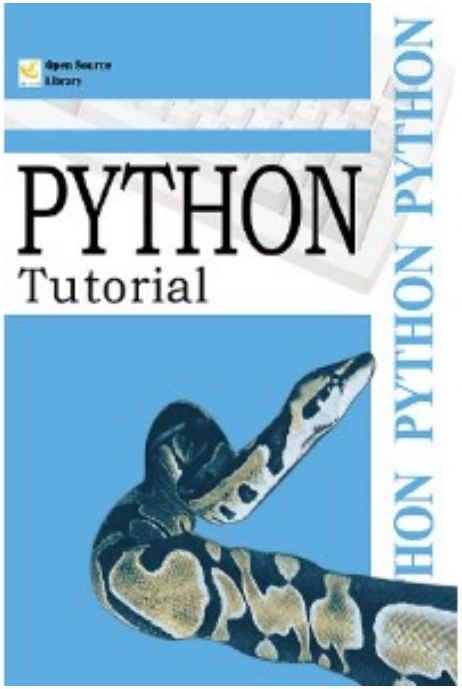
Data Structures in Python



Dra. Mª Dolores Rodríguez Moreno

Objectives

Specific Objectives

- Understanding the main data structures

Source

- https://docs.python.org/3/reference/datamodel.html
- Charles R. Severance (www.pythonlearn.com)
- https://ellibrodepython.com/
- Python Tutorial - Tapa blanda. GuidoVan Rossum (2012)
- Abhijeet Anand on NumPy

Outline

- **Introduction**
- List
- Tuple
- Set
- Dictionary
- Enum
- Array

Introduction

- Programming focuses on the representation of information
- Simple data types like numbers, characters, and strings are straightforward to handle
- Real-world scenarios often involve more complexity
- A class can represent a single object, but we need to manage multiple objects effectively
- Representing complex data requires robust solutions
- This is where data structures come into play, providing powerful tools for organizing and storing information

Outline

- Introduction
- **List**
- Tuple
- Set
- Dictionary
- Enum
- Array

List

- List initialization: list = [item1, ..., itemN]
- Methods:
  - list.append(x)
  - list.insert(i, x)
  - list.remove(x)
  - list.pop()
  - list.index(x)
  - list.count(x)
  - list.sort()
  - list.reverse()

Example: List

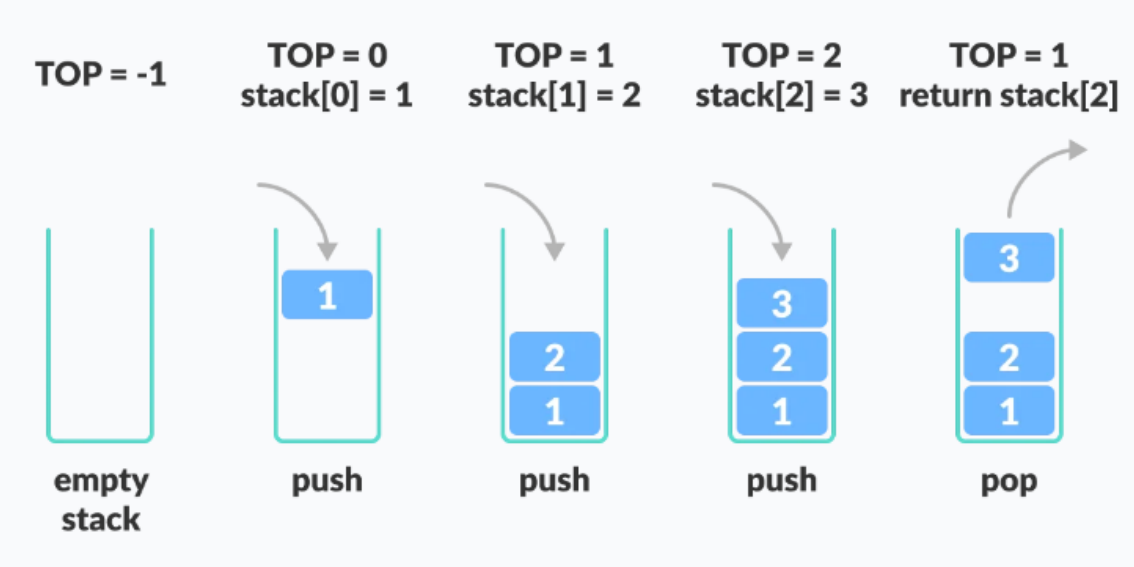
```
friends = ['Joseph', 'Glenn', 'Sally']

print(len(friends)) #3



print(list(range(len(friends))))

#[0,1,2]
```

