lecture00_python_tutorial_exercises

September 13, 2016

In [ ]:
```
#-------------------------------------------------#
# PYTHON EXERCISES
# September 12, 2016 #
# EECS 445: Machine Learning #
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# -------------------------------------------------#
```

1 Question 1: Numbers and Data Structures

- Example: If we list all the natural numbers below 10 that are multiples of 3 or 5, we get 3, 5, 6 and 9. The sum of these multiples is 23.
- ***Question: Find the sum of all the multiples of 3 or 5 below 1000 in 3 ways.***
- *Hint 1:* Loop through all the possible numbers, i.e., $x \in \mathbb{N} \wedge x < 1000$ and simply add up the multiples as you go through them. Use two loops first and then try making your code more concise.
- *Bonus:* Use the inclusion-exclusion principle. Write a function that calculates the sum of the first n numbers in an arithmetic series. Hint: $S_n = \frac{n}{2}(u_1 + u_n) = \frac{n}{2}(2u_1 + (n-1) \cdot d)$

In [ ]:
```
# 1. With Loops
# OK, not very "Pythonic"
def sum_of_multiples_with_loop(l, max_):
    total = 0
    # [1, 1000)
    for i in range(1, max_):
        for j in l:
            if i % j == 0:
                total += i
                break
    return total

# With Filter.
# Better (At least more "Pythonic")
def sum_of_multiples_with_loop1(l, max_):
    return sum(filter(lambda k: any(k % i == 0 for i in l), list(range(max_
```

```
print (sum_of_multiples_with_loop([3, 5], 1000))
print (sum_of_multiples_with_loop1([3, 5], 1000))
```

2 Question 2: Strings and Data Structures

Note: *You are free to use any functions and libraries that come with Python.* The aim is not to necessarily implement code from scratch, but to get familiar with Python (specifically the syntax and data structures) and, to some extent, write concise readable working code.

- *** (a): Given a non-empty string like "Code" return a string like "CCoCodCode". ***
- *** (b): Given strings a, b and c, write a function that will replace all occurences of a in b with c. ***
- *** (c): Given a string s that has been Caeser enciphered with a numeric shift n. Return the deciphered string.*** For example, s = "vjku ku c eqfg" and n = -2, returns "this is a code" Note: You can assume the string is all in lowercase without any special characters.
- *** (d): Given a string s, return whether s is a palindrome, i.e, it is spelt the same when read from either direction. *** Note: Ignore case, special characters and spacing.
- *** (e): Using the higher order function filter(), define a function filter_long_words() that takes a list of words and an integer n and returns the list of words that are longer than n (in the same order). ***
- *** (f): Given a string s and a number n, return a list of size n consisting of tuples with two elements, the first being the correct string in the look-and-say-sequence and the second being a dictionary of character: count pairs that is sorted (Hint: Use Ordered Dictionaries and sorted()). *** For example, if s = "1" and n = 5, the look-and-say-sequence is as follows:

```
1 ("1", {"1" : 1}) 11 ("11", {"1" : 2}) 21 ("21", {"1" : 1, "2"
: 1}) 1211 ("1211", {"1" : 3, "2" : 1}) 111221 ("111221", {"1"
: 4, "2" : 2}) correct output: [("1", {"1" : 1}), ("11", {"1" :
2}), ("21", {"1" : 1, "2" : 1}),  ("1211", {"1" : 3, "2" : 1}),
("111221", {"1" : 4, "2" : 2})]
```

In [64]:
```
# Implement part (a) below
def string_repeater(s):
    return ''.join([s[:i] for i in range(len(s) + 1)])

# Implement part (b) below
def string_occurence_remover(a, b, c):
    return b.replace(a, c)

# Implement part (c) below
def caeser_decipher(s, n):
    import string
    return s.translate(str.maketrans(string.ascii_lowercase, string.ascii_

def is_palindrome(s):
```

```
        s = ''.join(c for c in s if c.isalpha()).lower()
        return s == s[::-1]

    def filter_long_words(l, n):
        return list(filter(lambda s: len(s) > n, l))

    def look_and_say(s, n):
        from collections import OrderedDict
        from itertools import groupby, accumulate
        temp = [s for i in range(n)]
        strings = list(accumulate(temp, lambda s_, _: ''.join(str(len(list(g))
        dictionaries = [OrderedDict(sorted({c : strings[seq_index].count(c)
                                            for c in list(set(strings[seq_inde
                        for seq_index in range(len(strings))]
        return list(zip(strings, dictionaries))
```

