

ILP 2022 – W4S3

Numpy library (part 1) and imports

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Outline (Week4, Session3 – W4S3)

- Memory management and lists: aliasing, shallow and deep copies
- The Numpy library (part 1): arrays, math functions, etc.
- About the import procedure
- Project organizing
- Mini-project

Memory of a computer

- The memory of a computer consists of several “boxes”, which can contain values for variables. Each “box” is identified by an **integer**, which corresponds to the **address/ID** of the “box”.

Identifier	Memory	
	Address	Value
x1	140725454247872	10

Memory of a computer

- The memory of a computer consists of several “boxes”, which can contain values for variables. Each “box” is identified by an **integer**, which corresponds to the **address/ID** of the “box”.
- When a variable is created:
 - A “box” is assigned for the variable and its value is stored in the “box”.
 - The variable name simply refers to the address/ID of the “box”.

Identifier	Memory	
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x1	140725454247872	10

Memory of a computer

- The memory of a computer consists of several “boxes”, which can contain values for variables. Each “box” is identified by an **integer**, which corresponds to the **address/ID** of the “box”.
- When a variable is created:
 - A “box” is assigned for the variable and its value is stored in the “box”.
 - The variable name simply refers to the address/ID of the “box”.

Identifier	Memory	
	Address	Value
x1	140725454247872	10


```
1 x1 = 10
2 print(x1)
3 print(id(x1))
```

```
10
140725454247872
```

Recall: the `id()` function

- The `id()` function returns an integer, which corresponds to the **address/ID**, where the variable is stored in memory.

```
1 x1 = 10
2 print(x1)
3 print(id(x1))
```

```
10
140725454247872
```

```
1 x2 = 17
2 print(x2)
3 print(id(x2))
```

```
17
140725454248096
```

Recall: the `id()` function

- The `id()` function returns an integer, which corresponds to the **address/ID**, where the variable is stored in memory.
- Two variables names with identical values will have the same `id()`.

```
1 x1 = 10
2 print(x1)
3 print(id(x1))
```

```
10
140725454247872
```

```
1 x2 = 17
2 print(x2)
3 print(id(x2))
```

```
17
140725454248096
```

```
1 x3 = x1
2 print(x3)
3 print(id(x3))
4 print(id(x1))
```

```
10
140725454247872
140725454247872
```

Recall: the `id()` function

- The `id()` function returns an integer, which corresponds to the **address/ID**, where the variable is stored in memory.
- Two variables names with identical values will have the same `id()`.
- **Aliasing:** Python saves memory space by having two variables names **point to the same memory ID**.

Identifier	Memory	
	Address	Value
x1, x3	140725454247872	10


```
1 x3 = x1
2 print(x3)
3 print(id(x3))
4 print(id(x1))
```

```
10
140725454247872
140725454247872
```


Recall: the `id()` function

- The `id()` function returns an integer, which corresponds to the **address/ID**, where the variable is stored in memory.
- Two variables names with identical values will have the same `id()`.
- **Aliasing:** Python saves memory space by having two variables names **point to the same memory ID**.

Identifier	Memory	
	Address	Value
x3 →	140725454247872	10
x1 →	140725454247936	12

```
1 x1 = 12
2 print(x1)
3 print(x3)
4 print(id(x1))
5 print(id(x3))
```

12

10

140725454247936

140725454247872

Memory management in lists

- A **list** is a collection of variables.

```
1 list1 = [x1, x2, x3]
2 print(list1)
3 print(id(list1))
```

[12, 17, 10]

1769354632448

```
1 print(id(list1))
2 print("-")
3 print(id(list1[0]))
4 print(id(x1))
5 print("-")
6 print(id(list1[1]))
7 print(id(x2))
8 print("-")
9 print(id(list1[2]))
10 print(id(x3))
```

1769354632448

-

140725454247936

140725454247936

-

140725454248096

140725454248096

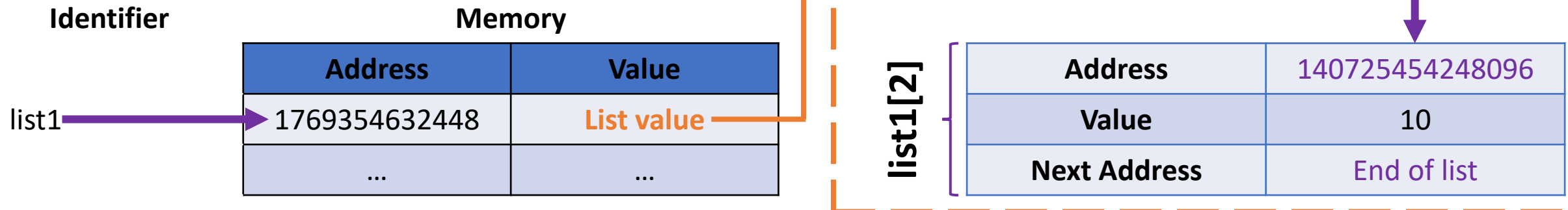
-

140725454247872

140725454247872

Memory management in lists

- A **list** is a collection of variables. The variables in a list are **chained** together.



Memory management in lists

- A **list** is a collection of variables. The variables in a list are **chained** together.
- If x1 is changed, Python will adjust so that the list remains unaffected.
- It simply reallocates x1 to another location in memory.

```
1 print(x1)
2 print(id(x1))
3 x1 = "Hello"
4 print(id(x1))
5 print(list1)
```

```
12
140726382041088
2120755150000
[12, 17, 10]
```