Example: Loops in List

```
friends = ['Joseph', 'Glenn', 'Sally']

#Both loops do the same.

for friend in friends :

    print('Happy New Year:',  friend)

for i in range(len(friends)) :

    friend = friends[i]

    print('Happy New Year:',  friend)
```

Stack (as a list)

- Collection of elements that follows the LIFO (Last In, First Out) principle
- Last element added is the first one to be removed
- Main Operations:
  - push: adds an element to the top of the stack
  - pop: removes and returns the element at the top of the stack
  - peek: returns the element at the top of the stack without removing it
  - is_empty: checks if the stack is empty
  - size: returns the number of elements in the stack



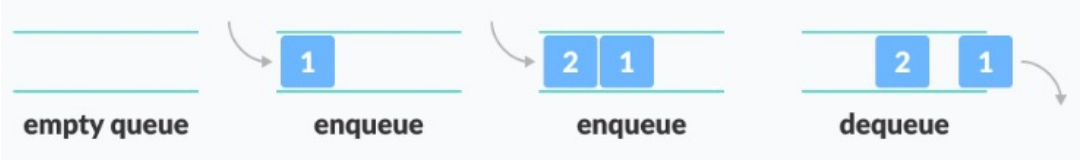
source

Example: Stack

```
# Initialize an empty stack
stack = []

# Push operation: Add elements to the top of the stack
stack.append(1)  # Stack: [1]

stack.append(2)  # Stack: [1, 2]

stack.append(3)  # Stack: [1, 2, 3]

# Pop operation: Remove and return the top element of the stack
top_element = stack.pop()  # Returns 3, Stack: [1, 2]

# Peek operation: Return the top element without removing it
top_element = stack[-1]  # Returns 2, Stack: [1, 2]

# Check if the stack is empty
is_empty = len(stack) == 0  # Returns False

# Get the size of the stack
stack_size = len(stack)  # Returns 2
```

Queue

- Collection of elements that follows the FIFO (First In, First Out) principle
- First element added is the first one to be removed
- Main Operations:
  - enqueue: adds an element to the end of the queue
  - dequeue: removes and returns the element at the front of the queue
  - front: returns the element at the front of the queue without removing it
  - is_empty: checks if the queue is empty
  - size: returns the number of elements in the queue
- Queue with List not efficient → Class deque



source

Example: Queue

```
from collections import deque

# Initialize an empty queue

queue = deque()

# Enqueue operation: Add elements to the end of the queue

queue.append('Eric')    # Queue: ['Eric']

queue.append('John')    # Queue: ['Eric', 'John']

queue.append('Michael') # Queue: ['Eric', 'John', 'Michael']

# Dequeue operation: Remove and return the element at the front of the queue

front_element = queue.popleft()  # Returns 'Eric', Queue: ['John', 'Michael']
```

Exercise

- Create a class “Stack” with the functionality of the Stack previously explained

```
#Example Usage
stack = Stack()
stack.push(1)
stack.push(2)
stack.push(3)
print(stack.pop())  # Output: 3
print(stack.peek())  # Output: 2
print(stack.is_empty())  # Output: False
print(stack.size())  # Output: 2
print(stack)
```

