Politecnico di Torino

Data Science and Machine Learning for Engineering Applications

Python programming

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Outline

- Python Programming – Theory (1.5 hours)
  - Python basics
- Start coding in Python – Applied (1.5 hours)
  - Setup
    - Install Python and Anaconda-Navigator
    - Create a Jupyter notebook
  - First laboratory on Python basics

Why Python?

- Simplicity of the syntax
  - Clean code
  - Readability
  - Fewer line of code
- Large community
  - Documentation
  - Libraries and Frameworks
- Interpreted language
  - Can be threated object-oriented or functional
  - Don’t need compilation
  - You can run code directly

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**

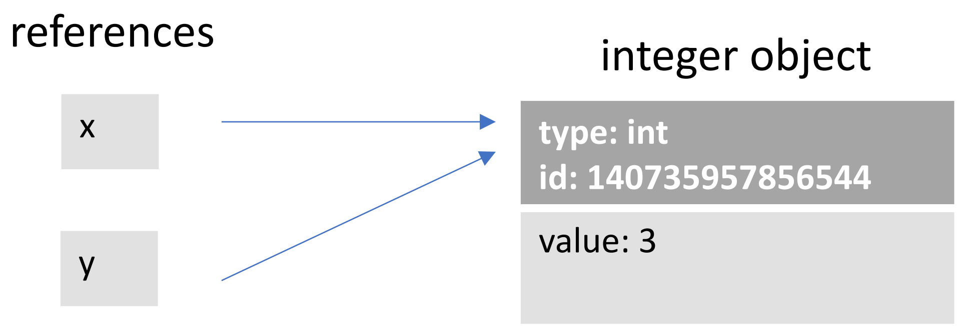
Example of an integer object

type: int
id: 140735957856544

value: 3

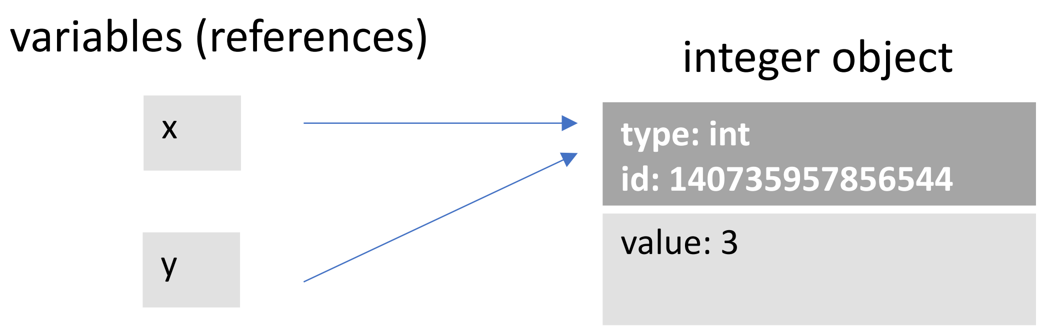
Python data types

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



Python data types

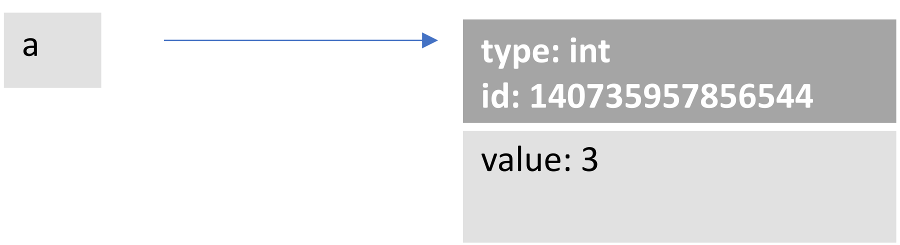
- In Python
  - **Variable** = **reference** to an object
- When you **assign** an object to a variable it becomes a **reference** to that object