In [67]:
```
# Simple Tests for part (a)
assert(string_repeater("Code") == "CCoCodCode")
assert(string_repeater("EECS445") == "EEEEECEECSEECS4EECS44EECS445")

# Simple Tests for part (b)
assert(string_occurence_remover("Boring", "PythonIsBoring", "Fun") == "Pyt
assert(string_occurence_remover("12", "Today is September 12 and 12 is my
       "Today is September 9 and 9 is my favorite number.")

# Simple Tests for part (c)
assert(caeser_decipher("vjku ku eqfg", -2) == "this is code")
assert(caeser_decipher("h khjd bnlotsdqr", 1) == "i like computers")

# Simple Tests for part (d)
assert(is_palindrome("Rats live on no evil star."))
assert(is_palindrome("On a clover, if alive, erupts a vast pure evil; a fi
assert(not is_palindrome("Hello, this is Jupyter Notebook speaking."))
assert(not is_palindrome("I am currently in a hands-on lecture."))

# Simple Tests for part (e)
assert(filter_long_words(['a', '', '0', 'a0', 'a0b02030', 'ee', 'cs', 'eec
assert(filter_long_words(['1', '2'], 0) == ['1', '2'])

# Simple Test for part (f)
from collections import OrderedDict
assert(look_and_say("aabbcc", 5) == [('aabbcc', OrderedDict([('a', 2), ('b
 ('2a2b2c', OrderedDict([('2', 3), ('a', 1), ('b', 1), ('c', 1)])),
 ('121a121b121c',
  OrderedDict([('1', 6), ('2', 3), ('a', 1), ('b', 1), ('c', 1)])),
 ('1112111a1112111b1112111c',
  OrderedDict([('1', 18), ('2', 3), ('a', 1), ('b', 1), ('c', 1)])),
 ('3112311a3112311b3112311c',
```

```
OrderedDict([('1', 12), ('2', 3), ('3', 6), ('a', 1), ('b', 1), ('c', 1)
```

3 Question 3: Classes and Interactive I/O

*** (a) Define a class which has at least two methods, getString: to get a string from console input and printString: to print the string in upper case. Also write a simple test to check the functionality class methods. ***

```
In [78]: class StringUppercaseMaker(object):
             def __init__(self):
                 curr_str = None

             def getString(self):
                 self.x = input("Please enter a string.")

             def printString(self):
                 print(self.x.upper())

         test_object = StringUppercaseMaker()
         test_object.getString()
         test_object.printString()
         test_object.printString()
         test_object.getString()
         test_object.printString()
```

```
Please enter a string.Hello
HELLO
HELLO
Please enter a string.Hi
HI
```

*** (b) Write a program able to play the "Guess the number"-game, where the number to be guessed is randomly chosen between 1 and 20.***

(Source: http://inventwithpython.com) This is how it should work when run in a terminal:

```
Hello! What is your name?
Valli
Well, Valli, I am thinking of a number between 1 and 20.
Take a guess.
10
Your guess is too low.
Take a guess.
15
Your guess is too low.
Take a guess.
18
Good job, Valli! You guessed my number in 3 guesses!
```

In [102]:
```
import random
class GuessTheNumber(object):
    # Create a constructor here (__init__ function) that takes two numbe
    # the range that guesses can take. Save these in variable min_guess a
    # initialize a Boolean called incorrect to be true. (Note: Python boo
    def __init__(self, min_guess, max_guess):
        self.min_guess = min_guess
        self.max_guess = max_guess
        self.incorrect = True

    def play(self):
        # Write code to get input from the user and save it into a string
        name = input("Hello! What is your name? ")
        print("Well, " + name + ", I am thinking of a number between " +
              str(self.min_guess) + " and " + str(self.max_guess) + ".\n"
        answer = random.randrange(self.min_guess, self.max_guess + 1)
        # Write the main loop to collect guesses and check whether they a
        # Additionally, if the guess is out of range or input is unexpect
        # simply print an error message and break from the loop.
        count = 0
        while self.incorrect:
            x = int(input("Take a guess. "))
            if x == answer:
                self.incorrect = False
                print("Good job, " + name + "! You guessed my number in "
            else:
                count += 1
                if x > answer:
                    print("Your guess is too high.\n")
                elif x < answer:
                    print("Your guess is too low.\n")
        incorrect = True
```

In [106]:
```
# Test out your game!
g = GuessTheNumber(1, 20)
g.play()
```

```
Hello! What is your name? Anonymous
Well, Anonymous, I am thinking of a number between 1 and 20.

Take a guess. 10
Your guess is too high.

Take a guess. 5
Your guess is too low.

Take a guess. 7
Good job, Anonymous! You guessed my number in 2 guesses.
```