Aliasing in lists: problem

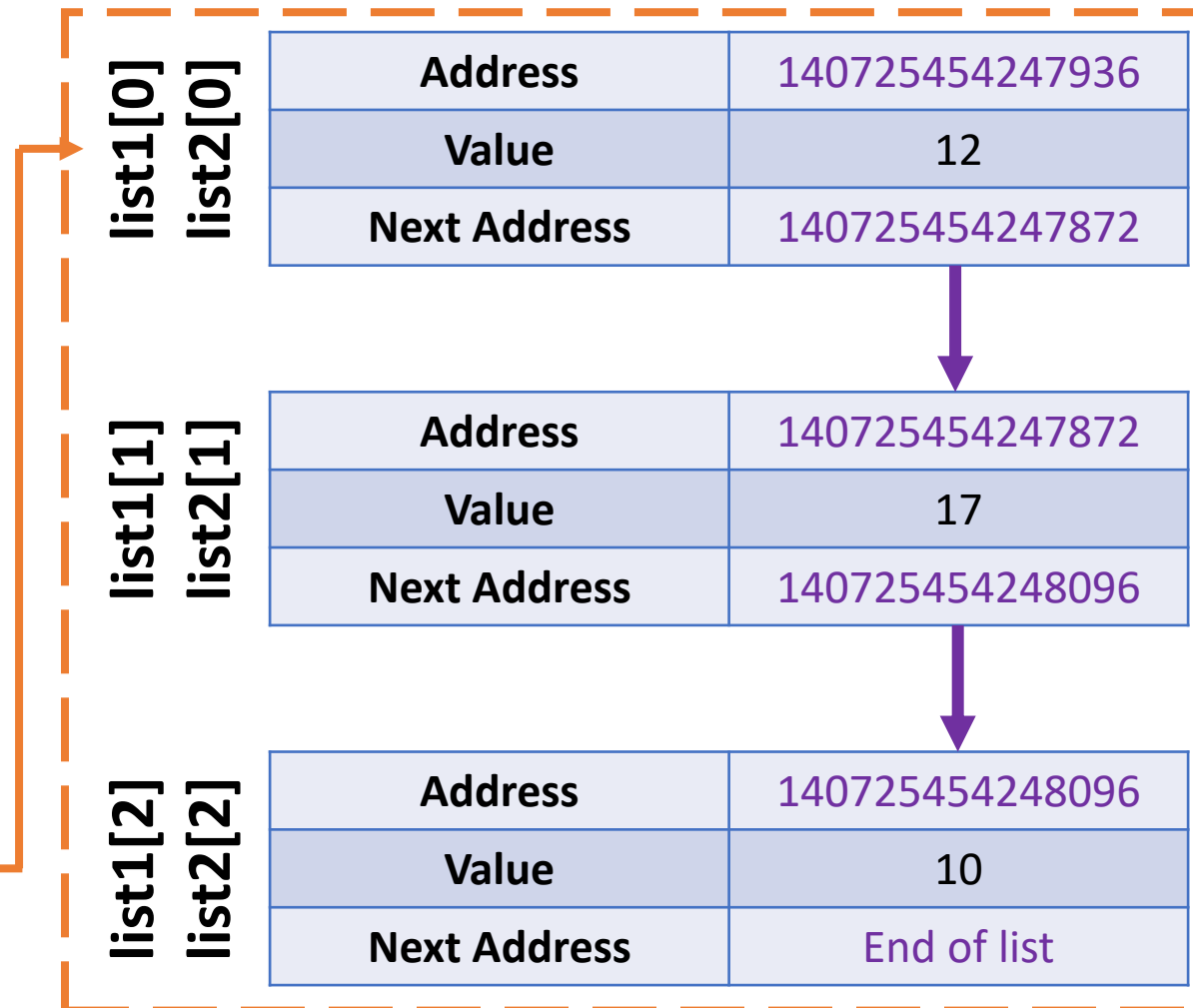
- A **list** is a collection of variables. The variables in a list are **chained** together.
- **Aliasing:** We can assign a list to another variable name.

```
1 list2 = list1
2 print(list2)
3 print(id(list1))
4 print(id(list2))
```

```
[12, 17, 10]
1983742564288
1983742564288
```

Aliasing in lists: problem

- A **list** is a collection of variables. The variables in a list are **chained** together.
- **Aliasing:** We can assign a list to another variable name.



Aliasing in lists: problem

- A **list** is a collection of variables. The variables in a list are **chained** together.
- **Aliasing:** We can assign a list to another variable name.
- **Problem:** changing `list1[0]` changes `list1` values, but also changes `list2`.

```
1 print(id(list1[0]))
2 list1[0] = "SUTD"
3 print(list1)
4 print(id(list1[0]))
```

```
140726382041088
['SUTD', 17, 10]
2120755353584
```

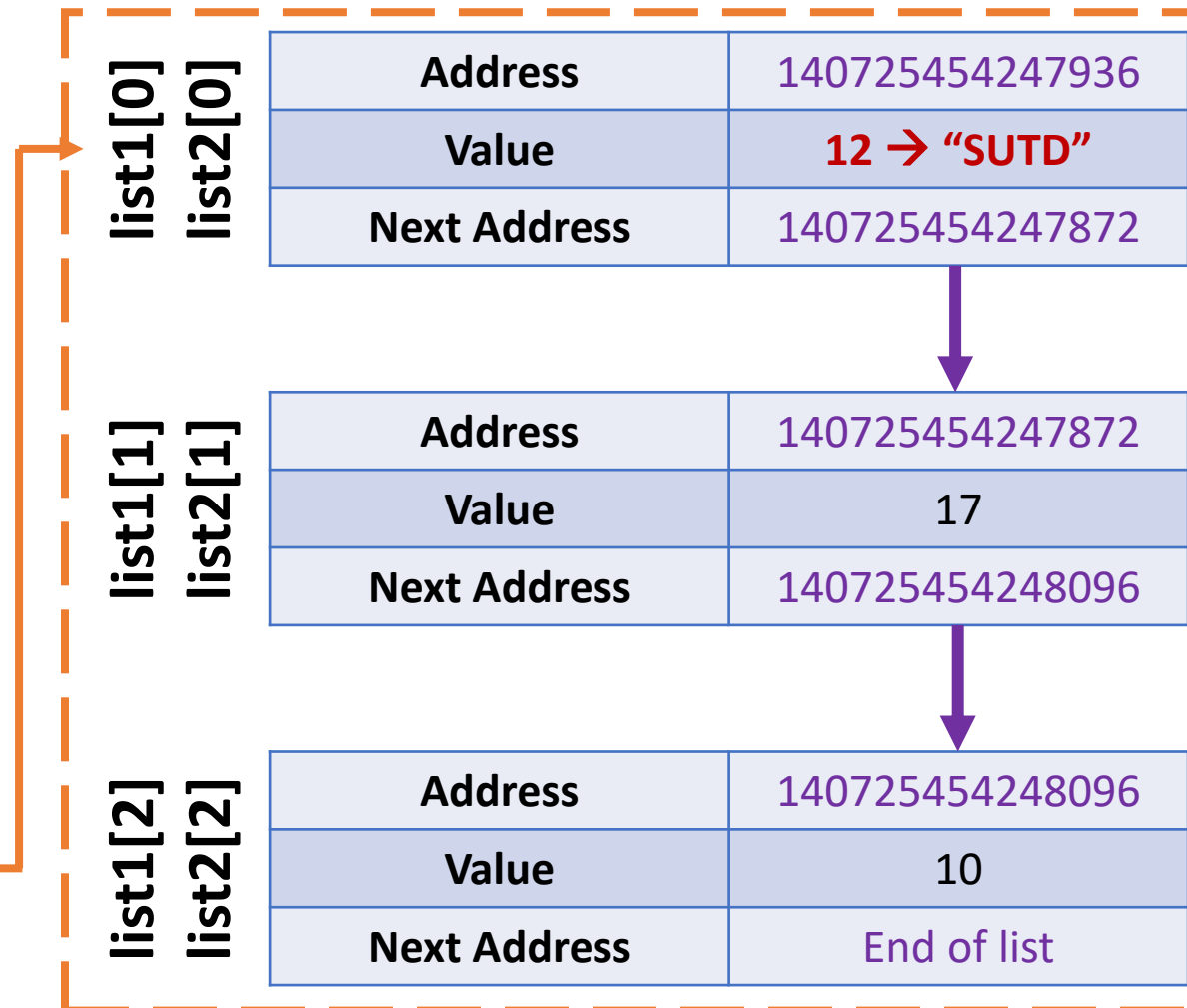
```
1 print(list2)
2 print(id(list2[0]))
```

```
['SUTD', 17, 10]
2120755353584
```

Aliasing in lists: problem

- A **list** is a collection of variables. The variables in a list are **chained** together.
- **Aliasing:** We can assign a list to another variable name.
- **Problem:** changing list1[0] changes list1 values, but also changes list2.