Python data types

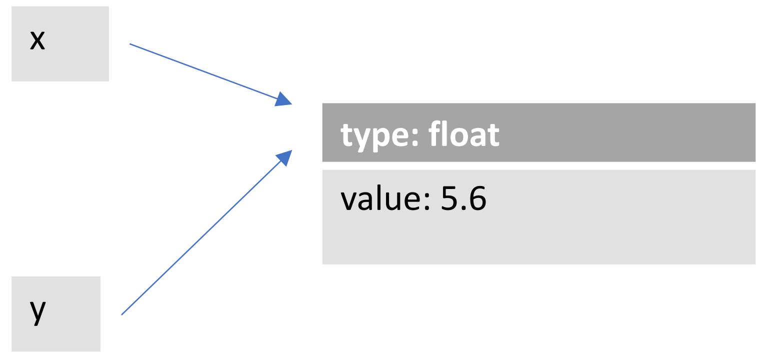
- **Defining a variable**
  - **No need** to specify its data type
  - **Just assign** a value to a new variable name

```
a = 3
```



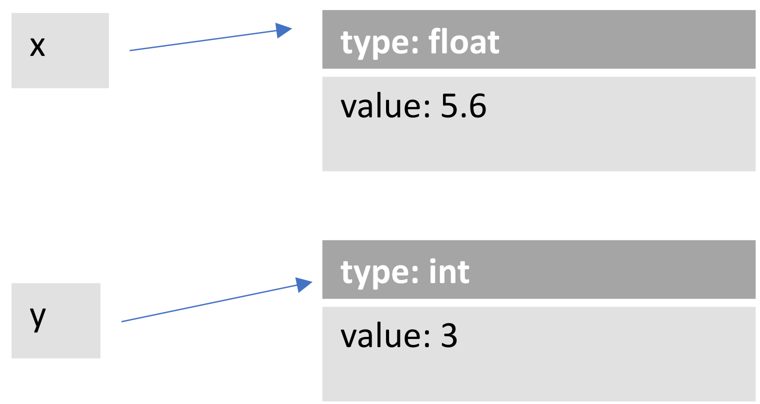
- Example

```
x = 5.6

y = x
```



- If you assign y to a new value…

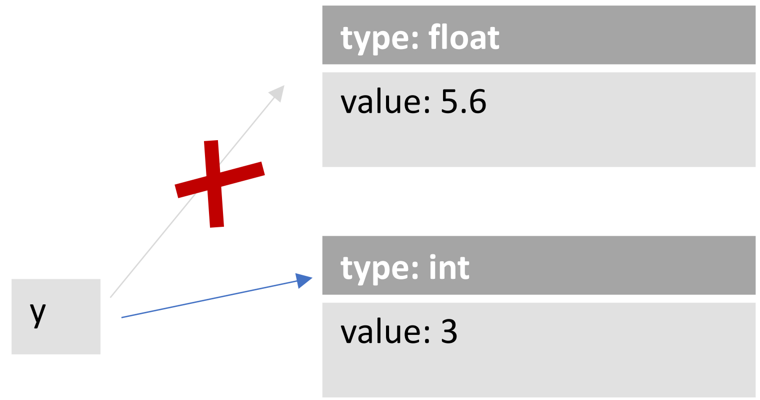
```
y = 3
```



Python data types

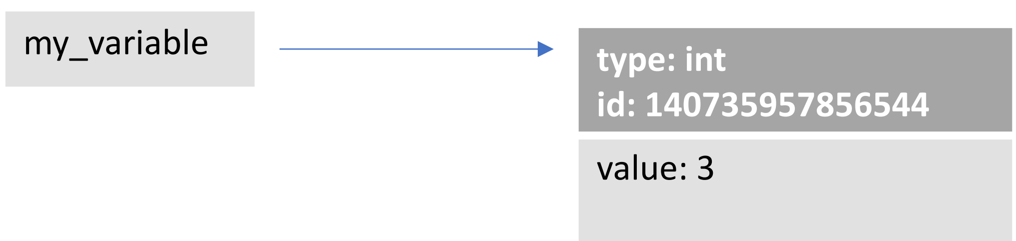
- From the previous example we learn that:
  - Basic data types, such as integer and float variables are **immutable**:
    - Assigning a new number will not change the value inside the object by rather create a new one

