Data Structures

Python offers 4 built-in data types for storing collections of data:

1. **Lists:** A collection of data which is ordered, changeable and allows duplicate members

2. **Tuples:** A collection of data which is ordered, unchangeable and allows duplicate members

3. **Sets:** A collection of data which is unordered, unchangeable and does not allow duplicate members

4. **Dictionaries:** A collection of data which is stored in *key:value pairs* and is ordered, changeable and does not allow duplicate members (Dictionaries were unordered before Python 3.7)

Data Structures

Examples of the collection data are given below. Notice the bracket types.

```
x_list = [1, 2, 3, 4, 5]

x_tuple = (1, 2, 3, 4, 5)

x_set = {1, 2, 3, 4, 5}

x_dictionary = {"name" : "Ali"
                "age" : 31
              "result" : False}
```

Lists

- A List is a collection of data that is
  - Ordered
  - Changeable (Mutable)
  - Allows Duplicate Members

- A List is a sequence of values (called items or elements)
- Whereas a string is a sequence of characters, a list can be a sequence of any data type

- Lists are among the commonly used data types in python
- Lists are used extensively in ROS such as in reading laser data
- A List works similar to the arrays in C++

Lists - Creation

- To create a list, the simplest way is to use square brackets to enclose the items and use commas to separate the items

```
x = [1, 2, 3, 4, 5]

print(x)
```

Output:

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

Lists

- Lists can hold different types of data:

```
a = [11, 2, 93, 401, 560]
b = [1.5, 6.6, 7.3, 8.9]
c = ["apple", "banana", "cherry"]
d = [True, True, False, True, False]
e = []
f = list("ROBOT")

print(a)
print(b)
print(c)
print(d)
print(e)
print(f)
```

Output:

```
[11, 2, 93, 401, 560]
[1.5, 6.6, 7.3, 8.9]
['apple', 'banana', 'cherry']
[True, True, False, True, False]
[]
['R', 'O', 'B', 'O', 'T']
```

Lists

- The same list can also hold different types of data:

```
g = [31.5, "Robotics", 4, True, 9]

print(g)
```

Output:

```
[31.5, 'Robotics', 4, True, 9]
```

Lists

- Lists can nest other lists:

```
h = ["wheels", 35, 5.2, [10, 20], 50]

print(h)
print(h[3])
print(h[3][0])
print(h[3][1])
```

Output:

```
['wheels', 35, 5.2, [10, 20], 50]
[10, 20]
10
20
```

Lists

- Lists allow duplicates of data:

```
j = ["apple", "banana", "cherry", "apple", "watermelon"]

print(j)
```

Output:

```
['apple', 'banana', 'cherry',
'apple', 'watermelon']
```

Accessing Items in a List

- To access individual items in a list, square brackets are used which contain the index number of the item
- The index of the first item starts at zero
- The index of the last item is (number of items – 1)

0	1	2	3	4	5	6	7

```
my_list = [14, 20, 93, 41, 56, 77, 38, 62]

print(my_list[0])
print(my_list[1])
print(my_list[5])
print(my_list[7])
```

Output:

```
14
20
77
62
```

Changing Items in a List

- The value of an item in a list can be changed by using its index

0	1	2	3	4	5	6	7

```
my_list = [14, 20, 93, 41, 56, 77, 38, 62]
print(my_list)

my_list[2] = 37
print(my_list)
```

Output:

```
[14, 20, 93, 41, 56, 77, 38, 62]
[14, 20, 37, 41, 56, 77, 38, 62]
```

Accessing Items with Negative Index

- Items can also be indexed from the end. This is done by using negative numbers for the index
- The negative indexing starts from -1 (not zero)

	0	1	2	3	4	5	6	7
my_list =	14	20	93	41	56	77	38	62
	-8	-7	-6	-5	-4	-3	-2	--1

```
print(my_list[-1])
print(my_list[-2])
print(my_list[-3])
print(my_list[-8])
```