Identifier	Memory	
	Address	Value
list1, list2	1769354632448	List value



Shallow copy of a list

- **Problem:** changing `list1[0]` changes `list1` values, but also changes `list2`.
- **Shallow copy:** `list1[:]` makes `list2` a shallow copy of `list1`. By doing so, `list2` will be saved to its own location of memory.

```
1 list1 = [12, 17, 10]
2 list2 = list1[:]
3 print(list1)
4 print(list2)
5 print(id(list1))
6 print(id(list2))
```

[12, 17, 10]

[12, 17, 10]

2120755431296

2120755345920

Shallow copy of a list

- **Problem:** changing `list1[0]` changes `list1` values, but also changes `list2`.
- **Shallow copy:** `list1[:]` makes `list2` a shallow copy of `list1`. By doing so, `list2` will be saved to its own location of memory.
- Changing a value in `list1`, with `list1[index] = ...`, no longer affects `list2`.
- **Note:** you can also use the `copy()` method.

```
1 list1 = [12, 17, 10]
2 list2 = list1[:]
3 print(list1)
4 print(list2)
5 print(id(list1))
6 print(id(list2))
```

```
[12, 17, 10]
[12, 17, 10]
2120755431296
2120755345920
```

```
1 list1[0] = "SUTD"
2 print(list1)
3 print(list2)
```

```
['SUTD', 17, 10]
[12, 17, 10]
```

Shallow copy: problem

- **Note:** if an element of a list is a list (case of lists of lists), then the shallow copy will not copy the sublists to different locations of memory.
- **Problem:** changing a sublist element then affects both lists, even though these lists are shallow copies of each other.

```
1 list1 = [[8, 9, 11], 7, 4]
2 list2 = list1[:]
3 print(list1)
4 print(list2)
5 print(id(list1))
6 print(id(list2))
7 print(id(list1[0][1]))
8 print(id(list2[0][1]))
```

```
[[8, 9, 11], 7, 4]
[[8, 9, 11], 7, 4]
2120755333248
2120755332928
140726382040992
140726382040992
```

```
1 list1[0][1] = "Damn it!"
2 print(list1)
3 print(list2)
```

```
[[8, 'Damn it!', 11], 7, 4]
[[8, 'Damn it!', 11], 7, 4]
```

Deep copy

- **Solution:** make a **deep copy**, using the Python built-in **copy** library.
- A deep copy forces Python to make sure **all elements and sub-elements** are assigned to different locations in memory.

```
1 from copy import deepcopy
```

```
1 list1 = [[8, 9, 11], 7, 4]
2 list2 = deepcopy(list1)
3 print(list1)
4 print(list2)
5 print(id(list1[0]))
6 print(id(list2[0]))
```

```
[[8, 9, 11], 7, 4]
[[8, 9, 11], 7, 4]
2120754851072
2120754850304
```

```
1 list1[0][1] = "Deep copy works?"
2 print(list1)
3 print(list2)
4 print(id(list1[0][1]))
5 print(id(list2[0][1]))
```

```
[[8, 'Deep copy works?', 11], 7, 4]
[[8, 9, 11], 7, 4]
2120755409424
140726382040992
```

Matt's Great advice #10

Matt's Great Advice #10: Keep the aliasing, shallow and deep copies concepts in mind for now.

If you find that modifying a list object ends up unexpectedly changing another, then you might have an aliasing or shallow copy problem.

When in doubt, make a deep copy.

For now, do not worry about understanding all these memory concepts, these will be covered in another advanced course!



About the numpy library

- **Numpy** is one of the most common (if not the most popular) **libraries** in Python.
- Used for many applications: computing, modelling, data science, astrophysics, etc.
- **Linear algebra** (one of the main concepts of math with many applications in computing)



FIRST IMAGE OF A BLACK HOLE



How NumPy, together with libraries like SciPy and Matplotlib that depend on NumPy, enabled the Event Horizon Telescope to produce the first ever image of a black hole

A new type of objects: Numpy Arrays

- **Numpy arrays** are objects from the **Numpy** library.
 - Typically used to describe **matrices** and **vectors**,
 - Or **tables** of data.
- They look very similar to (**nested lists of**) **lists**, which we have used earlier for many applications.
- The Numpy library, however, comes with many additional functions and methods.

```
1 import numpy as np
```

```
1 array1 = np.array([0, 2, 1, 4])  
2 print(array1)
```

```
[0 2 1 4]
```

```
1 print(array1)  
2 print(type(array1))  
3 array1_as_list = list(array1)  
4 print(array1_as_list)  
5 print(type(array1_as_list))
```

```
[0 2 1 4]  
<class 'numpy.ndarray'>  
[0, 2, 1, 4]  
<class 'list'>
```

Length, size, shape

- Just like lists, the Numpy arrays have a length, which can be checked with `len()`.
- They also have a **shape** and a **size attribute**, which give additional information, in the case of arrays with more than 1D.
- **Attribute:** “sub-variable” of an object; applies to an object using the `.` operator. (Object-oriented concept, not covered yet)

```
1 array1 = np.array([0, 2, 1, 4])
2 print(len(array1))
3 print(array1.shape)
4 print(array1.size)
```

```
4
(4,)
4
```

```
1 two_d_array = np.array([[1, 2], [3, 4]])
2 print(two_d_array)
3 print(len(two_d_array))
4 print(two_d_array.shape)
5 print(two_d_array.size)
```

```
[[1 2]
 [3 4]]
2
(2, 2)
4
```


Indexing an array

- Just like lists, the Numpy arrays are indexed and their element can be accessed with `[]`.
- You can equivalently use the `[i,j]` and `[i][j]` notations on arrays.
- Replacing an index with a colon symbol `:`, means “take all”.
- For instance, `[:, j]` means **all elements in column j**, whereas `[i, :]` means **all elements in row i**.

```
1 array1 = np.array([0, 2, 1, 4])
2 print(array1)
3 print(array1[0])
4 print(array1[1])
```

```
[0 2 1 4]
```

```
0
```

```
2
```

```
1 two_d_array = np.array([[1,2],[3,4]])
2 print(two_d_array)
3 print(two_d_array[0])
4 print(two_d_array[0][1])
```

```
[[1 2]
```

```
 [3 4]]
```

```
[1 2]
```

```
2
```

```
1 print(two_d_array[0,1])
2 print(two_d_array[:,1])
3 print(two_d_array[0,:])
```

```
2
```

```
[2 4]
```

```
[1 2]
```

Traversing an array with **for**

- As with **lists**, we can traverse a Numpy array, in an element-wise manner, using a **for** loop.

```
1 array1 = np.array([0, 2, 1, 4])
2 print(array1)
3 for element in array1:
4     print(element)
```

[0 2 1 4]

0

2

1

4

```
1 my_list = [1, 4, 9, 14, 15]
2 print(my_list)
```

[1, 4, 9, 14, 15]

```
1 # Element-wise
2 for element in my_list:
3     print("--")
4     print(element)
```

--

1

--

4

--

9

--

14

--

15

The + operator on arrays

- **The + operator on lists:** On lists, the + operator will concatenate both lists into a new one.

```
1 a_list = [0, 1, 2]
2 another_list = [1, 4, 7]
3 list_sum = a_list + another_list
4 print(list_sum)
```

```
[0, 1, 2, 1, 4, 7]
```