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



Python data types

- 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]:

```python
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 (sequences)**
  - *tuple* (**immutable** list of objects)
  - *list, set, dict* (**mutable** collections of objects)

Python data types

- **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]:
```
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(0)                   # r6 = False
```

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

Python data types

- **Working with strings**
  - **len:** get string length
  - **strip:** remove leading and trailing spaces (tabs or newlines)
  - **upper/lower**: convert uppercase/lowercase

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 '
```

Python data types

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


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

- **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]:

```
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}**"
  - Alternative:
    - "My float is **{}** and my int is **{}**".format(**var1**, **var2**)

- **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]:
```
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)

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

In [1]:

```
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
```

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

In [1]:
```python
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]:

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

Out[1]:

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

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

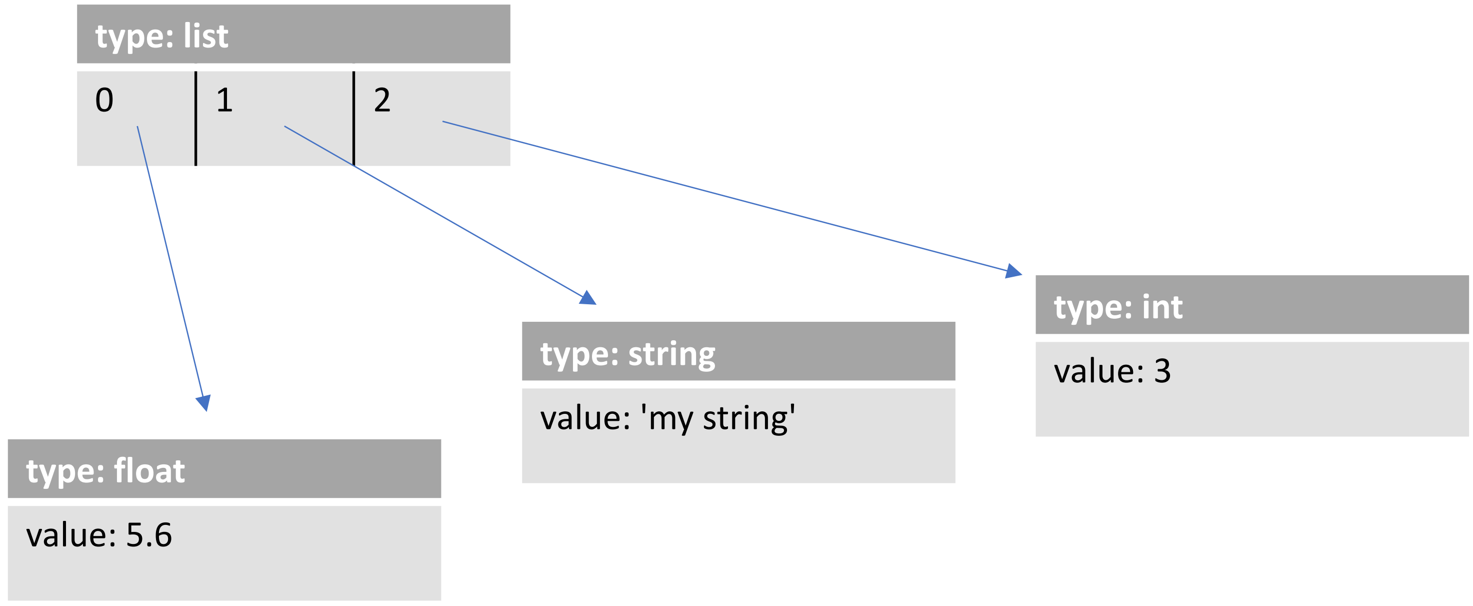
In [1]:

```
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



Python data types

- **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
```

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

In [1]:
```
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
    - list1.insert(index, element):
      - Insert element at position
    - list1.pop(index):
      - Remove element by position
    - list.index(element):
      - Returns position of *first* occurrence of element

