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Programming for Data Analytics

Week5: Introduction to Numpy and Scipy

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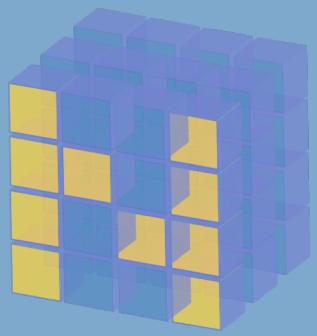


SciPy

NumPy

2018/2019

Introduction to Numpy and SciPy

- **NumPy** is an open-source add-on module to Python that provides routines for **manipulating large arrays** and matrices of numeric data in p**re-compiled**, fast functions.

- At the core of the NumPy package, is the **Ndarray** object.
  - This encapsulates n-dimensional arrays of **homogeneous** data types, with many operations being performed in compiled code for performance.

- There are several important differences between NumPy arrays and the standard Python lists

  - NumPy arrays have a **fixed size** at creation, unlike Python lists (which can grow dynamically). Changing the size of an ndarray will **create a new array** and delete the original.

  - The elements in a NumPy array are all required to be of the **same data type**.

Introduction

- NumPy arrays facilitate a range of mathematical and other types of operations on large amounts of data.
  - Typically, such operations are executed more efficiently and with less code than is possible using Python's built-in sequences.
  - Further, NumPy implements an array language, so that it attempts to **minimise the need for loops**.

- NumPy arrays make operations with large amounts of numeric data very fast and are generally much more efficient than lists.

Click here to view NumPy documentation

```
import numpy as np
import time

startPython = int(round(time.time() * 1000))
# Creates a list c by adding the elements of a and b
a = list(range(10000000))
b = list(range(10000000))
c = []
for i in range(len(a)):
  c.append(a[i] + b[i])
stopPython = int(round(time.time() * 1000))

# Below code does exactly the same thing but with Numpy Arrays
a = np.arange(10000000, dtype=int)
b = np.arange(10000000, dtype=int)
c = a + b

stopNumPy = int(round(time.time() * 1000))

# Here we express the time take by NumPy as a fraction of the time taken
# by Python to perform the same operation
print ((stopNumPy- stopPython)/(stopPython-startPython))
```

This code can take up to 5 seconds to run depending on the type of machine your use

The Numpy code by comparison is shorter, doesn't need a loop and it is almost instantaneous by comparison

Bike Sharing Dataset

1. instant: record index
2. season : season (1:springer, 2:summer, 3:fall, 4:winter)
3. yr : year (0: 2011, 1:2012)
4. mnth : month (1 to 12)
5. hr : hour (0 to 23)
6. holiday : weather day is holiday or not (extracted from [Web Link])
7. weekday : day of the week
8. workingday : if day is neither weekend nor holiday is 1, otherwise is 0.
9. + weathersit :
10. temp : Normalized temperature in Celsius. The values are divided to 41 (max)
11. atemp: Normalized feeling temperature in Celsius. The values are divided to 50 (max)
12. hum: Normalized humidity. The values are divided to 100 (max)
13. windspeed: Normalized wind speed. The values are divided to 67 (max)
14. casual: count of casual users
15. registered: count of registered users
16. cnt: count of total rental bikes including both casual and registered