The + operator on arrays

- **The + operator on lists:** On lists, the + operator will concatenate both lists into a new one.
- **The + operator on Numpy arrays – (vector sum):** On Numpy arrays, however, the + operator will sum the elements of both Numpy arrays.

```
1 a_list = [0, 1, 2]
2 another_list = [1, 4, 7]
3 list_sum = a_list + another_list
4 print(list_sum)
```

```
[0, 1, 2, 1, 4, 7]
```

```
1 array1 = np.array([0, 2, 1, 4])
2 array2 = np.array([1, 2, 3, 5])
3 print(array1)
4 print(array2)
5 sum_array = array1 + array2
6 print(sum_array)
```

```
[0 2 1 4]
```

```
[1 2 3 5]
```

```
[1 4 4 9]
```

The + operator on arrays

- **The + operator on lists:** On lists, the + operator will concatenate both lists into a new one.
- **The + operator on Numpy arrays – (vector sum):** On Numpy arrays, however, the + operator will sum the elements of both Numpy arrays.
- **Broadcasting:** If summed with a number instead, the elements in the Numpy array will each be incremented by the given value.

```
1 a_list = [0, 1, 2]
2 another_list = [1, 4, 7]
3 list_sum = a_list + another_list
4 print(list_sum)
```

```
[0, 1, 2, 1, 4, 7]
```

```
1 array1 = np.array([0, 2, 1, 4])
2 array2 = np.array([1, 2, 3, 5])
3 print(array1)
4 print(array2)
5 sum_array = array1 + array2
6 print(sum_array)
```

```
[0 2 1 4]
```

```
[1 2 3 5]
```

```
[1 4 4 9]
```

```
1 array1 = np.array([0, 2, 1, 4])
2 number = 7
3 print(array1)
4 sum_array = array1 + number
5 print(sum_array)
```

```
[0 2 1 4]
```

```
[ 7  9  8 11]
```

Concatenation on arrays

- Since the **+** operator cannot be used for **concatenation**, Numpy comes with a **concatenate()** function.

```
1 print(array1)
2 print(array2)
3 conc_array = np.concatenate([array1, array2])
4 print(conc_array)
```

```
[0 2 1 4]
```

```
[1 2 3 5]
```

```
[0 2 1 4 1 2 3 5]
```

The `*` operator on arrays

- The `*` operator behaves as the `+` operator on Numpy arrays.
- It consists of an **element-wise multiplication** of the elements in arrays.
- **Broadcasting:** if a Numpy array is multiplied by a number, the number will multiply each element in the array.

```
1 array1 = np.array([0, 2, 1, 4])
2 array2 = np.array([1, 2, 3, 5])
3 print(array1)
4 print(array2)
5 mult_arrays = array1*array2
6 print(mult_arrays)
```

```
[0 2 1 4]
[1 2 3 5]
[ 0  4  3 20]
```

```
1 n = 4
2 mult_array_int = array1*n
3 print(mult_array_int)
```

```
[ 0  8  4 16]
```

Additional functions

Additional Numpy functions

- **Min, max:** returns the minimal, resp. maximal, values in array.
- **Argmin, argmax:** returns the index where the minimal, resp. maximal, values are.
- **Mean, median:** returns the mean, resp. median, value for a given array.
- **Sum:** sums all the elements in the array together

```
1 array1 = np.array([0, 2, 1, 4, 7])
2 print(array1)
3 min_val = np.min(array1)
4 print(min_val)
5 argmin_val = np.argmin(array1)
6 print(argmin_val)
7 max_val = np.max(array1)
8 print(max_val)
9 argmax_val = np.argmax(array1)
10 print(argmax_val)
11 mean_val = np.mean(array1)
12 print(mean_val)
13 median_val = np.median(array1)
14 print(median_val)
15 summed_val = np.sum(array1)
16 print(summed_val)
```

[0 2 1 4 7]

0

0

7

4

2.8

2.0

14

Mathematical functions and constants

Numpy also contains

- Many **mathematical functions** (cosine, sine, logarithm, exponential, etc.)
- And many **mathematical constants** (pi, etc.)

```
1 print(np.cos(0))
2 print(np.sin(0))
3 print(np.pi)
4 print(np.log(1))
5 print(np.exp(0))
```

1.0

0.0

3.141592653589793

0.0

1.0

Aliasing, Shallow and Deep copies in arrays

- As with lists, Numpy arrays are subject to the same issues about aliasing, shallow and deep copies.
- If needed, use deep copies of the arrays.

```
1 two_d_array1 = np.array([[1,2],[3,4]])
2 two_d_array2 = two_d_array1
3 print(two_d_array1)
4 print(two_d_array2)
5 print(id(two_d_array1))
6 print(id(two_d_array2))
```

```
[[1 2]
 [3 4]]
[[1 2]
 [3 4]]
1750029422960
1750029422960
```

```
1 two_d_array1[0][0] = 17
2 print(two_d_array1)
3 print(two_d_array2)
```

```
[[17  2]
 [ 3  4]]
[[17  2]
 [ 3  4]]
```

And so much more! RTFM!

- Numpy has **many more functions and tools** to offer!
- **Random functions** (to be covered in an upcoming session, if time allows?)
- Learn more about Numpy (RTFM!) here:

<https://numpy.org/doc/stable/>

```
1  # Numpy.random.choice() mimics a dice roll
2  dice_roll = np.random.choice([1, 2, 3, 4, 5, 6])
3  print(dice_roll)
4  dice_roll = np.random.choice([1, 2, 3, 4, 5, 6])
5  print(dice_roll)
6  dice_roll = np.random.choice([1, 2, 3, 4, 5, 6])
7  print(dice_roll)
8  dice_roll = np.random.choice([1, 2, 3, 4, 5, 6])
9  print(dice_roll)
10 dice_roll = np.random.choice([1, 2, 3, 4, 5, 6])
11 print(dice_roll)
12 dice_roll = np.random.choice([1, 2, 3, 4, 5, 6])
13 print(dice_roll)
```

4
6
1
4
3
2

Activity 1 - Exam adjustments

- Let us assume, that I have **grades** from my students listed in some **np.array** variables, as shown below.

```
columns_labels_list = ["MidTerm Score", "FinalExam Score", "Average Score"]
students_list = ["Chris", "Oka", "Norman", "Natalie", "Tony"]
grades_table = np.array([[60, 80, 70], \ # Chris scored 60% on MidTerm, 80% on Finals, Average is 70%
                        [50, 80, 65], \
                        [40, 70, 55], \
                        [60, 70, 65], \
                        [60, 90, 75]])

print(grades_table)
```

```
[[60 80 70]
 [50 80 65]
 [40 70 55]
 [60 70 65]
 [60 90 75]]
```

Activity 1 - Exam adjustments

- Let us assume, that I have **grades** from my students listed in a **np.array**.
- The first line contains the column labels (student name, some scores) and the other lines will consist of entries regarding some of the students.
- Let us assume that, as a professor, I have decided to be lenient towards my students.
- I realized that the midterm was a bit too difficult compared to last year.
- To compensate for that, I would like to increase the scores of all students on the midterm by 50%.