Output:

```
62
38
77
14
```

Changing Items with Negative Index

- Negative indexing can also be used to change the value of items

-8	-7	-6	-5	-4	-3	-2	--1

```
my_list = [14, 20, 93, 41, 56, 77, 38, 62]
print(my_list)

my_list[-5] = 500
print(my_list)
```

Output:

```
[14, 20, 93, 41, 56, 77, 38, 62]
[14, 20, 93, 500, 56, 77, 38, 62]
```

Accessing Range of Items

- The access a range of items, the colon (:) is used (slice operation)
- Note the post-colon number is NOT included in the index


```
my_list = [14, 20, 93, 41, 56, 77, 38, 62]
```

```
print( my_list[2:5] )
```


```
print( my_list[2:] )
```


```
print( my_list[:5] )
```

Output:

```
[93, 41, 56]
[93, 41, 56, 77, 38, 62]
[14, 20, 93, 41, 56]
```

Changing Range of Items

- The range of items, accessed with the colon (:), can be changed


```
my_list = ["apple", "banana", "cherry", "orange", "mango"]
print( my_list)

my_list[2:4] = ["grapes", "melon"]
print( my_list)
```

Output:

```
['apple', 'banana', 'cherry', 'orange', 'mango']
['apple', 'banana', 'grapes', 'melon', 'mango']
```

Changing Range of Items

- If you insert more items than you replace, the list will increase in length
- In the example below, banana and cherry are replaced by 3 items


```
my_list = ["apple", "banana", "cherry", "orange"]
print( my_list)

my_list[1:3] = ["carrot", "potato", "turnip"]
print( my_list)
```

Output:

```
['apple', 'banana', 'cherry', 'orange']
['apple', 'carrot', 'potato', 'turnip', 'orange']
```

Changing Range of Items

- If you insert less items than you replace, the list will decrease in length
- In the example below, banana and cherry are replaced by 1 item


```
my_list = ["apple", "banana", "cherry", "orange"]
print( my_list)

my_list[1:3] = ["strawberry"]
print( my_list)
```

Output:

```
['apple', 'banana', 'cherry', 'orange']
['apple', 'strawberry', 'orange']
```

Checking Items in List

- The **in** and **not in** keywords can used to check for items in a list:

```
my_list = ["apple", "banana", "cherry", "orange"]

print( "orange" in my_list )
print( "mango" in my_list )

print( "orange" not in my_list )
print( "mango" not in my_list )
```

Output:

```
True
False
False
True
```

Looping a List

- The **for** loop can used to iterate through the items of a list
- The number of times the loop executes is equal to the number of items
- The iterator (fruit) takes the value of each item of every iteration

```
my_list = ["apple", "banana", "cherry", "orange"]

for fruit in my_list:
    print(fruit)
```

Output:

```
apple
banana
cherry
orange
```

Looping a List

- If the indices are needed in the loop, then the **range** and **length** functions can be used

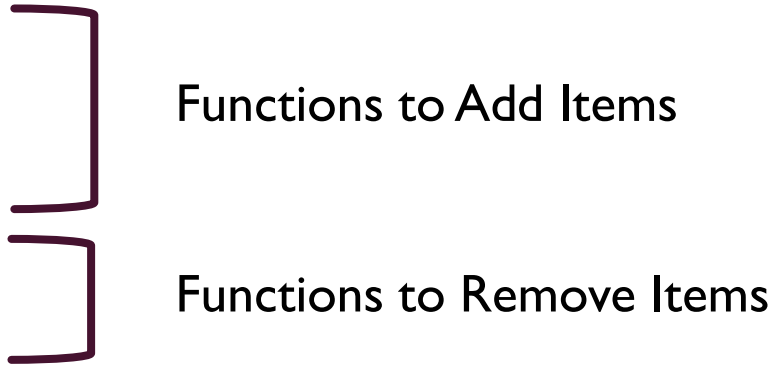
```
my_list = [1,2,3,4,5]

for i in range(len(my_list)):
    my_list[i] = 2 * my_list[i]

print(my_list)
```

