Tools & Models for Data Science

Introduction to Python

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Python

- Old language, first appeared in 1991
  - But updated often over the years
- Important characteristics
  - Interpreted
  - Dynamically-typed
  - High level
  - Multi-paradigm (imperative, functional, OO)
  - Generally compact, readable, easy-to-use
- Boom in popularity last five years
  - Now the first programming language learned in many CS departments

Python: Why So Popular for Data Science?

- Dynamic typing/interpreted
  - Type a command, get a result
  - No need for compile/execute/debug cycle
- Quite high-level: easy for non-CS people to pick up
  - Statisticians, mathematicians, physicists...
- More of a general-purpose programming language than R
  - More reasonable target for larger applications
  - More reasonable as API for platforms such as Spark
- Can be used as lightweight wrapper on efficient numerical codes
  - Unlike Java, for example

Python Basics

- Since Python is interpreted, can just fire up Python shell, ipython, or a Jupyter Notebook
  - Then start typing
- A first Python program

```
def Factorial (n):
    if n == 1 or n == 0:
        return 1
    else:
        return n * Factorial (n - 1)

Factorial (12)
```

Python Basics Continued

- Spacing and indentation
  - Indentation is important
  - No begin/end nor {}
  - Indentation signals code block
- Variables
  - No declaration
  - All type checking is dynamic
  - Just use them

Python Basics Continued

- Dictionaries
  - Standard container type is dictionary/map
  - Example: `wordsInDoc = {}` creates an empty dictionary
- Adding Data
  - Add data by saying `wordsInDoc[23] = 16`
  - Now can write something like `if wordsInDoc[23] == 16:` ...
  - What if `wordsInDoc[23]` is not there? Will crash
  - Protect with `wordsInDoc.get(23, 0) ...` returns 0 if key 23 not defined

Encapsulation

- Functions/Procedures
  - Defined using `def myFunc (arg1, arg2):`
  - Make sure to indent!
  - Procedure: no return statement
  - Function: return statement
- Remember:
  - No marker to end function or procedure
  - It ends when you stop indenting

```
def Factorial (n):
     if n == 1 or n == 0:
          return 1
     else:
          return n * Factorial (n - 1)

Factorial (12)
```

Loops

- Several common forms
- Looping through a range of values
  - Of form `for var in range (0, 50)`
  - Loops for `var` in `{0, 1, ..., 49}`
- Looping through data structures
  - Example: `for var in dataStruct`
  - loops through each entry in `dataStruct`
  - `dataStruct` can be an array, or a dictionary
  - If array, you loop through the entries
  - If dictionary, you loop through the keys

Loops Continued

- An example

```
a = {}
a[1] = 'this'
a[2] = 'that'
a[3] = 'other'
for b in a:
    print(a[b])

this
that
other
```

NumPy

- NumPy is a Python package
- Most important one for data science!
  - Can use it to do super-fast math, statistics
  - Most basic type is NumPy array
  - Used to store vectors, matrices, tensors
- You will get some reasonable experience with NumPy
- Load with `import numpy as np`

NumPy Arrays: What Are They?

- Multi-dimensional array data structure
- And associated API
- Widely used for data intensive programming...
  - Linear algebra
  - Data science
  - Machine Learning

NumPy Arrays: Your Best Friend In DS

- Writing control flow code in DS programming is BAD
  - Kind of like in SQL
- Python is interpreted
  - Time for each statement execution generally large
  - And in DS, you have a lot of data
  - So this code can take a long time:

```
for b in range(0, BIG):
    a[b] = b

sum = 0
for b in a:
    sum += a[b]
```

- Fewer statements executed, even if the work is the same...
  - ...means better performance!

To Reduce Number of Statements...

