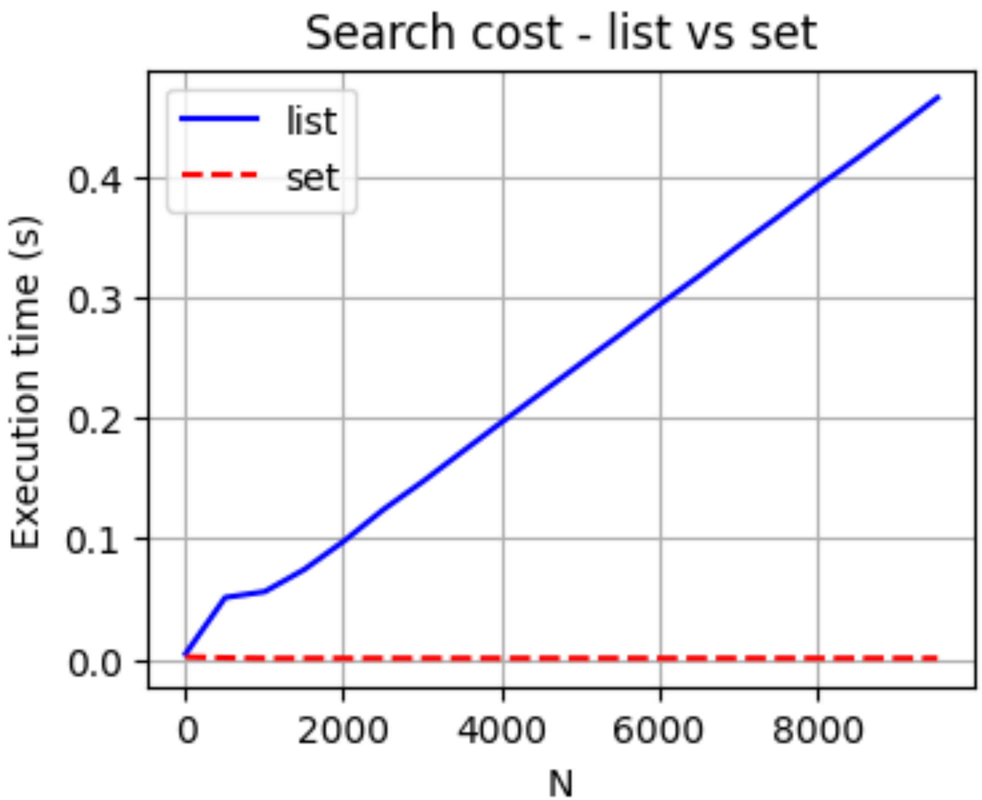
* Implementation dependent – Since Python 3.7 dicts are ordered based on insertion order

Serach cost – list vs set

- Practical example of seraching an element
  - In a list vs in a set
- Same Python syntax

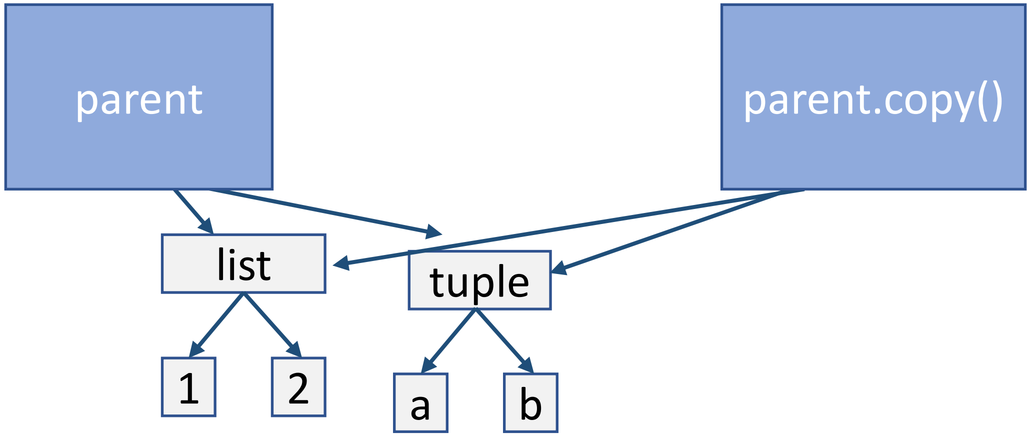
```
L = [1, 2, 3]
S = {1, 2, 3}


3 in L # search 3 in a list L
3 in S # search 3 in a set S
```