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	1	1	0	1	0	0	6	0	1	0.24	0.2879	0.81	0	3	13	16	
2	2	1	0	1	1	0	6	0	1	0.22	0.2727	0.8	0	8	32	40	
3	3	1	0	1	2	0	6	0	1	0.22	0.2727	0.8	0	5	27	32	
4	4	1	0	1	3	0	6	0	1	0.24	0.2879	0.75	0	3	10	13	
5	5	1	0	1	4	0	6	0	1	0.24	0.2879	0.75	0	0	1	1	
6	6	1	0	1	5	0	6	0	2	0.24	0.2576	0.75	0.0896	0	1	1	
7	7	1	0	1	6	0	6	0	1	0.22	0.2727	0.8	0	2	0	2	
8	8	1	0	1	7	0	6	0	1	0.2	0.2576	0.86	0	1	2	3	
9	9	1	0	1	8	0	6	0	1	0.24	0.2879	0.75	0	1	7	8	
10	10	1	0	1	9	0	6	0	1	0.32	0.3485	0.76	0	8	6	14	
11	11	1	0	1	10	0	6	0	1	0.38	0.3939	0.76	0.2537	12	24	36	
12	12	1	0	1	11	0	6	0	1	0.36	0.3333	0.81	0.2836	26	30	56	
13	13	1	0	1	12	0	6	0	1	0.42	0.4242	0.77	0.2836	29	55	84	
14	14	1	0	1	13	0	6	0	2	0.46	0.4545	0.72	0.2985	47	47	94	
15	15	1	0	1	14	0	6	0	2	0.46	0.4545	0.72	0.2836	35	71	106	
16	16	1	0	1	15	0	6	0	2	0.44	0.4394	0.77	0.2985	40	70	110	
17	17	1	0	1	16	0	6	0	2	0.42	0.4242	0.82	0.2985	41	52	93	
18	18	1	0	1	17	0	6	0	2	0.44	0.4394	0.82	0.2836	15	52	67	
19	19	1	0	1	18	0	6	0	3	0.42	0.4242	0.88	0.2537	9	26	35	
20	20	1	0	1	19	0	6	0	3	0.42	0.4242	0.88	0.2537	6	31	37	
21	21	1	0	1	20	0	6	0	2	0.4	0.4091	0.87	0.2537	11	25	36	
22	22	1	0	1	21	0	6	0	2	0.4	0.4091	0.87	0.194	3	31	34	
23	23	1	0	1	22	0	6	0	2	0.4	0.4091	0.94	0.2239	11	17	28	
24	24	1	0	1	23	0	6	0	2	0.46	0.4545	0.88	0.2985	15	24	39	
25	25	1	0	1	0	0	0	0	2	0.46	0.4545	0.88	0.2985	4	13	17	
26	26	1	0	1	1	0	0	0	2	0.44	0.4394	0.94	0.2537	1	16	17	
27	27	1	0	1	2	0	0	0	2	0.42	0.4242	1	0.2836	1	8	9	
28	28	1	0	1	3	0	0	0	2	0.46	0.4545	0.94	0.194	2	4	6	

- Take a basic problem.
- If I want to calculate the average wind speed with normal file processing I would have to read through every line the in file and add the wind speed to a counter variable.

```
fileObj = open("bikeSharing.csv")
sumWind = 0
numOfRows = 0

for line in fileObj:
    lineContents = line.split(',')
    sumWind += float(lineContents[12])
    numOfRows += 1

print ("Average is ", (sumWind/numOfRows)*67)
```

Basic of NumPy - Arrays

- Arrays can be created from lists

```
import numpy as np

arr = np.array([5.5, 45.6, 3.2], float)
print (arr)
```

Above Code will Output => [5.5 45.6 3.2]

Adding Elements NumPy Arrays

- Can add individual elements to an array using **append**

```
import numpy as np


arr1 = np.array([5.5], float)
arr2 = np.append(arr1, 4.3)
print (arr2)
```

Above Code will Output => [5.5 4.3]

Adding Elements NumPy Arrays

- Can add a list to an array using append

```
import numpy as np


arr1 = np.array([5.5], float)
arr2 = np.append(arr1, [4.3, 6.4, 6])
print (arr2)
```

Above Code will Output => [5.5 4.3 6.4 6.]

Word of caution about using append or insert in large arrays!