- Use NumPy arrays where possible
- Goal: one line of Python to process entire array!
- Some guidelines:
  - Try to replace dictionaries with NumPy arrays
  - Try to replace loops with bulk array operations
    - Backed by efficient, low-level implementations
  - This is known as “vectorized” programming

Creating and Filling NumPy Arrays

- To create a 2 by 5 array, filled with 3.14

```
>>> np.full((2, 5), 3.14)

array([[ 3.14,  3.14,  3.14,  3.14,  3.14],
       [ 3.14,  3.14,  3.14,  3.14,  3.14]])
```

- To create a 2 by 5 array, filled with 0

```
>>> np.zeros((2, 5))

array([[ 0.,  0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0.]])
```

1D Numpy Arrays vs. Python Lists

- Just like Python lists
- Create an array from a range

```
>>> a = np.arange(1, 11, 2)
array([1, 3, 5, 7, 9])
>>> l = list(range(1, 11, 2))
[1, 3, 5, 7, 9]
```

Accessing Elements

- Just like Python lists

```
>>> a[0]
1
>>> l[0]
1
>>> a[3:]
array([7, 9])
>>> l[3:]
[7,9]
```

Other Useful Numpy Functions

- sqrt – return an array with the square root of each member of the array

  `np.sqrt(a)`

- square – return an array with the square of each member of the array

  `np.square(a)`

- sum - return the sum of the values in the array

  `a.sum()`

Pause Here Until Later

1. Python review
2. Introduction to numpy arrays

? How can we use what we learned today?

? What do we know now that we didn't know before?

More Complicated Creation Examples

- To create an array with odd numbers thru 10

```
>>> np.arange(1, 11, 2)

array([1, 3, 5, 7, 9])
```

- To "tile" an array

```
>>> np.tile (np.arange(1, 11, 2), (1, 2))

array([[1, 3, 5, 7, 9, 1, 3, 5, 7, 9]])

>>> np.tile (np.arange(1, 11, 2), (2, 1))

array([[1, 3, 5, 7, 9],
       [1, 3, 5, 7, 9]])
```

Accessing Subparts of Arrays

- First we create a 2-d array (matrix)

```
>>> a1 = np.arange(1, 6, 1)
>>> a2 = np.arange(2, 7, 1)
>>> a3 = np.arange(3, 8, 1)
>>> a = np.row_stack ((a1, a2, a3))
>>> a

array([[1, 2, 3, 4, 5],
       [2, 3, 4, 5, 6],
       [3, 4, 5, 6, 7]])
```

$$\begin{array}{rccccccc}
 & & & & & & & \text{row} \\
a = & [[\,1\,, & 2\,, & 3\,, & 4\,, & 5\,], & & 0 \\
 & [\,2\,, & 3\,, & 4\,, & 5\,, & 6\,], & & 1 \\
 & [\,3\,, & 4\,, & 5\,, & 6\,, & 7\,]] & & 2 \\
\text{cloumn} & 0 & 1 & 2 & 3 & 4 & &
\end{array}$$

Accessing Subparts of Arrays (cont)

```
array([[1, 2, 3, 4, 5],
       [2, 3, 4, 5, 6],
       [3, 4, 5, 6, 7]])
```

- Say we want first two rows:

  ```
  >>> a[1:,]
  ```

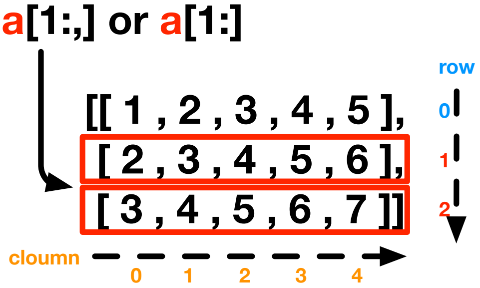
? Will this work?

Accessing Subparts of Arrays (cont)

```
array([[1, 2, 3, 4, 5],
       [2, 3, 4, 5, 6],
       [3, 4, 5, 6, 7]])

>>> a[1:,]

array([[2, 3, 4, 5, 6],
       [3, 4, 5, 6, 7]])

>>> a[1:]
array([[2, 3, 4, 5, 6],
       [3, 4, 5, 6, 7]])
```