- **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]
```

Python data types

- **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

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

- **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}
```

- **Set**
  - **Operators between two sets**
    - | (union), & (intersection), - (difference)
    - <, <= ((proper) subset), >, >= ((proper) superset)

In [1]:
```
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]:
```python
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

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

  - **Iterate** over set elements

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

Python data types

- **"in" operator**
  - **Check** whether element belongs to a set

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

  - **Iterate** over set elements

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

Note

Sets are <u>unordered</u> – the order during iterations is not well-defined

```
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]
```

Python data types

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

  - **Definition:**

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

- **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]
```

- **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}
```

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

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

- **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]:

```python
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

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)
Limitations 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

- **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
```

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

parameters

function name

return value

invocation

In [1]:
```python
def euclidean_distance(x, y):
    dist = 0
    for x_el, y_el in zip(x, y):
        dist += (x_el-y_el)**2
    return math.sqrt(dist) # alternatively, 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]:

```
def 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
```

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
                        in the global scope
    return x + y + z
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]:

```
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
```

Uncovered Topics

Formatting strings: older versions

PoliTo DBMG

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

values to be replaced

float placeholder

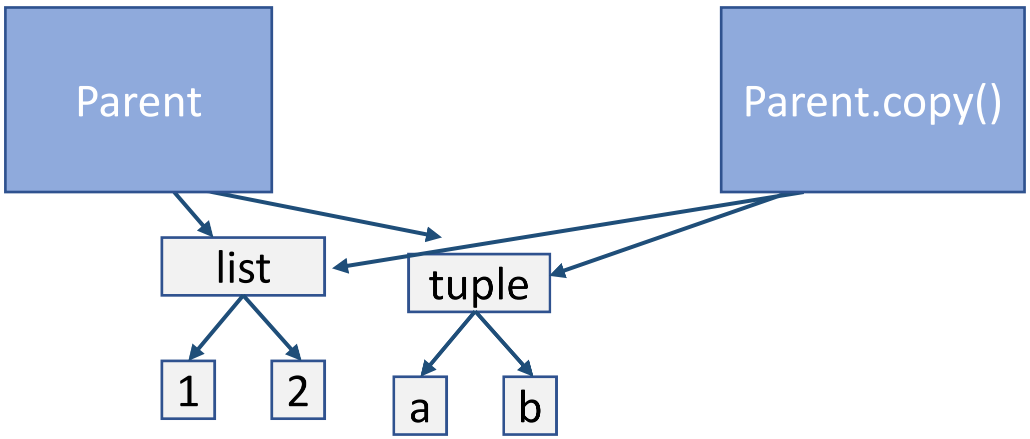
int placeholder

My float is	17.5	and my int is	5

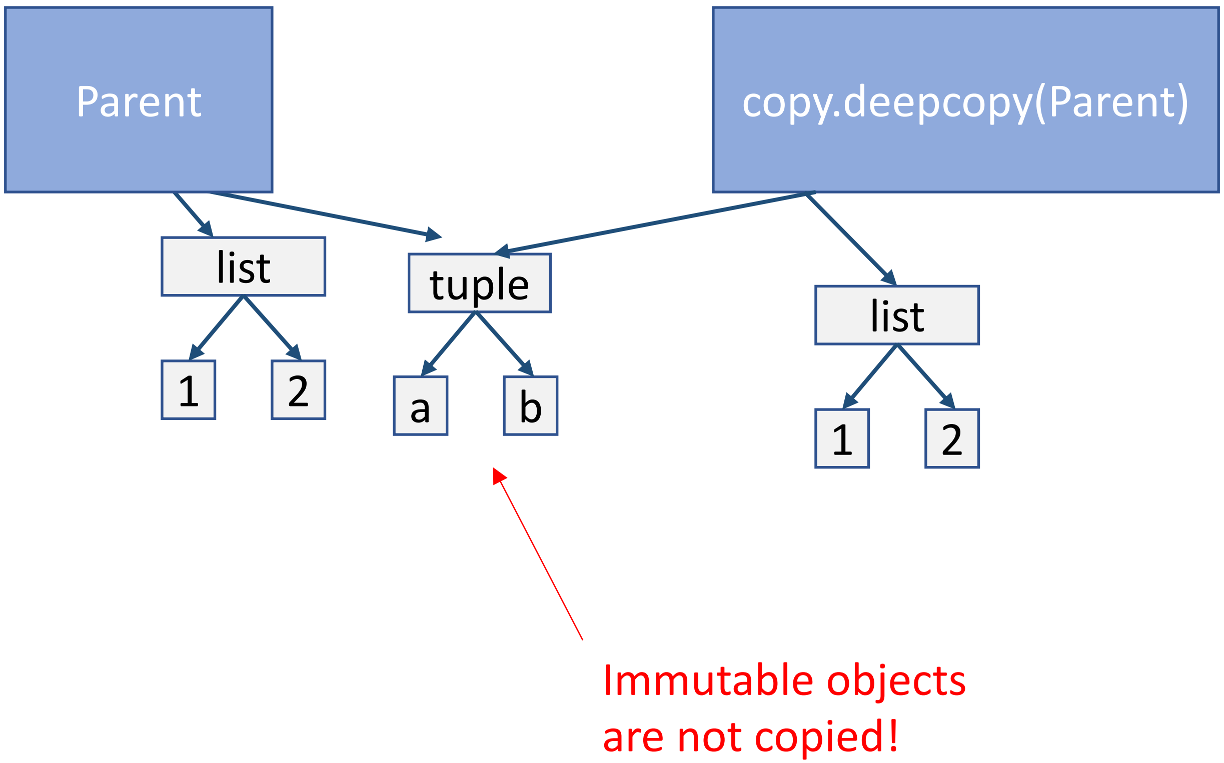
- "My float is {0} and my int is {1}".format(17.5, 5)

index of variable that
will replace the braces

- **Shallow vs deep copy**
  - Shallow: copies the parent object, shares references to children



- **Shallow vs deep copy**
  - 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]}
```