Activity 1 - Exam adjustments

Write a function

grade_adjustment(),

- which **receives** a grades table, **grades_table**,
- **increases** the **scores** of all students on the **midterm** by **50%**,
- **re-calculates** the **average score**, with the **new adjusted midterm score**,
- and then returns the **updated grades table** as its sole output.

Activity 1 - Exam adjustments

Write a function

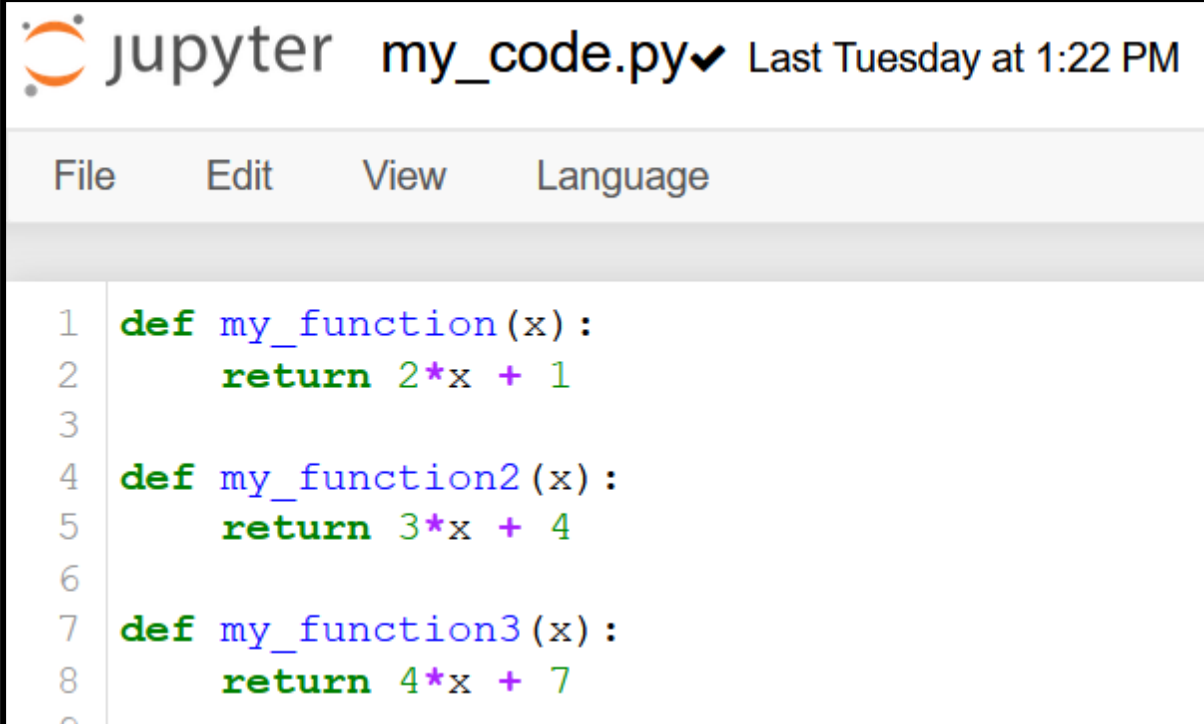
grade_adjustment(),

- which **receives** a grades table, **grades_table**,
- **increases** the **scores** of all students on the **midterm** by **50%**,
- **re-calculates** the **average score**, with the **new adjusted midterm score**,
- and then returns the **updated grades table** as its sole output.

- **Important note:** The **maximal score** for the midterm exam is **capped to 100**. This means that a student which scores 80 points on the midterm, will not obtain 120 points after the adjustment, but only 100.

The **import** procedure

- The import procedure is used to **import functions defined in external .py files.**

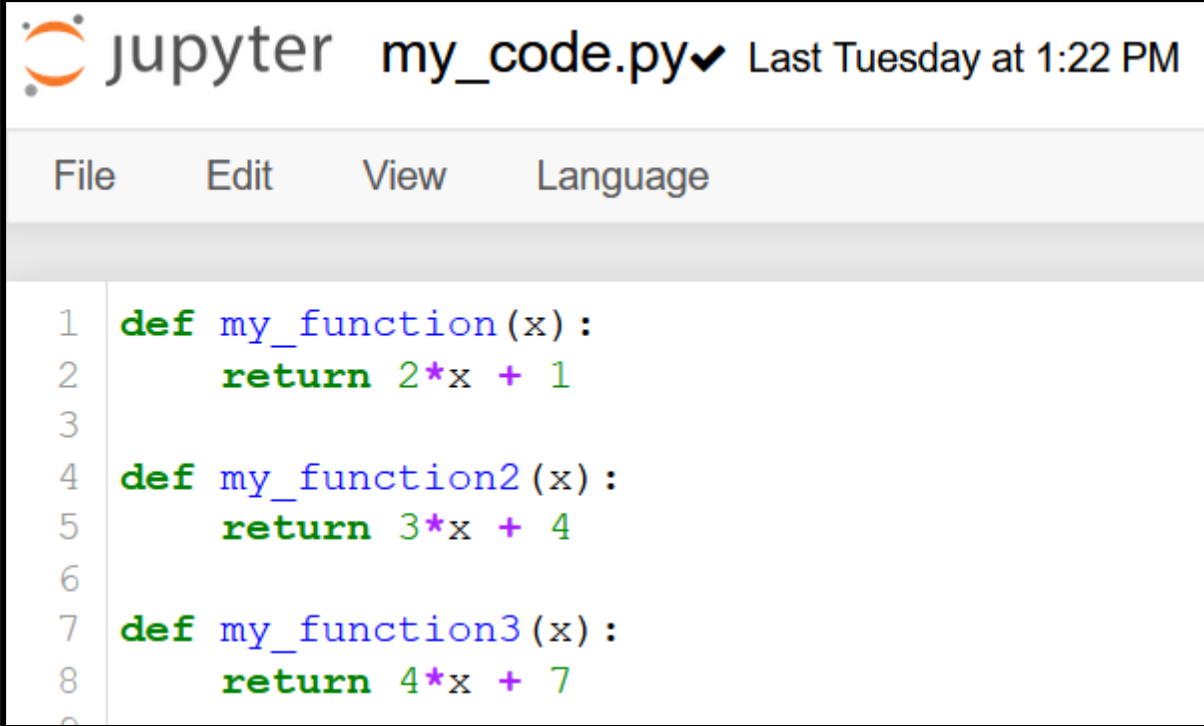


```
jupyter my_code.py✓ Last Tuesday at 1:22 PM
File Edit View Language

1 def my_function(x):
2     return 2*x + 1
3
4 def my_function2(x):
5     return 3*x + 4
6
7 def my_function3(x):
8     return 4*x + 7
9
```


The **import** procedure

- The import procedure is used to **import functions defined in external .py files.**
- To demonstrate, we have defined a **my_code.py** file with three functions.