Outline

- Introduction
- List
- **Tuple**
- Set
- Dictionary
- Enum
- Array

Tuple

- Function much like a list with elements indexed starting at 0
- An **immutable** sequence of elements (similar to a string), typically used to store collections of heterogeneous data
- Main Operations:
  - Creation: can be created using parentheses () or without them
  - Access: elements can be accessed using indexing
  - Slicing: similar to lists, tuples support slicing
  - Unpacking: can be unpacked into individual variables

Example: Tuple

```
# Creating tuples

tup1 = (1, 2, 3)

tup2 = "a", "b", "c"

tup3 = (1, "a", 3.14)

# Accessing elements

first_element = tup1[0]  # Returns 1

# Slicing

sub_tuple = tup1[1:3]  # Returns (2, 3)

# Adding

print(tup1+tup2)  # (1, 2, 3, 'a', 'b', 'c')
```

Tuple: Unpacking

- You can assign a tuple of values to a tuple of variables in one step (i.e., it can be on the left side)
- Parentheses are optional in some contexts
- Python can infer that you are working with a tuple from the context
- Swapping values: is a common pattern without needing a temporary variable

Example with ()

```
(x, y) = (4, 'maria')

print(y)  # Output: maria
```

Example without ()

```
a, b = 99, 98

print(a)  # Output: 99
```

Example swapping

```
x, y = y, x
```

Example: Tuple (NOT to do)

```
x = (1, 2, 3)

x.sort()    #Traceback:AttributeError:  'tuple' object has no attribute 'sort'

x.append(5) #Traceback:AttributeError:  'tuple' object has no attribute 'append'

x.reverse() #Traceback:AttributeError:  'tuple' object has no attribute 'reverse'



dir(x) #['count', 'index']

x.index(2) # Output: 1 (index of the first occurrence of 2 in the tuple x)

x.count(1) # Output: 1 (the number 1 appears once)
```

Tuples more efficient

- Since tuples don't need to be modifiable, they are simpler in design and translates to better memory usage and performance

- When your program needs temporary variables, reach for tuples instead of lists. Their efficient nature will give your code a boost!

Tuples are comparable

- You can compare tuples and other sequences
- If the first item is equal, Python goes on to the next element, and so on, until it finds elements that differ

Example with numbers

```
(2, 3, 4) < (3, 3, 4)        #True

(2, 3, 4000000) < (2, 4, 1) #True
```

Example with strings

```
('Anna', 'Bob') < ('Anna', 'Carol') #True

('Anna', 'Bob') > ('Alice', 'David') #False
```

Outline

- Introduction
- List
- Tuple
- **Set**
- Dictionary
- Enum
- Array

Set

- An unordered collection of unique elements
- Mutables, for an immutable version, you can use *frozenset*
- It supports mathematical operations like union, intersection, and difference
- Main Operations:
  - Creation: sets can be created using curly braces {} or the set() function
  - Add: add an element to the set using add()
  - Remove: remove an element from the set using remove() or discard()
  - Membership: check if an element is in the set using the ***in*** keyword
  - Set Operations: union, intersection, and difference using operators or methods

Example: Set

```
# Creating sets

set1 = {1, 2, 3}

set2 = set([2, 3, 4])

# Adding elements

set1.add(4)  # set1 = {1, 2, 3, 4}

# Removing elements

set1.remove(1)  # set1 = {2, 3, 4}

# Membership check

is_member = 2 in set1  # Returns True
```

Example: Set

```
# Set operations

#set1 = {2, 3, 4}   #set2 = set([2, 3, 4])

# union_set = set1.union(set2)

union_set = set1 | set2  # Returns {2, 3, 4}

intersection_set = set1 & set2  # Returns {2, 3, 4}

difference_set = set1 - set2  # Returns set()

# Creating an immutable frozenset

frozen_set = frozenset([1, 2, 3])

# Attempting to modify the frozenset will raise an error

# frozen_set.add(4)  # Raises AttributeError
```