4 Question 4: Pandas and Data Exploration

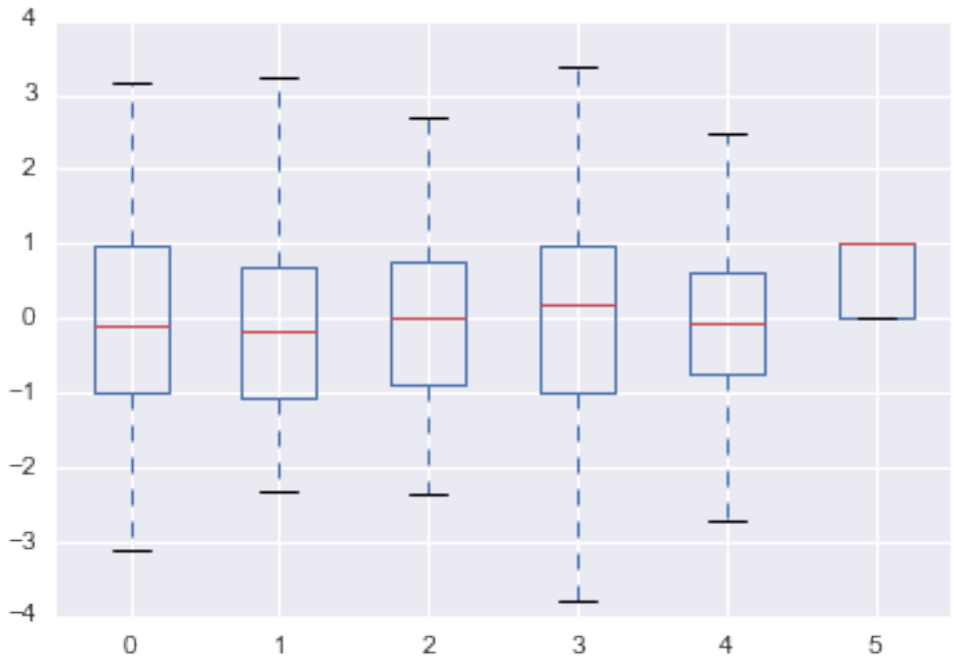
In [6]:
```
# Generate some Data for analysis
from sklearn.datasets import make_classification
X, y = make_classification(1000, n_features=5, n_informative=2,
                           n_redundant=2, n_classes=2, random_state=0)
```

In [7]:
```
# (a) Get a glimpse of the data by making a Pandas DataFrame from the data
# few rows.
import pandas as pd
import numpy as np

df = pd.DataFrame(np.hstack((X, y[:, None])))
print("First few rows: ")
print(df.head())

print("Last few rows: ")
print(df.tail())
```

```
First few rows:
          0         1         2         3         4    5
0 -0.744656 -1.002108 -0.229806  0.834371  0.250114  0.0
1  1.798666 -0.022413  1.666616  0.980480 -0.404352  1.0
2 -0.940481 -1.219292 -0.311325  0.996956 -2.005125  0.0
3  0.567027  0.260004  0.403881 -0.018421 -1.033165  1.0
4  1.352852 -0.507426  1.476739  1.339058 -1.572796  1.0
Last few rows:
            0         1         2         3         4    5
995  1.290408 -0.480536  1.407000  1.272998 -0.950518  1.0
996  1.502635  2.975858  0.029783 -2.853239 -1.774745  1.0
997  0.377319 -0.408477  0.533336  0.700845 -1.171190  1.0
998  1.634704 -1.307860  2.100499  2.469990  1.274045  1.0
999 -1.272671 -1.354099 -0.555906  0.986270 -0.575256  0.0
```

In [8]:
```
# (b) Plot a boxplot of each column to visualize the distribution of the da
%matplotlib inline
ax = df.boxplot()
```

```
/Users/Valli/anaconda/envs/py3k/lib/python3.5/site-packages/ipykernel/__main__.py:3
The default value for 'return_type' will change to 'axes' in a future release.
 To use the future behavior now, set return_type='axes'.
 To keep the previous behavior and silence this warning, set return_type='dict'.
  app.launch_new_instance()
```



In [9]:
```
# (c) Try using the describe() function of the DataFrame.
df.describe()
```