NumPy - Arrays

- We can use numpy.concatenate to add **one NumPy array to another** Numpy Array
- Note: The concatenate will return a new independent copy of the data.

```
import numpy as np


arr1 = np.array([5.5, 45.6, 3.2], float)
arr2 = np.array([3.5, 4.1, 8.4], float)
arr3 = np.concatenate((arr1, arr2))
print (arr3)
```

Above Code will Output => [5.5 45.6 3.2 3.5 4.1 8.4]

NumPy - Arrays

- We can *insert* a value at a specific location
  - ***insert****(array, insertIndex, value)*

```
import numpy as np

arr1 = np.array([5.5, 45.6, 3.2], float)
arr2 = np.insert(arr1, 1, 99)
print (arr2)
```

Above Code will Output => [5.5 99. 45.6 3.2]

NumPy - Arrays

- We can *delete* a value at a specific location
  - ***delete****(array, insertIndex)*

```
import numpy as np


arr1 = np.array([5.5, 45.6, 3.2], float)
arr2 = np.delete(arr1, 1)
print (arr2)
```

Above Code will Output => [5.5 3.2]

NumPy - Arrays

- Array can be accessed using the **square bracket notation** just as with a list

```
import numpy as np

arr = np.array([5.5, 45.6, 3.2], float)
print (arr[0])
arr[0] = 5
print (arr)
```

```
5.5

[ 5.  45.6  3.2]
```

NumPy – Multi-Dimensional Arrays

- Arrays can be multidimensional. Elements are accessed using **[row, column]** format inside bracket notation

```
import numpy as np

arr = np.array([[1, 2, 3], [4, 5, 6]],
float)
print (arr)
print (arr[0, 0])
print (arr[1, 2])
```

```
[[ 1.  2.  3.]
 [ 4.  5.  6.]]

1.0

6.0
```

arr

	0	1	2
0	1	2	3
1	4	5	6

NumPy – Single Index to 2D Array

- A single index value provided to a multi-dimensional array will refer to an entire row.

```
import numpy as np

arr = np.array([[1, 2, 3], [4, 5, 6]], float)
arr[0, 1] = 12.2
print (arr)
print (arr[1])

arr[0] = 12.2
print (arr)
```

```
[[ 1.  12.2  3. ]
 [ 4.   5.   6. ]]

[ 4.  5.  6.]

[[ 12.2  12.2  12.2]
 [ 4.   5.   6. ]]
```

NumPy – Slicing Operations

- We can use slicing effectively to extract a subset of items from a NumPy array. We can slice along each axis.

NumPy – Slicing Operations

- We can also extract a single column using slicing.
- Use of a single **":"** in a dimension indicates the use of everything along that dimension

```
import numpy as np

arr = np.array([[1, 2, 3], [4, 5, 6]], float)
print (arr)

arr2 = arr[:,0]
print (arr2)

arr[:,0] = 56

print (arr)
```

```
[[ 1.  2.  3.]
 [ 4.  5.  6.]]

[ 1.  4.]

[[ 56.   2.   3.]
 [ 56.   5.   6.]]
```

Slicing with MD Arrays

- The following code will retrieve the elements in row 0 and 1 and the elements in column 0 and 1

```
import numpy as np

arr = np.array([[14.4, 2.4, 3.5], [54.3, 34.4,
98.22], [100, 200, 300]], float)
print (arr)

print (arr[0:2, 0:2])
```

```
[[ 14.4   2.4   3.5 ]
 [ 54.3  34.4  98.22]
 [100.  200.  300. ]]

[[ 14.4  2.4]
 [ 54.3 34.4]]
```

NumPy – Multi-Dimensional Arrays

- Notice that we can select a number of columns from a matrix.
- When we select a single column, NumPy flattens the array to again be one dimensional

```
import numpy as np

arr = np.array([[1, 2, 3, 4], [4, 5, 6, 7], [7, 8,
9, 10], [10, 11, 12, 13]], float)
print (arr)

arr2 = arr[:, 1:3]
print (arr2)

arr2 = arr[:,3]
print (arr2)
```

```
[[ 1.  2.  3.  4.]
 [ 4.  5.  6.  7.]
 [ 7.  8.  9. 10.]
 [10. 11. 12. 13.]]

[[ 2.  3.]
 [ 5.  6.]
 [ 8.  9.]
 [11. 12.]]

[ 4.  7. 10. 13.]
```