Outline

- Introduction
- List
- Tuple
- Set
- **Dictionary**
- Enum
- Array

What is a Collection

- Allows storage of multiple values in a single variable
- Contains multiple elements accessed via an index or key
- Convenient for managing groups of related data
- Types of Collections
  - List: ordered collection of elements
  - Dictionary: unordered collection of key-value pairs
- What is NOT a Collection?
  - Variables generally hold one value at a time
  - Assigning a new value overwrites the previous value

Dictionaries

- Also known as Associative Arrays, provide fast, flexible database-like operations
- Indexed by unique keys instead of numeric positions
- Other names in other languages
  - Dictionaries – Python, Objective-C, Smalltalk, REALbasic
  - Hashes – Ruby, Perl,
  - Maps – C++, Java, Go, Clojure, Scala, OCaml, Haskell
  - Property Bag - C#

Example: Dictionary

```
#Initialize an empty dictionary

purse = {}

#Add key-value pairs

purse['money'] = 15

purse['candy'] = 5

purse['tissues'] = 75

print(purse)  # Output: {'money': 15, 'candy': 5, 'tissues': 75}

#Modifying Dictionary Values. Access and update values using keys

print(purse['candy'])  # Output: 5

purse['candy'] += 2

print(purse)  # Output: {'money': 15, 'candy': 7, 'tissues': 75}
```

Missing Keys

- Accessing a non-existent key raises an error

example

```
c = {}

# print(c['unknown'])  # Raises KeyError

print('unknown' in c)  # Output: False
```

Counting with dictionaries

- Track occurrences of elements: get()
- Simplifies checking and updating dictionary entries

example

```
counts = {}

names = ['alice', 'bob', 'alice', 'eve', 'bob']

for name in names:

    counts[name] = counts.get(name, 0) + 1

print(counts)  # Output: {'alice': 2, 'bob': 2, 'eve': 1}
```

Example: Words Count

```
counts = {}

print('Enter a line of text:')

line = input()

words = line.split()

print('Words:', words)

print('Counting...')

for word in words:

    counts[word] = counts.get(word, 0) + 1

print('Counts:', counts)
```

Iterating

- Even if there is not order, we can iterate on dictionaries

example

```
counts = {'alice': 1, 'bob': 42, 'eve': 100}

for key in counts:

    print(key, counts[key])

# Output:

# alice 1

# bob 42

# eve 100
```

Retrieving Keys, Values, and Items

- Get lists of keys, values, or key-value pairs

example

```
dict1 = {'alice': 1, 'bob': 42, 'eve': 100}

print(list(dict1))  # Output: ['alice', 'bob', 'eve']

print(dict1.keys())  # Output: dict_keys(['alice', 'bob', 'eve'])

print(dict1.values())  # Output: dict_values([1, 42, 100])

print(dict1.items())  # Output: dict_items([('alice', 1), ('bob', 42),
('eve', 100)])
```

Example: Two iteration values. Loop through key-value pairs using two variables

```
jjj = {'alice': 1, 'bob': 42, 'eve': 100}

for key, value in jjj.items():

    print(key, value)

# Output:

# alice 1

# bob 42

# eve 100
```

Exercise

- Create a program that allows a teacher to input student names and their grades
  - Create an empty dictionary to store student names (keys) and their grades (values)
  - Write a loop that asks the user to input a student's name and grade. Add these to the dictionary. Continue until the user enters 'done'
  - Print out all student names and their grades
  - Calculate and print the average grade of the class
  - Find and print the name(s) of the student(s) with the highest grade

Summary

- List: li = [1, 2, 3]
- Tuple: tu = (1, 2, 3)

  tu = 1, 2, 3
- Set: se = {1, 2, 3}
- Dictionary: dic = {'abc': 1, 'bca': 2}

Outline

- Introduction
- List
- Tuple
- Set
- Dictionary
- **Enum**
- Array

What is an Enum?