- Very different results as the size of the object increases

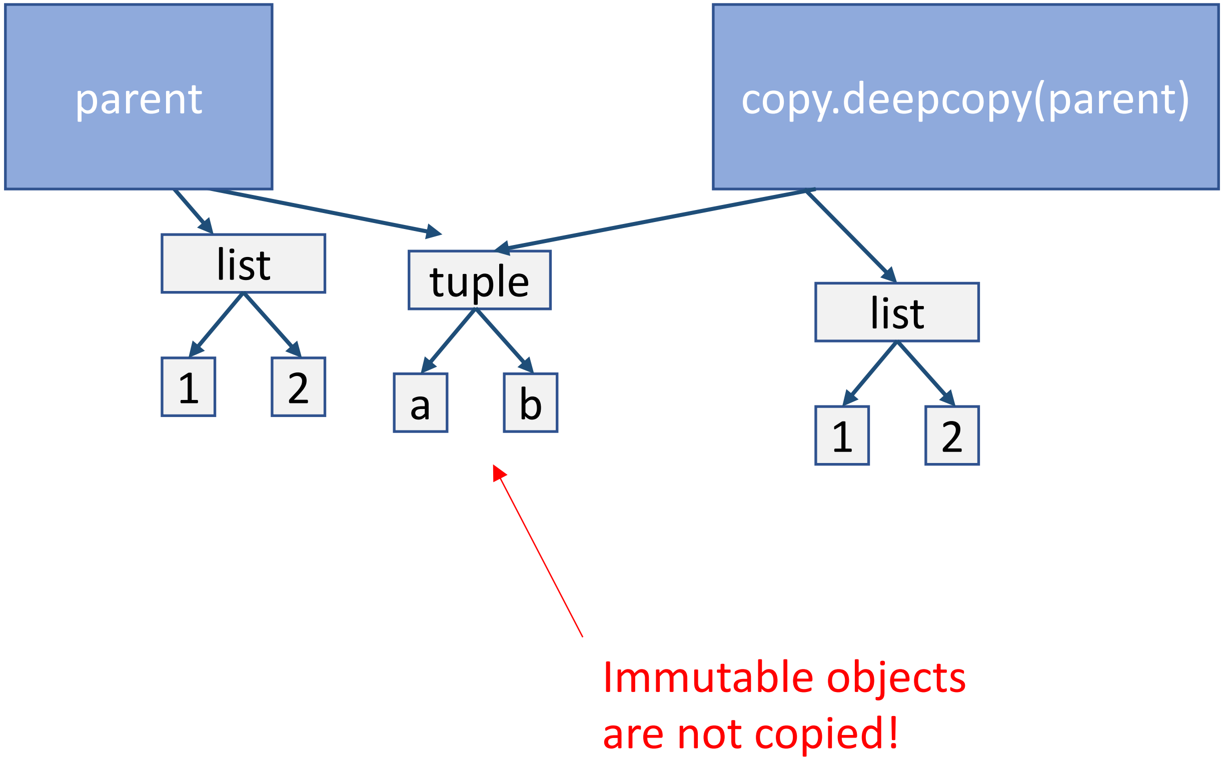


- Objects *can contain objects* within them
  - E.g., lists *of objects*
  - `parent = [ [ 1, 2 ], (‘a’, ‘b’) ]`

- We can create *shallow* or *deep* copies of objects
  - *Shallow*: copy the parent object, keep references to children



- We can create *shallow* or *deep* copies of objects
  - *Deep*: recursively copies all children nodes of parent object



Shallow copies of Python objects

In [1]:
```
temperatures = {'Turin':[10,12,10], 'Milan':[15,16,16]}
temp2 = temperatures.copy()
temp2['Turin'].append(13)           # Edit child node
temp2['Rome'] = [10, 11, 10]        # Edit parent node
print(temperatures)
print(temp2)
```

In [2]:
```
{'Turin': [10, 12, 10, 13], 'Milan’: [16, 15]}
{'Turin': [10, 12, 10, 13], 'Milan’: [16, 15], 'Rome': [10, 11,
10]}
```

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Deep copy of Python objects

In [1]:
```
import copy
temperatures = {'Turin':[10,12,10], 'Milan':[15,16,16]}
temp2 = copy.deepcopy(temperatures)
temp2['Turin'].append(13)                # Edit child node
temp2['Rome'] = [10, 11, 10]             # Edit parent node
print(temperatures)
print(temp2)
```