NumPy – Multi-Dimensional Arrays

We can use the same notation as an alternative way to access a specific row

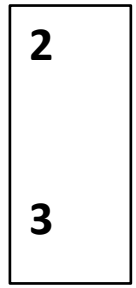
```
import numpy as np

arr = np.array([[1, 2, 3], [4, 5, 6]], float)
print (arr)

arr2 = arr[1,:]
print (arr2)
```

```
[[ 1.  2.  3.]
 [ 4.  5.  6.]]


[ 4.  5.  6.]
```

Use of len Function in M-D Arrays

- len function can be used to obtain the number of rows or the number of columns
  - len of 2D array will return the number of rows
  - len of 2D row will return the number of columns within that row

```
import numpy as np

arr = np.array([[14.4, 2.4, 56.4], [54.3, 34.4,
98.22]], float)

print (len(arr))
print (len(arr[0]))
```



Important consideration when slicing!!

- When we use slicing on **lists**, it returns a new list.
- However, when performing slicing on a NumPy array it will return **a view of the original array**. In other words while it is a subset of the array it is still pointing at the same data in memory as the original array.
- Technically, that means that the data of both objects is *shared*

```
import numpy as np

data = np.array([[1, 2, 3], [2, 4, 5], [4, 5, 7],
[6, 2, 3]], float)

resultA = data[:,0]
resultA[0] = 200
print (data)
```

```
[[ 200.   2.   3.]
 [   2.   4.   5.]
 [   4.   5.   7.]
 [   6.   2.   3.]]
```

Copying a NumPy Object

- To copy a NumPy array use **NumPy.copy** function, which takes in as an argument the array you want to copy

```
data = np.array([[1, 2, 3], [2, 4,
5], [4, 5, 7], [6, 2, 3]], float)

dataCopyA = data
dataCopyA[0,0] = 200

print (data)
```

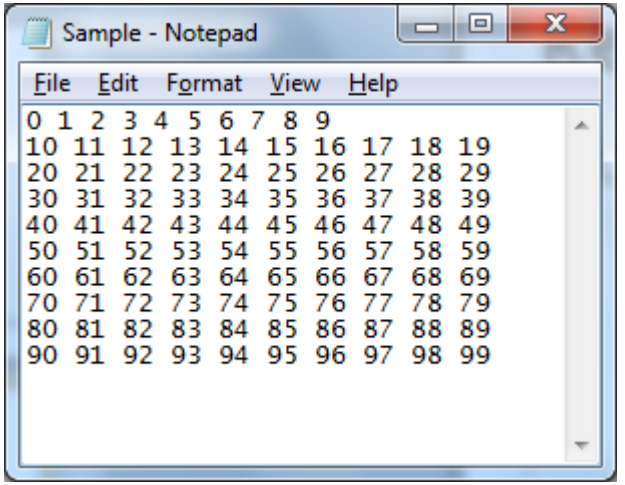
```
[[ 200.   2.   3.]
 [  2.   4.   5.]
 [  4.   5.   7.]
 [  6.   2.   3.]]
```

```
data = np.array([[1, 2, 3], [2, 4,
5], [4, 5, 7], [6, 2, 3]], float)

dataCopyA = np.copy(data)
dataCopyA[0,0] = 200

print (data)
```

```
[[ 1.  2.  3.]
 [ 2.  4.  5.]
 [ 4.  5.  7.]
 [ 6.  2.  3.]]
```

Reading Data From a File

- The code below shows how to read that data depicted in the file Sample.txt, into a two-dimension array.
- *np.genfromtxt* uses *dtype=float* by default
- The function had a broad range of parameters. One import parameter is called the delimiter and allows you to specify the delimiter used in the file you are reading.