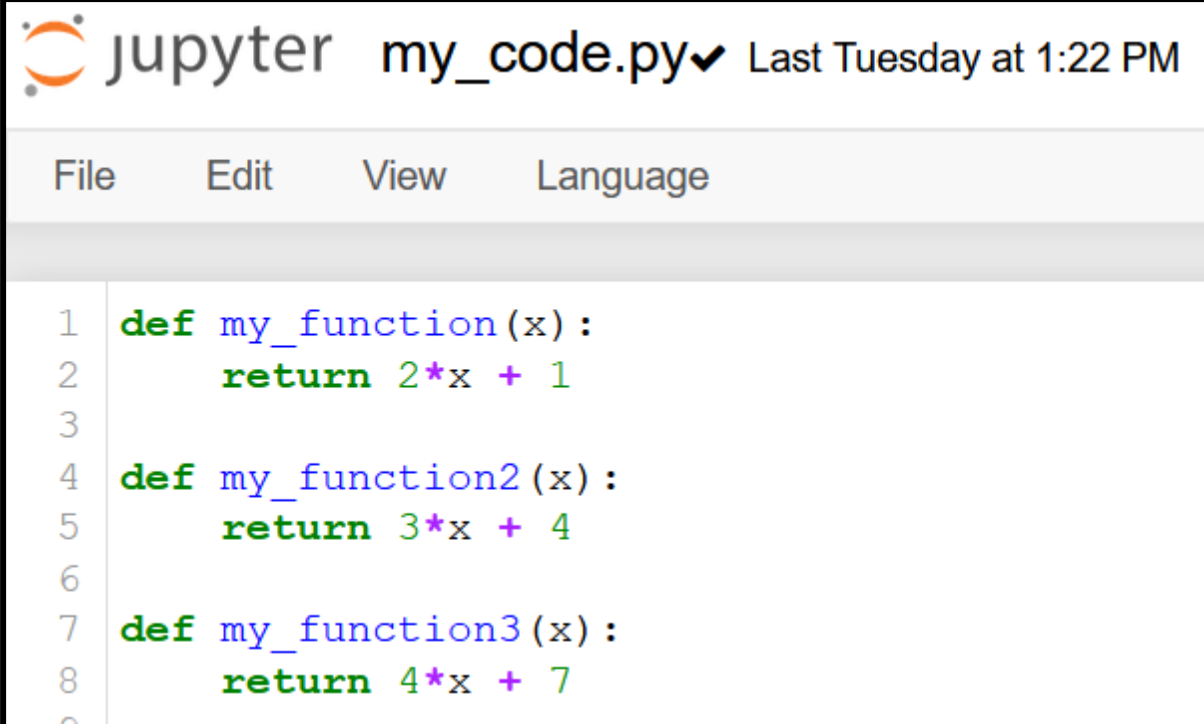
```
jupyter my_code.py ✓ Last Tuesday at 1:22 PM
File Edit View Language

1 def my_function(x):
2     return 2*x + 1
3
4 def my_function2(x):
5     return 3*x + 4
6
7 def my_function3(x):
8     return 4*x + 7
9
```

my_code.py file

The **import** procedure

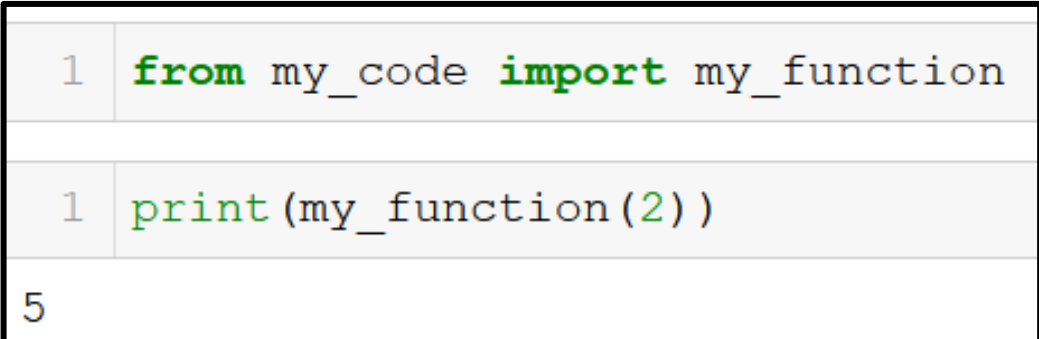
- The import procedure is used to **import functions defined in external .py files**.
- To demonstrate, we have defined a **my_code.py** file with three functions.
- We can then import one of these functions in our Notebook, by using the **from ... import ...** command.



```
jupyter my_code.py ✓ Last Tuesday at 1:22 PM
File Edit View Language

1 def my_function(x):
2     return 2*x + 1
3
4 def my_function2(x):
5     return 3*x + 4
6
7 def my_function3(x):
8     return 4*x + 7
9
```

In our notebook

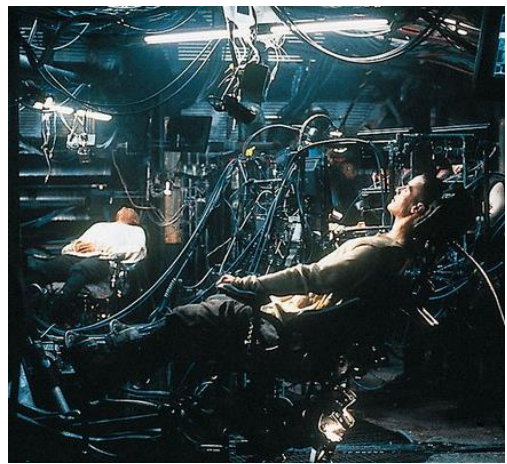


```
1 from my_code import my_function

1 print(my_function(2))

5
```

The **import** procedure



Operator:
“Cosine
function
coming
right up!”



1	<code>print(cos(0))</code>
---	----------------------------



Importing **as**

- If needed, we can **import** and **rename** a function by using the **as** keyword.
- The whole command then reads **from ... import ... as ...**
- **Note:** if you rename the function, its calling name changes to the alias you specified.

my_code.py file

```
jupyter my_code.py ✓ Last Tuesday at 1:22 PM
File Edit View Language

1 def my_function(x):
2     return 2*x + 1
3
4 def my_function2(x):
5     return 3*x + 4
6
7 def my_function3(x):
8     return 4*x + 7
9
```

In our notebook

```
1 from my_code import my_function2 as custom_name

1 print(my_function2(2))

-----
NameError                                Traceback (most recent call last)
<ipython-input-4-20b74e0a7273> in <module>
----> 1 print(my_function2(2))

NameError: name 'my_function2' is not defined

1 print(custom_name(2))

10
```

Importing several functions

- If needed, you can import **multiple functions** in a single import call.
- Simply use **commas (,)** symbols to separate the different functions names.
- Or, you can also **import all functions** at once, by simply entering *****.

my_code.py file

```
jupyter my_code.py✓ Last Tuesday at 1:22 PM
File Edit View Language
1 def my_function(x):
2     return 2*x + 1
3
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6
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9
```