In [2]:
```
{'Turin': [10, 12, 10], 'Milan': [15,16,16]}
{'Turin': [10, 12, 10, 13], 'Milan': [15,16,16], 'Rome': [10, 11, 10]}
```

```
import copy
a = [ [ 1, 2, 3 ], ('a', 'b', 'c') ]
ref = a
shallow_copy = a.copy()
deep_copy = copy.deepcopy(a)
id(a) == id(ref)                # True (references to the same object)
id(a) == id(shallow_copy)       # False (shallow copy)
id(a[0]) == id(shallow_copy[0]) # True (shallow_copy points to a’s children)
id(a[0]) == id(deep_copy[0])    # False (deep_copy copies a’s children
id(a[1]) == id(deep_copy[1])    # True (immutable objects are not copied)
```

- **if/elif/else**
  - Conditions expressed with >, <, >=, <=, ==, !=
    - Can include boolean operators (and, not, or)

In [1]:

```python
if sensor_on and temperature == 10:
    print("Temperature is 10")
elif sensor_on and 10 < temperature < 20:
    in_range = True
    print("Temperature is between 10 and 20")
else:
    print("Temperature is out of range or sensor is off.")
```

indentation is mandatory

- **While loop**
  - Iterate while the specified condition is True

In [1]:

```
counter = 0
while counter < 5:
    print (f"The value of counter is {counter}")
    counter += 2    # increment counter of 2
```

Out [1]:

```
The value of counter is 0
The value of counter is 2
The value of counter is 4
```

- **Iterating** for a fixed number of times
  - Use: `range(start, stop)`

In [1]:

```
for i in range(5, 8):
    txt = f"The value of i is {i}"
    print(txt)
```

Out [1]:

```
The value of i is 5
The value of i is 6
The value of i is 7
```

- **Enumerating** list objects
  - Use: `enumerate(my_list)`

In [1]:

```
my_list = ['a', 'b', 'c']
for i, element in enumerate(my_list):
    print(f"The value of my_list[{i}] is {element}")
```

Out [1]:

```
The value of my_list[0] is a
The value of my_list[1] is b
The value of my_list[2] is c
```

- **Iterating on multiple lists**
  - Use: `zip(list1, list2, ...)`

In [1]:

```
my_list1 = ['a', 'b', 'c']
my_list2 = ['A', 'B', 'C']
for el1, el2 in zip(my_list1, my_list2):
    print(f"El1: {el1}, el2: {el2}")
```

Out [1]:

```
El1: a, el2: A
El1: b, el2: B
El1: c, el2: C
```

- **Break/continue**
  - Alter the flow of a **for** or a **while** loop
  - Example

my_file.txt

```
car
skip
truck
end
van
```

```python
with open("./data/my_file.txt") as f:
    for line in f:          # read file line by line
        if line=='skip':
            continue        # go to next iteration
        elif line=='end':
            break           # interrupt loop
        print(line)
```

Out [1]:

```
car
truck
```

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- **Essential** to organize code and avoid repetitions

parameters

function name

return value

invocation

In [1]:

```
def euclidean_distance(x, y):
    dist = 0
    for x_el, y_el in zip(x, y):
        dist += (x_el-y_el)**2
    return dist ** 0.5
print(f"{euclidean_distance([1,2,3], [2,4,5]):.2f}")
print(f"{euclidean_distance([0,2,4], [0,1,6]):.2f}")
```

Out [1]:

```
3.00
2.24
```

Variable scope

- Rules to specify the **visibility** of variables
- **Local scope**
  - Variables defined inside the function

In [1]:

```
v my_func(x, y):
    z = 5            not accessible from outside
    return x + y + z

print(my_func(2, 4))
print(z)             error: z undefined
```

- **Variable scope**
  - **Global scope**
    - Variables defined outside the function

In [1]:

```
def my_func(x, y):
    return x + y + z

z = 5
my_func(2, 4)
```

z can be read inside the function

Out [1]:

```
11
```

Variable scope

Global scope vs local scope

In [1]:

```
def my_func(x, y):
    z = 2                  ← define z in local scope
    return x + y + z       ← use z from local scope

z = 5                      ← define z in global scope
print (my_func(2, 4))
print (z)                  ← z in global scope is not modified
```

Out [1]:

```
8
5
```

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Variable scope

- Force the usage of variables in the global scope

In [1]:

```
def my_func(x, y):
    global z            now z refers to global scope
    z = 2               this assigment is performed to z
    return x + y + z    in the global scope
z = 5
print (my_func(2, 4))
print (z)
```

Out [1]:

```
8
2
```

Variable scope

- Force the usage of variables in the global scope

In [1]:

```
def my_func(x, y):
    global z
    z = 2
    return x + y + z
z = 5
print (my_func(2, 4))
print (z)
```

now z ref

this assig

in the glo

Note
Avoid mixing global-local variables if possible. Pass all variables needed as arguments!