- **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]}
```

Lambda functions

- Functions that can be defined **inline** and **without a name**
- Example of lambda function definition:

input parameter(s)   return value

In [1]:
```python
squared = lambda x: x**2
print(squared(5))
```

Out [1]:
```
25
```

- **These patterns are useful shortcuts...**
  - Example: **filter** negative numbers from a list:

In [1]:

```
numbers = [1, -8, 5, -2, 5]
negative = []
for x in numbers:
    if x < 0:
        negative.append(x)
```

  - This code can be completely rewritten with lambda functions…

Filter and map patterns

- Both apply a function element-wise to the elements of a list (iterable)
- **Filter** the elements of a list based on a condition
- **Map** each element of a list with a new value

In [1]:

```
numbers = [1, -8, 5, -2, 5]
negative = list(filter(lambda x: x<0, numbers))
squared = list(map(lambda x: x**2, negative))
print(negative)
print(squared)
```

Out [1]:

```
[-8, -2]
[64, 4]
```

- **Lambda functions and conditions**
  - Example **conditional mapping**:

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

Out [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}]
```

- 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

- 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']
```

List comprehensions

- Allow specifying **conditions** on elements
  - Example: **square positive** numbers in a list
    - **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]
```

- Example: euclidean distance

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

↓

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

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 [1]: { v ** 2 for v in [ 4, 3, 2, -2, 1 ] }
Out[1]: {1, 4, 9, 16}
```

List comprehensions

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

Classes

- 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

- Simple class example:

In [1]:

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

triangle1 = Triangle()     ← class instantiation
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

self is a reference to the current object

initialize attributes

invoke constructor and instantiate a new Triangle

- 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]:

```python
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
```

Exception handling

- To track errors during program execution

In [1]:

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

In [2]:

can specify exception type

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

Exception handling

- 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()
```

Exception handling

- 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)