- An enumeration is a set of symbolic names (members) bound to unique, constant values
- Useful when you have a collection of related constant values like days of the week, states in a process, etc.
- Part of the standard library: (*from enum import Enum)*
- Introduced in Python 3.4
- Purpose: define named constants that can be compared and iterated over

Why use Enums?

- Code Readability: Enums make code more expressive
- Prevent Magic Numbers: No need to remember arbitrary values
- Safety: Enum members are immutable and unique
- Maintainability: Simplifies updates when constant values change

Example: Definition

```
from enum import Enum

class Weekday(Enum):

    MONDAY = 1

    TUESDAY = 2

    WEDNESDAY = 3

    THURSDAY = 4

    FRIDAY = 5
```

Example: Accessing

```
print(Weekday.MONDAY)
print(Weekday.MONDAY.name)
print(Weekday.MONDAY.value)

#Output: Weekday.MONDAY, 'MONDAY', 1
```

Iterating

Example:

```
for day in Weekday:
    print(day)



#Output: Weekday.MONDAY, Weekday.TUESDAY...
```

Comparing

Example:

```
if Weekday.MONDAY == Weekday.TUESDAY:
    print("Same day")
else:
    print("Different days")
```

Enums with Automatic Values

- Use auto() to automatically assign increasing values starting from 1

Example: Auto

```
from enum import Enum, auto

class Weekday(Enum):

    MONDAY = auto()

    TUESDAY = auto()

    WEDNESDAY = auto()

    THURSDAY = auto()

    FRIDAY = auto()
```

Useful Enum Methods

- Enum members can be accessed by name or value:

Example:

```
Weekday['MONDAY']
Weekday(1)
```

- You can get a dictionary of all enum member: *__members__*

Example:

```
print(Weekday.__members__)
```

Exercise

- Represent different states in a task management system
- Create a function that prints a message depending on the values
- For example:

  NOT_STARTED

  IN_PROGRESS

  COMPLETED

  BLOCKED

- Call: print_task_status(“Exam corrections", TaskStatus. NOT_STARTED)

#The task 'Exam corrections' has not started yet.

Outline

- Introduction
- List
- Tuple
- Set
- Dictionary
- Enum
- **Array**

Array

- An array is a collection of items stored at memory locations
- Python has an “array” library but it is not used much
  - import array
  - array_name = array.array(typecode, [elements])
- Instead, *numpy* library is used for creating and handling arrays
- Key Characteristics:
  - Fixed size
  - Homogeneous elements (all elements are of the same type)
  - Efficient numerical operations

NumPy

- NumPy stands for Numerical Python
- NumPy is a Python library used for working with arrays
- NumPy is the fundamental package for scientific computing in Python
- It has functions for working in the domain of linear algebra, Fourier transform, and matrices
- NumPy was created in 2005 by Travis Oliphant
- It is an open-source project and can be used freely

Why Use NumPy?

- In Python, we have lists that serve the purpose of arrays, but they are slow to process
- NumPy aims to provide an array object that is up to 50x faster than traditional Python lists
- NumPy's array class is called ndarray
- It provides a lot of supporting functions that make working with ndarray very easy
- Arrays are very frequently used in data science, where speed and resources are very important

1-D Array

- An array that has 0-D arrays as its elements is called a uni-dimensional or 1-D array