Out [1]:

```
8
2
```

- Functions can **return tuples**

In [1]:

```
def add_sub(x, y):
    return x+y, x-y


summ, diff = add_sub(5, 3)
print(f"Sum is {summ}, difference is {diff}.")
```

Out [1]:

```
Sum is 8, difference is 2.
```

Functions

- Parameters with **default value**

In [1]:

```python
def func(a, b, c='defC', d='defD'):
    print(f"{a}, {b}, {c}, {d}")
func(1, 2)                    # use default for c, d
func(1, 2, 'a')               # use default for d, not for c
func(1, 2, d='b')             # passing keyword argument
func(b=2, a=1, d='b')         # keyword order does not matter
func(1, c='a')                # Error: b not specified
```

Out [1]:

```
1, 2, defC, defD
1, 2, a, defD
1, 2, defC, b
1, 2, defC, b
```

Map & Filter patterns

- Some patterns are commonly adopted
  - Filter pattern
    - Given a sequence of values, *keep some* and *discard the rest*
    - A function looks at each element and decides what to do
    - Function: `filter(filter_function, sequence)`
  - Map pattern
    - Given a sequence of values, map each element to a new one
    - A function applies the mapping
    - Function: `map(map_function, sequence)`

Filter pattern

- Task: Remove negative elements from a list of values
- Filter pattern
  - Given a sequence of values, *keep some* and *discard the rest*
  - A function looks at each element and decides what to do
    - return `True` if an element should be kept, `False` if it should be discarded
  - Function: `filter(filter_function, sequence)`

In [1]:

```
def is_positive(number):
    return number >= 0

numbers = [1, -8, 5, -2, 5]
positive = list(filter(is_positive, numbers))
# positive == [ 1, 5, 5 ]
```

Map pattern

- Task: Get squared values of the elements of a sequence
- Map pattern
  - Given a sequence of values, map each element to a new one
  - A function applies the mapping, element-wise
  - Function: `map(map_function, sequence)`

In [1]:

```
def square(number):
    return number ** 2

numbers = [1, -8, 5, -2, 5]
squares = list(map(square, numbers))
# squares == [ 1, 64, 25, 4, 25 ]
```

Lambda functions

- The previous examples require creating a new function used only once
  - `is_positive(), square()`
- We can define lambda functions *inline* and *without a name*

return value

input parameter(s)

In [1]:
```
numbers = [1, -8, 5, -2, 5]
positive = list(filter(lambda x: x >= 0, numbers))
squares = list(map(lambda x: x ** 2, numbers))
```

Lambda functions

- Lambda functions and conditions
  - Possible with the *ternary operator*
    - `[value_true] if [condition] else [value_false]`
  - Examples of *conditional mappings*

In [1]:

```
numbers = [1, -1, 2, -2, 1]
sign = list(map(lambda x: '-' if x <= 0 else '+', numbers))
abs_values = list(map(lambda x: x if x > 0 else -x, numbers))
print(sign)
print(abs_values)
```

Out [1]:

```
['+', '-', '+', '-', '+']
[1, 1, 2, 2, 1]
```

Sort/min/max by key

In [1]:

```
records = [{'name':'v1', 'val':5}, {'name':'v2', 'val':1},
           {'name':'v3', 'val':6}]
min_val = min(records, key=lambda r: r['val'])
sorted_records = sorted(records, key=lambda r: r['val'])

print(f"Min: {min_val}")
print(f"Sorted: {sorted_records}")
```

Out [1]:

```
Min: {'name':'v2', 'val':1}
Sorted: [{'name':'v2', 'val':1}, {'name':'v1', 'val':5},
           {‘name':'v3', 'val':6}]
```

List comprehensions

- Allow creating **lists** from other **iterables**
  - Useful for implementing the **map pattern**
  - Syntax:

iterate all the elements

e.g. list or tuple

In [1]:

```
res_list = [f(el) for el in iterable]
```

transform **el** to another value

List comprehensions

- Example: convert to uppercase dictionary keys
  - (**map** pattern)

In [1]:

```
dct = {'a':10, 'b':20, 'c':30}

my_list = [s.upper() for s in dct.keys()]
print(my_list)
```

Out [1]:

```
['A', 'B', 'C']
```

- Allow specifying *conditions* on elements
  - Example: **square** the **positive** numbers in a list, discard the negative ones
    - **Filter** + **map** patterns

In [1]:

```
my_list1 = [-1, 4, -2, 6, 3]

my_list2 = [el**2 for el in my_list1 if el > 0]
print(my_list2)
```

Out [1]:

```
[16, 36, 9]
```

List comprehensions

- Example: Euclidean distance

```python
def euclidean_distance(x, y):
    dist = 0
    for x_el, y_el in zip(x, y):
        dist += (x_el-y_el)**2
    return dist ** 0.5
```