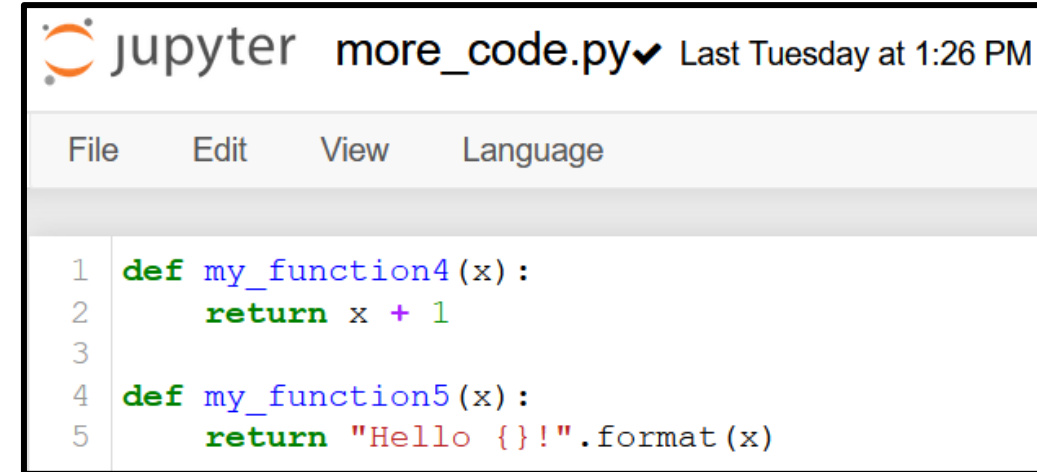
In our notebook

```
1 from my_code import my_function, my_function2
1 from my_code import *
1 print(my_function3(2))
15
```

Importing an entire **module**

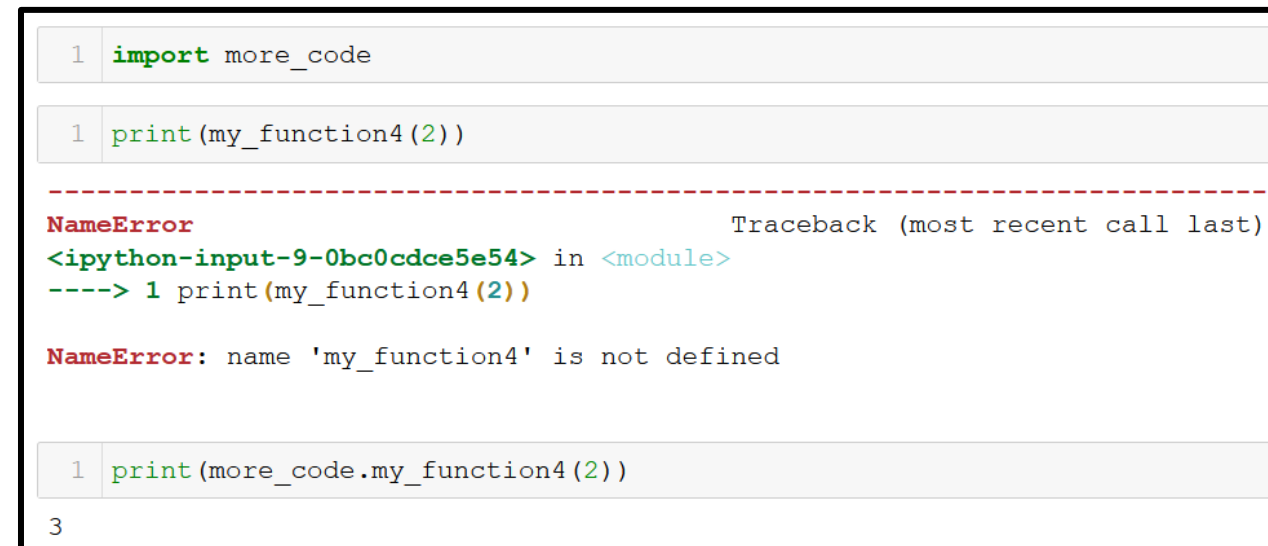
- You can also import a whole file, as a **module**.
- To do so, simply start with **import** instead of **from**.
- By doing so, you import all the functions, but **they have to be called using the module name and the dot operator (.)**.
- This can make the code more readable, but is also a bit more inconvenient.

more_code.py file



```
jupyter more_code.py✓ Last Tuesday at 1:26 PM
File Edit View Language
1 def my_function4(x):
2     return x + 1
3
4 def my_function5(x):
5     return "Hello {}".format(x)
```

In our notebook



```
1 import more_code

1 print(my_function4(2))

-----
NameError                                Traceback (most recent call last)
<ipython-input-9-0bc0cdce5e54> in <module>
----> 1 print(my_function4(2))

NameError: name 'my_function4' is not defined

1 print(more_code.my_function4(2))

3
```

Importing an entire **module**

- You can also use an alias for the module using the **as** keyword, as before.
- Typically, we often do it with Numpy!

```
import numpy as np
```

more_code.py file

```
jupyter more_code.py✓ Last Tuesday at 1:26 PM
File Edit View Language
1 def my_function4(x):
2     return x + 1
3
4 def my_function5(x):
5     return "Hello {}".format(x)
```

In our notebook

```
1 import more_code as mc
1 print(mc.my_function4(2))
3
1 import numpy as np
1 print(np.cos(0))
1.0
```

Folders to import from

- **Observation:** Python imported functions from `my_code.py`, which was located in the same folder as my Notebook.
- **But there was no numpy.py file in this location.**
- **What happened?**

Folders to import from

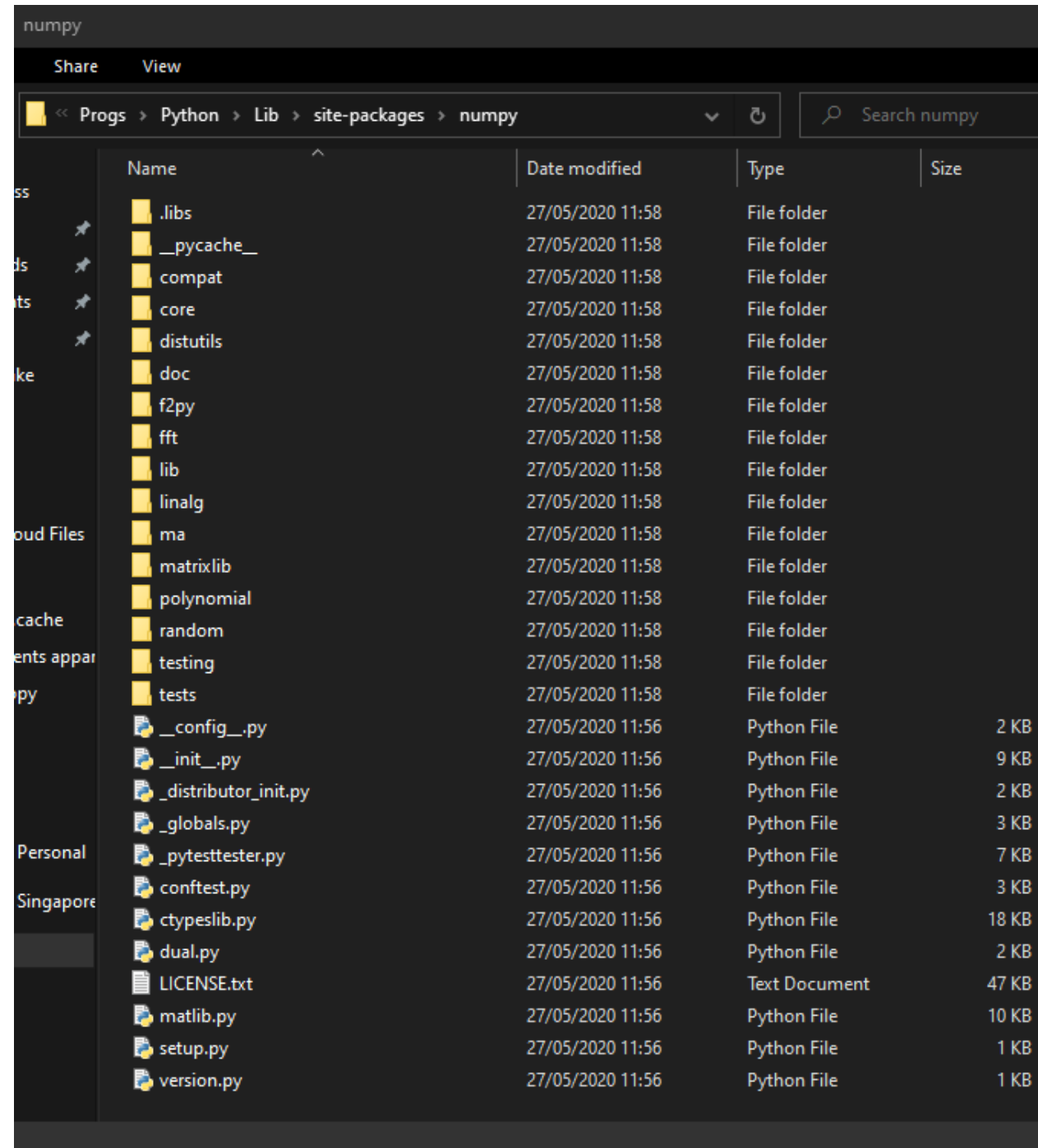
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- and then looks in your Python installation directory.