Output:

```
[2, 4, 6, 8, 10]
```

List Functions

- List functions (also called methods) are useful functions that can be used with a list
- Python provides the following list functions:
    - Append()
    - Insert()
    - Extend()
    - Remove()
    - Pop()
    - Count()
    - Index()
    - Reverse()



Functions to Add Items

- To add items, Python provides 3 list functions:
  - Append
  - Insert
  - Extend

- The **append** function adds an item to the end of a list:

```
listA = ["apple","banana","cherry"]
print(listA)

listA.append("mango")
print(listA)
```

Output:

```
['apple', 'banana', 'cherry']
['apple', 'banana', 'cherry', 'mango']
```

Functions to Add Items

- The **insert** function adds an item to a certain index
- The items are readjusted and the list size increases

```
listA = ["apple","banana","cherry"]
print(listA)

listA.insert(1, "mango")
print(listA)
```

Output:

```
['apple', 'banana', 'cherry']
['apple', 'mango', 'banana', 'cherry']
```

Functions to Add Items

- The **extend** function adds a list to another list

```
listA = ["apple","banana","cherry"]
print(listA)

listB = ["carrot", "onion"]
listA.extend(listB)
print(listA)
```

- Another way to do this is to use the addition operation to concatenate the lists (`listA = listA + listB`)

Output:

```
['apple', 'banana', 'cherry']
['apple', 'banana', 'cherry', 'carrot', 'onion']
```

Functions to Remove Items

- To remove items, Python provides 2 list functions:
  - Pop
  - Remove

- The **remove** function can remove a specified item:

```
listA = ["apple","banana","cherry", "mango"]
print(listA)

listA.remove("cherry")
print(listA)
```

Output:

```
['apple', 'banana', 'cherry', 'mango']
['apple', 'banana', 'mango']
```

Functions to Remove Items

- The **pop** function can remove an item from a specific index:

```
listB = ["apple","banana","cherry", "mango"]
print(listB)

listB.pop(1)
print(listB)
```

Output:

```
['apple', 'banana', 'cherry', 'mango']
['apple', 'cherry', 'mango']
```

Other List Functions

- The **count** function returns the total number of a specified item

```
listC = [1,1,3,4,3,5,7,4,3,7,8,3,2]
number = listC.count(3)
print(number)
```

Output:

```
4
```

- The **index** function returns the index of the first occurrence of a specified item

```
index_val = listC.index(3)
print(index_val)
```

Output:

```
2
```

Other List Functions

- The **reverse** function reverses the order of the items in the list

```
listA = ["apple","banana","cherry", "mango"]
listA.reverse()
print(listA)
```

Output:

```
['mango', 'cherry', 'banana', 'apple']
```

2-D Lists

- The following is a 2-D list (a list of lists)
- The element of such lists can be accessed by multiple indexes
- The first index selects among the "items" of the outer list
- The second index selects among the items of the inner sub-list
- Remember that indexing in python starts from zero

```
my_2d_list = [[11, 22, 33, 44, 55],
              [71, 27, 42, 99, 58],
              [61, 62, 63, 64, 65],
              [83, 85, 19, 24, 21]]

print( my_2d_list[2][3] )
```

Output: **64**

Strings - Review

- Python supports the string data type which is an array of characters

```
h = "Manipulator"
print(h)
```

Output:

```
Manipulator
```

- You can get individual characters with square brackets

```
print(h[0])
print(h[1])
print(h[8])
```

Output:

```
M
a
p
```

- You can get the number of characters with the len() function

```
g = len(h)
print(g)
```

Output:

```
11
```

Strings - Review

- You can concatenate strings easily in python

```
c = "Computer"
d = "Vision"
e = c + d
print(e)
```

Output:

```
ComputerVision
```

```
f = c + " " + d
print(f)
```

Output:

```
Computer Vision
```

- You can check if a character is present in the string with the "in" keyword

```
print("t" in c)
print("s" in c)
```