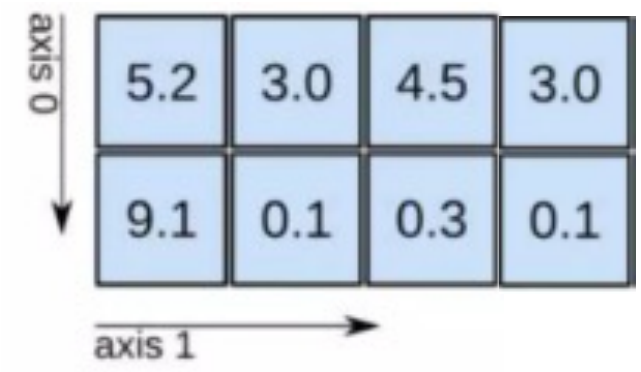
- Elements: 7

Example: numpy – 1D

```
import numpy as np

arr = np.array([1, 2, 3, 4, 5])

#Accessing Elements in 1D:

print(arr[0])  # Output: 1

#Negative Indexing:

print(arr[-1])  # Output: 5

#updating Elements

arr[1] = 10 # Output: [ 1 10  3  4  5]

#Appending Elements:

arr = np.append(arr, 6) # Output: [ 1 10  3  4  5  6]
```

2-D Array

- An array that has 1-D arrays as its elements is called a 2-D array
- These are often used to represent a matrix or 2nd order tensors



- Dimension: 2 X 4

Example: numpy – 2D

```
arr_2d = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])

#Accessing Elements in 2D:

print(arr_2d[1, 2])  # Output: 6

#Slicing:

print(arr_2d[0:2, 1:3])

#updating Elements

arr_2d[0, 0] = 10

#Appending Elements:

arr_2d = np.append(arr_2d, [[10, 11, 12]], axis=0)
```

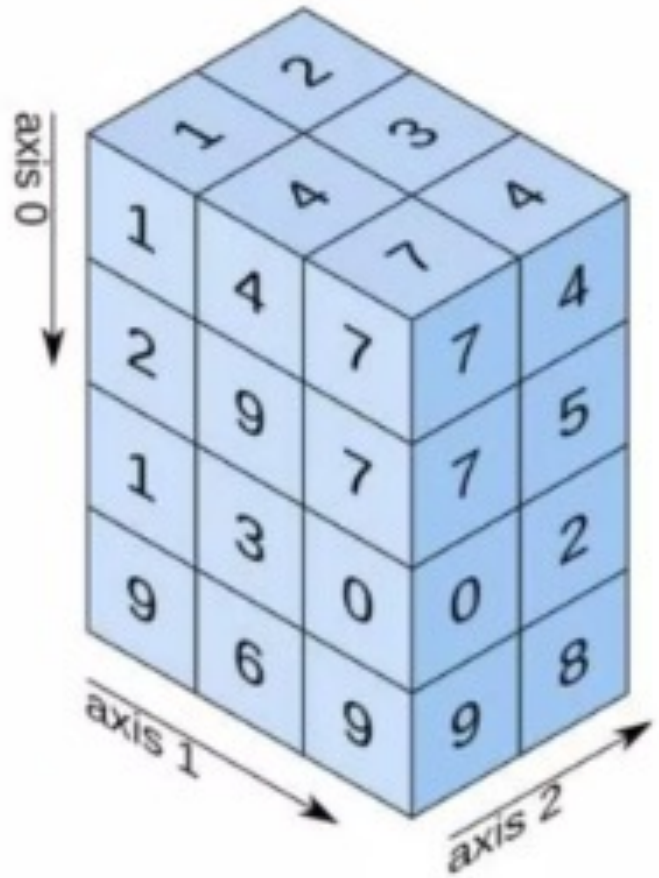
```
[[2 3]
 [5 6]]
```

```
[[10  2  3]
 [ 4  5  6]
 [ 7  8  9]]
```

```
[[10  2  3]
 [ 4  5  6]
 [ 7  8  9]
 [10 11 12]]
```