- Indices start with 0
- Gets rows 1, 2, 3, and so on

Elements of a from element 1 to the end

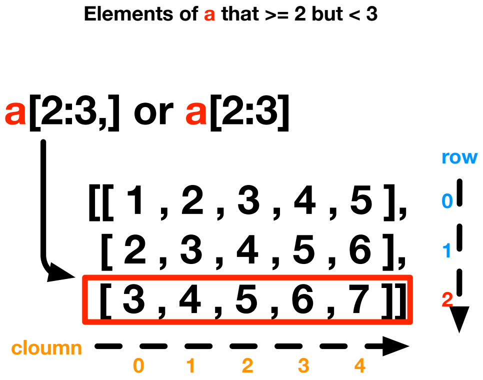


- Say we want the last row:

```
>>> a[2:3,]
array([[3, 4, 5, 6, 7]])

>>> a[2:3]
array([[3, 4, 5, 6, 7]])
```

- Note: still a 2-d array. Want a vector?

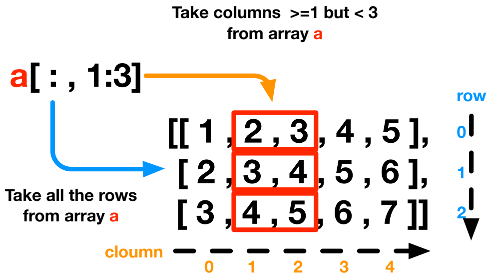
```
>>> a[2:3][0]

array([3, 4, 5, 6, 7])
```



Accessing Subparts of Arrays (cont)

- Now we want the second, third columns:

```
>>> a[:,1:3]

array([[2, 3],
       [3, 4],
       [4, 5]])

>>> a[:,np.array((1,2))]

array([[2, 3],
       [3, 4],
       [4, 5]])
```



Aggregations Over Arrays

- In statistical/data analytics programming...
  - Tabulations: max, min, etc. over NumPy arrays are ubiquitous
- Key operation allowing this is sum

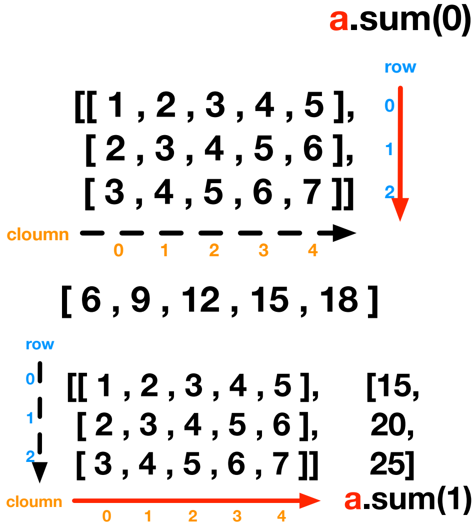
```
>>> a = np.arange(1, 6, 1)
>>> a

array([1, 2, 3, 4, 5])

>>> a.sum ()

15
```

Aggregations Over Arrays (cont)

- Can sum along dimension(s) of higher-d array

```
>>> a

array([[1, 2, 3, 4, 5],
       [2, 3, 4, 5, 6],
       [3, 4, 5, 6, 7]])

>>> a.sum (0)

array([6, 9, 12, 15, 18])

>>> a.sum (1)

array([15, 20, 25])
```

- Think about sum collapsing the array along the specified axis



Aggregations Over Arrays (cont)

- Can find the maximum the same way

```
>>> a
array([[10, 2,  3, 4, 5],
       [ 2, 3, 13, 5, 6],
       [ 3, 4,  5, 6, 7]])

>>> a.max ()

13

>>> a.max (0)

array([10, 4, 13, 6, 7])

>>> a.max (1)

array([10, 13, 7])
```

Aggregations Over Arrays (cont)

- Can find the position of the max as well

```
>>> a

array([[10, 2,  3, 4, 5],
       [ 2, 3, 13, 5, 6],
       [ 3, 4,  5, 6, 7]])

>>> a.argmax ()

7

>>> a.argmax (1)

array([0, 2, 4])
```

Shape

- Get a tuple of array dimensions

```
>>> a

array([[10, 2,  3, 4, 5],
       [ 2, 3, 13, 5, 6],
       [ 3, 4,  5, 6, 7]])

>>> a.shape

(3, 5)
```

Wrap up

1. Python review
2. Introduction to numpy

? How can we use what we learned today?

? What do we know now that we didn't know before?