Output:

```
True
False
```

Strings - Review

- The **for** loop can go through a sequence of characters
- The iterable object will be a string variable in this case

```
for i in "PYTHON":
    print(i)
```

Output:

```
P
Y
T
H
O
N
```

Dictionaries

- A dictionary is another data structure
- A dictionary is like a list but somewhat more general
- In a list, index positions have to be integers; in a dictionary, index positions can be (almost) any type

- A Dictionary is a collection of data that is
  - Ordered (as of Python 3.7)
  - Changeable (Mutable)
  - Does NOT Allow Duplicate Members

Dictionaries - Creation

- A dictionary is a mapping of a set of indices (called keys) to a set of values
- Each key maps to a value
- Each key-value pair is an item of a dictionary
- To create a dictionary, key-value pairs are enclosed in braces

```
eng2span = {'one': 'uno',
            'two': 'dos',
          'three': 'tres'}

print(eng2span)
```

Output:

```
{'one': 'uno', 'two': 'dos', 'three': 'tres'}
```

Dictionaries - Accessing

- The following dictionary maps English (keys) to Spanish (values)

```
eng2span = {'one': 'uno',
            'two': 'dos',
          'three': 'tres'}
```

- The keys are used as indexes to look up the corresponding values

```
print(eng2span['one'])
print(eng2span['two'])
print(eng2span['three'])
```

Output:

```
uno
dos
tres
```

Dictionaries - Accessing

- The following dictionary maps English (keys) to Numbers (values)

```
eng2num = {'one': 1,
           'two': 2,
         'three': 3}
```

- The keys are used as indexes to look up the corresponding values

```
print(eng2num['one'])
print(eng2num['two'])
print(eng2num['three'])
```

Output:

```
1
2
3
```

Dictionaries – Changing Value

- Consider the following dictionary which maps prices

```
prices = {'burger': 250,
          'sandwich': 150,
            'pizza': 400}
```

- The value can be changed by using its key:

```
prices['sandwich'] = 180
print(prices)
```

Output:

```
{'burger': 250, 'sandwich': 180, 'pizza': 400}
```

Dictionaries

- The following example illustrates a use of dictionaries:

```
commands = { "moveForward" : [1, 0],
             "moveBack"    : [-1, 0],
             "turnRight"   : [0, 1],
             "turnLeft"    : [0, -1],
             "stop"        : [0, 0]}
```

- Each key is a command for a robot's movement
- Note that the value in this case is a list of two elements
- The first element of the list is the linear motion
- The second element of the list is the angular motion

Importing Modules

- In python, we use the **import** keyword to use libraries (modules) which contain functions and classes
- There are many libraries commonly used in python such as NumPy, Pandas, OpenCV, Matplotlib, SciPy, Tensorflow, Keras, PySerial, Math and Datetime etc

- We will use the Math library as an example:

```
import math
var = math.sqrt(64)
print(var)
```

```
8.0
```

- We can also assign an *alias* for the library:

```
import math as mt
var = mt.sqrt(25)
print(var)
```

```
5.0
```

Importing Modules

- The math library contains some common mathematical functions:

```
print( math.sqrt(64))
print( math.ceil(1.5) )
print( math.floor(1.5) )
print( math.pi )
print( math.inf )
print( math.sin(30) )
print( math.cos(30) )
print( math.tan(30) )
print( math.log(5) )
print( math.log10(5) )
print( math.radians(180) )
print( math.degrees(math.pi) )
print( math.exp(4) )
```

```
8.0
2
1
3.141592653589793
inf
-0.9880316240928618
0.15425144988758405
-6.405331196646276
1.6094379124341003
0.6989700043360189
3.141592653589793
180.0
54.598150033144236
```

NumPy

- NumPy (Numerical Python) is a library used for creating computationally efficient arrays for matrix operations

```
import numpy as np
A = np.array([[1, 2, 3],
              [4, 5, 6]])
```

- There are various operations and functions for NumPy arrays

```
A + B                    np.dot(A,B)
A - B                    np.sum(A, axis=0)
A*B                      np.mean(A, axis=0)
A/B                      np.std(A, axis=0)
```