↓

```python
def euclidean_distance(x, y):
    dist = sum([(x_el-y_el)**2 for x_el, y_el in zip(x, y)])
    return dist ** 0.5
```

Other comprehensions

- Dictionary comprehensions
  - Similarly to lists, allow building dictionaries

In [1]:

```
keys = ['a','b','c']
values = [-1, 4, -2]

my_dict = {k:v for k, v in zip(keys, values)}
print(my_dict)
```

Out [1]:

```
{'a': -1, 'b': 4, 'c': -2}
```

- Set comprehensions

In [2]:

```
{ v ** 2 for v in [ 4, 3, 2, -2, 1 ] }
```

Out [2]:

```
{1, 4, 9, 16}
```

List comprehensions

- List comprehensions and lambda functions can shorten your code, but …
  - Pay attention to **readability**!!
  - **Comments** are welcome!!

Notebook Examples

- **1-Python Examples.ipynb**
  - **2) Euclidean distance between lists**

- A class is a model that specifies a collection of
  - attributes (= variables)
  - methods (that interact with attributes)
  - a constructor (a special method called to initialize an object)
- An object is an **instance** of a specific class

- Example:
  - class: Triangle (all the triangles have 3 edges)
  - object: a specific instance of Triangle

Classes

- Simple class example:

In [1]:

```
class Triangle:                    ← class name
    num_edges = 3                  ← attribute definition

triangle1 = Triangle()             ← class instantiation (object) creation
print(triangle1.num_edges)         ← access to attribute
```

Out [1]:

```
3
```

- In this example all the object instances of Triangle have the same attribute value for num_edges: 3

- Constructor and initialization:

In [1]:

```
class Triangle:
    num_edges = 3
    def __init__(self, a, b, c):
        self.a = a
        self.b = b
        self.c = c


triangle1 = Triangle(2, 4, 3)
triangle2 = Triangle(2, 5, 2)
```

self is always the first parameter

constructor parameters

initialize attributes

invoke constructor and instantiate a new Triangle

self is a reference to the current object

- Methods
  - Equivalent to Python functions, but defined inside a class
  - The first argument is always **self** (reference to current object)
    - **self** allows accessing the object attributes
  - Example:

```
class MyClass:
    def my_method(self, param1, param2):
        ...
        self.attr1 = param1
        ...
```

- Example with methods

In [1]:

```
class Triangle:
    def __init__(self, a, b, c):
        self.a, self.b, self.c = a, b, c
    def get_perimeter(self):
        return self.a + self.b + self.c


triangle1 = Triangle(2,4,3)
triangle1.get_perimeter()
```

method

use **self** for referring to attributes

method invocation (**self** is passed to the method automatically)

Out [1]:

```
9
```

- **Private** attributes
  - Methods or attributes that are **available only inside the object**
  - They are **not accessible** from outside
  - Necessary when you need to define elements that are useful for the class object but must not be seen/modified from outside

Private attributes

In [1]:

```
class Triangle:
    def __init__(self, a, b, c):
        self.a, self.b, self.c = a, b, c
        self.__perimeter = a + b + c
    def get_perimeter(self):
        return self.__perimeter

triangle1 = Triangle(2,4,3)
print(triangle1.get_perimeter())
print(triangle1.__perimeter)
```

2 leading underscores make variables private

Error! Cannot access private attributes

Out [1]:

```
9
```

Notebook Examples

- **1-Python Examples.ipynb**
  - **3) Classes and lambda functions: rule-based classifier**

Exception handling

- To track errors during program execution

In [1]:

```
try:
    res = my_dict['key1']
    res += 1
except:
    print("Exception during execution")
```

In [2]:

```
try:
    res = a/b
except ZeroDivisionError:
    print("Denominator cannot be 0.")
```

can specify exception type

- The **finally** block is executed in any case after try and except
  - It tipically contains cleanup operations
  - Example: reading a file

In [1]:

```
try:
    f = open('./my_txt','r')      # open a file
    ...                           # work with file
except:
    print("Exception while reading file")
finally:
    f.close()
```

- The try/except/finally program in the previous slide can also be written as follows:

In [1]:
```
try:
    with open('./my_txt', 'r') as f:
        for line in f:
            ... # do something with line
except:
    print("Exception while reading file")
```

- If there is an **exception** while reading the file, the with statement ends
- In any case, when the with statement ends the file is automatically closed (similarly to the finally statement)

Notebook Examples

- **1-Python Examples.ipynb**
  - **4) Classes and exception handling: reading csv files**