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Project organizing

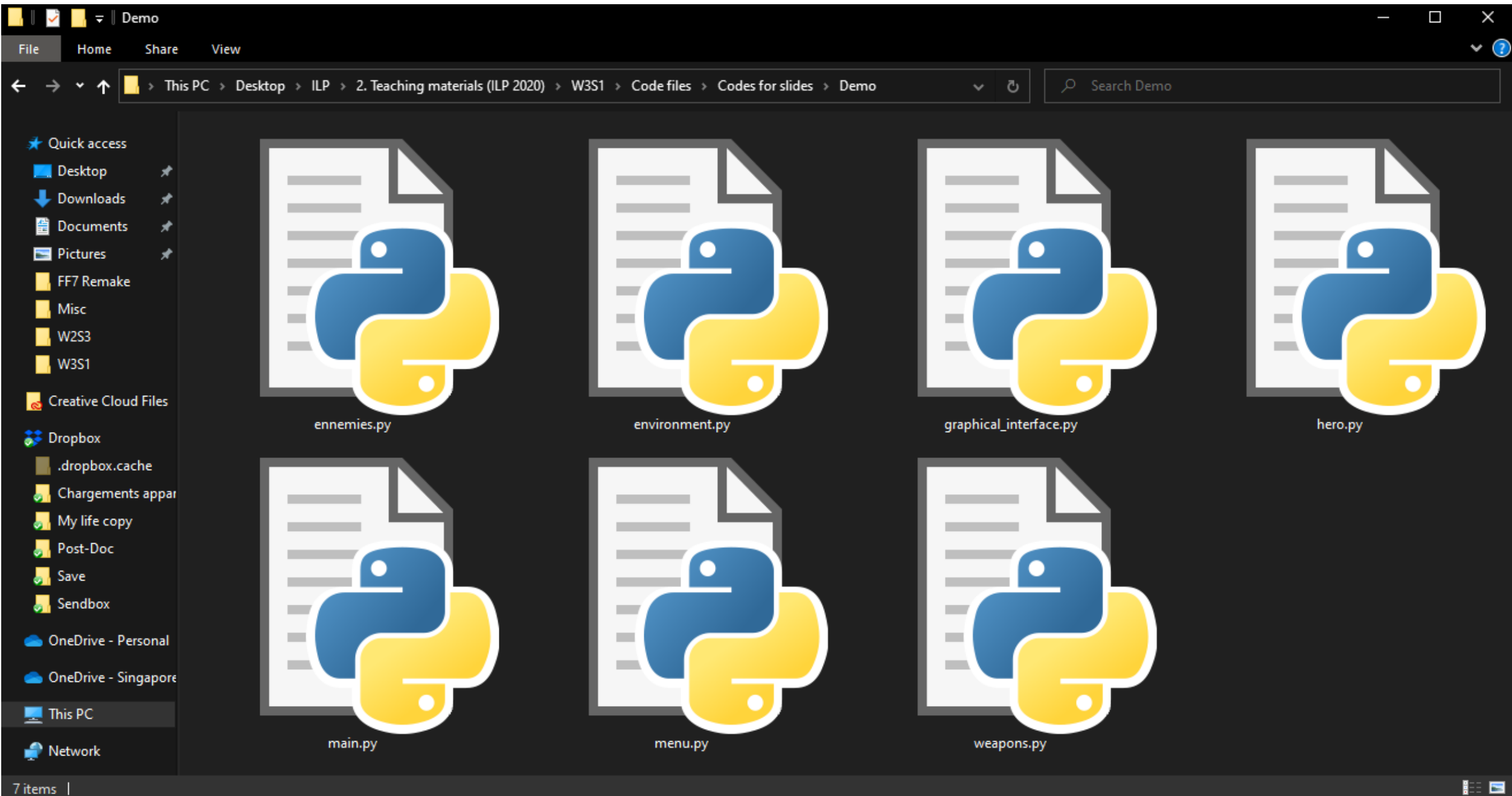
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Project organizing

- In many projects, several developers will often collaborate on a single project.
- And each one of them will end up working on a single aspect of the project.

E.g. in a video game:

- One developer can design the main character,
- Another one will develop enemies,
- Another one will develop items and weapons,
- Another one will design the map/environment in which heroes and enemies evolve,
- Etc.



Project organizing

- Each developer will then work on his/her own .py file, taking care of his/her specific subtask.
- Later on, other developers might **import** functions from files created by other people.
- Eventually assemble all pieces in a **main.py** file!

Project organizing

- Each developer will then work on his/her own .py file, taking care of his/her specific subtask.
- Later on, other developers might **import** functions from files created by other people.
- Eventually assemble all pieces in a **main.py** file!
- This is something very common in programming projects.
- **Important:** you need to build the habit of documenting your functions!

Matt's Great advice #11

Matt's Great Advice #11: Good import practices

Some good practices in projects

1. As with the variables and functions names, it is a good idea to **make your file names explicit**.
2. Have **a file for each sub-concept**, and **a single main file that assembles them all** at the end.
3. It is often better to **import only what is needed** (**from ... import ...**) rather than importing everything (**from ... import *, import ...**).



Conclusion

- Memory management and lists: aliasing, shallow and deep copies
- The Numpy library (part 1): arrays, math functions, etc.
- About the import procedure
- Project organizing
- Mini-project