Code:

```
import numpy as np
arr=np.arange(1,10,2)
print("Elements of array: ",arr)
arr1=arr[np.array([4,0,2,-1,-2])]
print("Indexed Elements of array arr: ",arr1)
```

Output:

```
Elements of array:  [1 3 5 7 9]
Indexed Elements of array arr:  [9 1 5 9 7]
```

Indexing in 1 dimension

Code:

```
import numpy as np
arr1=np.arange(4)
print("Array arr11:",arr1)
print("Element at index 0 of arr1 is:",arr1[0])
print("Element at index 1 of arr1 is:",arr1[1])
```

Output:

```
Array arr1: [0 1 2 3]
Element at index 0 of arr1 is: 0
Element at index 1 of arr1 is: 1
```

2D array

Code:

```
arr=np.arange(12)
arr1=arr.reshape(3,4)
print("Array arr1:\n",arr1)
print("Element at 0th row and 0th column of arr1 is:",arr
print("Element at 1st row and 2nd column  of arr1 is:",ar
```

Output:

```
Array arr1:
 [[ 0  1  2  3]
 [ 4  5  6  7]
 [ 8  9 10 11]]
Element at 0th row and 0th column of arr1 is: 0
Element at 1st row and 2nd column  of arr1 is: 6
```

Picking a Row or Column in 2-D NumPy Array

Code:

```
import numpy as np
arr=np.arange(12)
arr1=arr.reshape(3,4)
print("Array arr1:\n",arr1)
print("\n")
print("1st row :\n",arr1[1])
```

Output:

```
Array arr1:
 [[ 0  1  2  3]
 [ 4  5  6  7]
 [ 8  9 10 11]]


1st row :
 [4 5 6 7]
```

Indexing in 3 Dimensions

There are three dimensions in a 3-D array, suppose we have three dimensions as (i, j, k), where i stands for the 1st dimension, j stands for the 2nd dimension and, k stands for the 3rd dimension.

Let's look at the given examples for a better understanding. Remember: **Indexing starts from zero.**

Code:

```
import numpy as np
arr=np.arange(12)
arr1=arr.reshape(2,2,3)
print("Array arr1:\n",arr1)
print("Element:",arr1[1,0,2])
```

Output:

```
Array arr1:
 [[[ 0  1  2]
  [ 3  4  5]]

 [[ 6  7  8]
  [ 9 10 11]]]
Element: 8
```

Picking a Row or Column in a 3D Array

Code:

```
import numpy as np
arr=np.arange(12)
arr1=arr.reshape(2,2,3)
print("Array arr1:\n",arr1)
print("1st row :",arr1[0,1])
```

Output:

```
Array arr1:
 [[[ 0  1  2]
  [ 3  4  5]]

 [[ 6  7  8]
  [ 9 10 11]]]
1st row : [3 4 5]
```

Picking a matrix in a 3D array

Code:

```
import numpy as np
arr=np.arange(12)
arr1=arr.reshape(2,2,3)
print("Array arr1:\n",arr1)
print("\n")
print("1st matrix :\n",arr1[1])
```

Output:

```
Array arr1:
 [[[ 0  1  2]
  [ 3  4  5]]

 [[ 6  7  8]
  [ 9 10 11]]]


1st matrix :
 [[ 6  7  8]
 [ 9 10 11]]
```

Code:

```
import numpy as np
arr=np.arange(12)
arr1=arr.reshape(3,4)
print("Array arr1:\n",arr1)
print("\n")
print("elements of 1st row and 1st column upto last column :\n",arr1[1:,1:4])
```

Output:

```
Array arr1:
 [[ 0  1  2  3]
 [ 4  5  6  7]
 [ 8  9 10 11]]


elements of 1st row and 1st column upto last column :
 [[ 5  6  7]
 [ 9 10 11]]
```

refresnces

- https://www.scaler.com/topics/numpy/numpy-indexing-and-slicing/Perform the Lab Tasks given in the manual