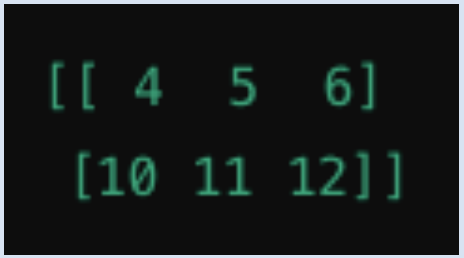
3-D Arrays

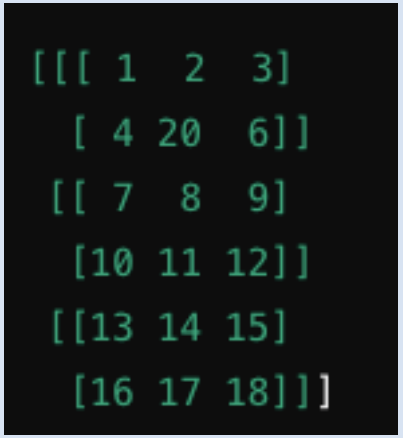
- An array that has 2-D arrays (matrices) as its elements is called a 3-D array
- These are often used to represent a 3rd order tensor



Example: numpy – 3D

```
arr = np.array([[[1, 2, 3], [4, 5, 6]], [[7, 8, 9], [10, 11, 12]]])

#Accessing Elements

print(arr[1, 0, 1])  # Output: 8

#Slicing

print(arr[:, 1, :])

#Updating Elements:

arr[0, 1, 1] = 20

#Appending Elements

arr = np.append(arr, [[[13, 14, 15], [16, 17, 18]]], axis=0)
```





Example: numpy – 3D

```
#Inserting Elements

arr = np.insert(arr, 1, [[[-1, -2, -3], [-4, -5, -6]]], axis=0)
```

```
[[[ 1  2  3]
  [ 4 20  6]]
 [[-1 -2 -3]
  [-4 -5 -6]]
 [[ 7  8  9]
  [10 11 12]]
 [[13 14 15]
  [16 17 18]]]
```

```
#Deleting Elements

arr = np.delete(arr, 1, axis=0)
```

```
[[[ 1  2  3]
  [ 4 20  6]]
 [[ 7  8  9]
  [10 11 12]]
 [[13 14 15]
  [16 17 18]]]
```

Initialization

- np.array([1, 2, 3]): 1D array #You can specify type: np.array([1, 2, 3], dtype = float)
- np.array([[1, 2, 3], [4, 5, 6]]): 2D array
- np.arange(start, stop, step): Create an array (from start to stop with increments "steps"
- np.linspace(0, 2, 9): Add evenly spaced values between intervals to array of length
- np.zeros((1, 2)): Create an array filled with zeros (1x2)
- np.ones((1, 2)): Create an array filled with ones
- np.random.random((5, 5)): Create a random array (5x5)
- np.empty((2, 2)): Create an empty array (2x2)

Array Properties

- array.shape: Dimensions (Rows, Columns)
- len(array): Length of Array
- array.ndim: Number of Array Dimensions (uni, bidim, trimdim...)
- array.size: Number of Array Elements
- array.dtype: Data Type
- type(array): Type of Array

Copying & Sorting

- np.copy(array): Creates a copy of array
- array.sort(): Sorts an array
- array.sort(axis=0): Sorts axis of array

Operations

- np.add(x, y): Addition
- np.subtract(x, y): Subtraction
- np.divide(x, y): Division
- np.multiply(x, y): Multiplication
- np.sqrt(x): Square Root
- np.sin(x): Element-wise sine
- np.cos(x): Element-wise cosine
- np.log(x): Element-wise natural log
- np.dot(x, y): Dot producto (escalar product)
- np.roots([1, 0, -4]): Roots of given polynomial coefficients

Exercise

- Represent the grades of 3 students in 3 subjects
  1. Create a 2D Array to represent the grades
  2. Retrieve the grade of the second student in the third subject
  3. Modify the grade of the first student in the first subject
  4. Add a new student with different grades
  5. Insert a new subject at the second position
  6. Remove the second student
  7. Change the shape of the array to represent 2 students with 4 subjects each