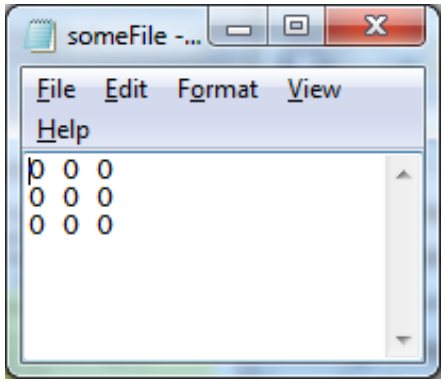

```
import numpy as np


data = np.genfromtxt('Sample.txt', dtype=int)
print (data[0,0])
print (data[1,0])
print (data[2,0])
print (data[3,0])
```

```
0
10
20
30
```

Writing Data To a File

- Use savetxt method to save data from an array to a file. The code below saves the 2D array data to the file called someFile.txt.

```
import numpy as np


data = np.zeros((3,3))

np.savetxt("someFile.txt", data)
```



Use of in statement in M-D Arrays

- The *in* statement can be used to test if values are present in an array:

```
import numpy as np

arr = np.array([[14.4, 2.4, 56.4], [54.3, 34.4, 98.22]], float)

if 2.4 in arr:
    print ("Found")
else:
    print ("Not Found")
```

Other Ways to Create Arrays

- The *arange* function is similar to the range function but returns an numpy array. However, unlike the range function, the arrange function immediately create the NumPy array.
- Only possible to create 1D array with arange
  - But we can reshape arrays (see next slide)

```
import numpy as np

arr1 = np.arange(5, dtype=float)
arr2 = np.arange(1, 6, 2, dtype=int)

print (arr1)
print (arr2)
```

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

[1, 3, 5]
```

Reshaping Arrays

- Arrays can be reshaped by specifying new dimensions.
  - In the example, we turn a ten-element one-dimensional array into a two-dimensional one whose first axis has 10 elements and whose second axis has 10 elements:
  - The capacity of the new array must match exactly the capacity of the original array.

```
import numpy as np


arr1 = np.arange(0,100, dtype=float)
arr2 = arr1.reshape((10, 10))
print (arr2)
```

```
[[ 0.  1.  2.  3.  4.  5.  6.  7.  8.  9.]
 [10. 11. 12. 13. 14. 15. 16. 17. 18. 19.]
 [20. 21. 22. 23. 24. 25. 26. 27. 28. 29.]
 [30. 31. 32. 33. 34. 35. 36. 37. 38. 39.]
 [40. 41. 42. 43. 44. 45. 46. 47. 48. 49.]
 [50. 51. 52. 53. 54. 55. 56. 57. 58. 59.]
 [60. 61. 62. 63. 64. 65. 66. 67. 68. 69.]
 [70. 71. 72. 73. 74. 75. 76. 77. 78. 79.]
 [80. 81. 82. 83. 84. 85. 86. 87. 88. 89.]
 [90. 91. 92. 93. 94. 95. 96. 97. 98. 99.]]
```

Other Ways to Create Arrays

- The functions zeros and ones create new arrays of specified dimensions filled with these values
  - Commonly used functions to create new arrays

```
import numpy as np

arr1 = np.ones((2,3), dtype=float)
arr2 = np.zeros(7, dtype=int)
print (arr1)
print (arr2)
```

```
[[ 1.  1.  1.]
 [ 1.  1.  1.]]

[0 0 0 0 0 0 0]
```

Exercise

- Use np.zeros to create an array with 12 rows and three columns. Print out the array.

- Next use np.reshape to convert it to an array with 6 rows and 6 columns

```
import numpy as np

arr = np.zeros((12, 3), float)

print (arr)

arr2 = np.reshape(arr, (6,6))

print (arr2)
```

Lab Exercises – Bike Sharing Scheme

Lets go back to our bike sharing exercise that we looked at earlier in the lecture.

If I want to calculate the average wind speed with normal file processing I would have to read through every line the in file and add the wind speed to a counter variable.

Discussion

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Thank you

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