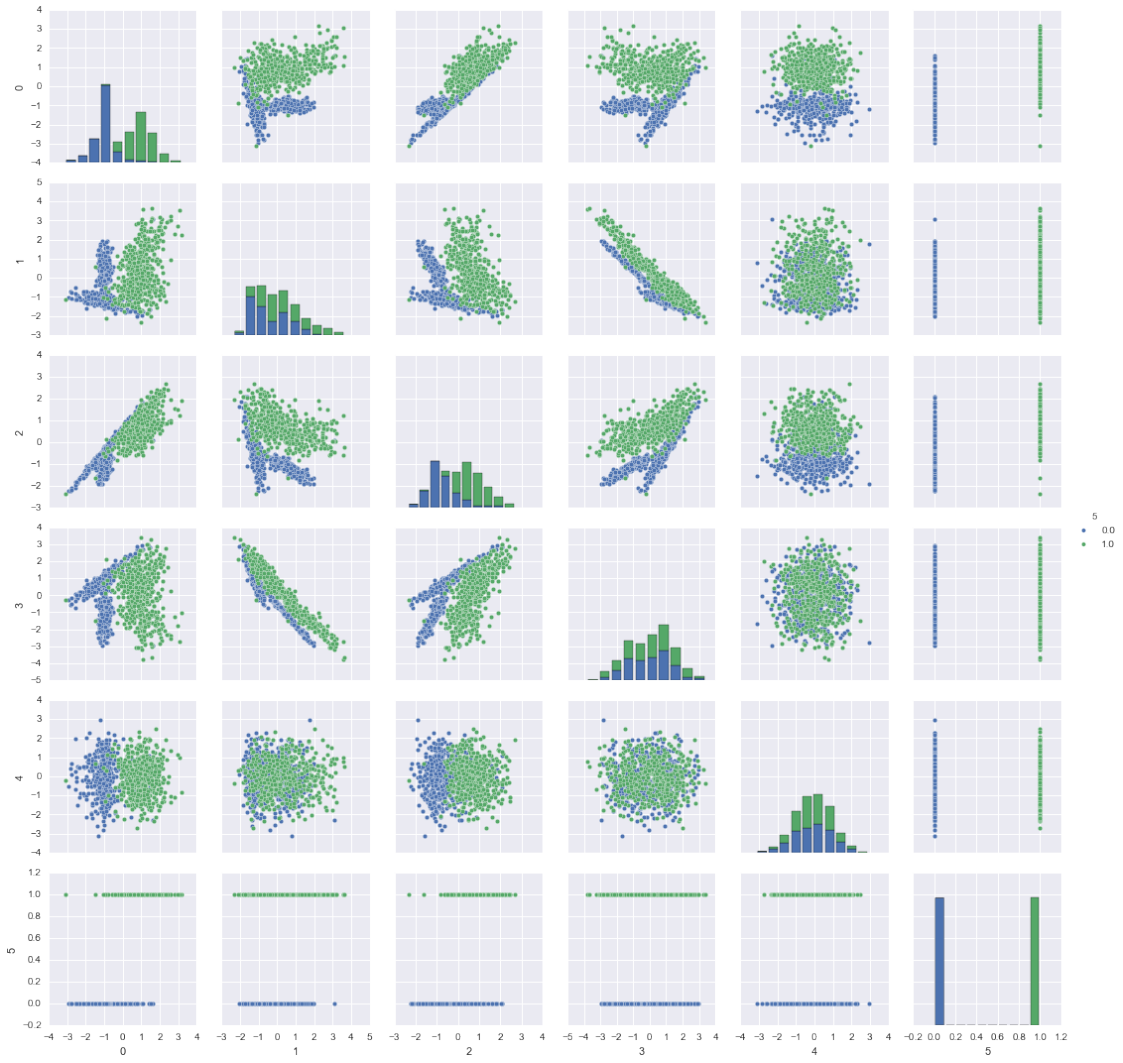
Out[9]:

	0	1	2	3	4	\
count	1000.000000	1000.000000	1000.000000	1000.000000	1000.000000	
mean	-0.026570	-0.035264	-0.008423	0.029168	-0.052110	
std	1.182997	1.166586	1.015775	1.327471	0.954592	
min	-3.107342	-2.339154	-2.346431	-3.806020	-3.116857	
25%	-1.000162	-1.058573	-0.879891	-1.006694	-0.735595	
50%	-0.100546	-0.157854	0.003162	0.185798	-0.050095	
75%	0.975560	0.686004	0.748515	0.987554	0.600995	
max	3.172533	3.646599	2.677722	3.378403	2.929096	

	5
count	1000.000000
mean	0.501000
std	0.500249
min	0.000000
25%	0.000000
50%	1.000000
75%	1.000000
max	1.000000

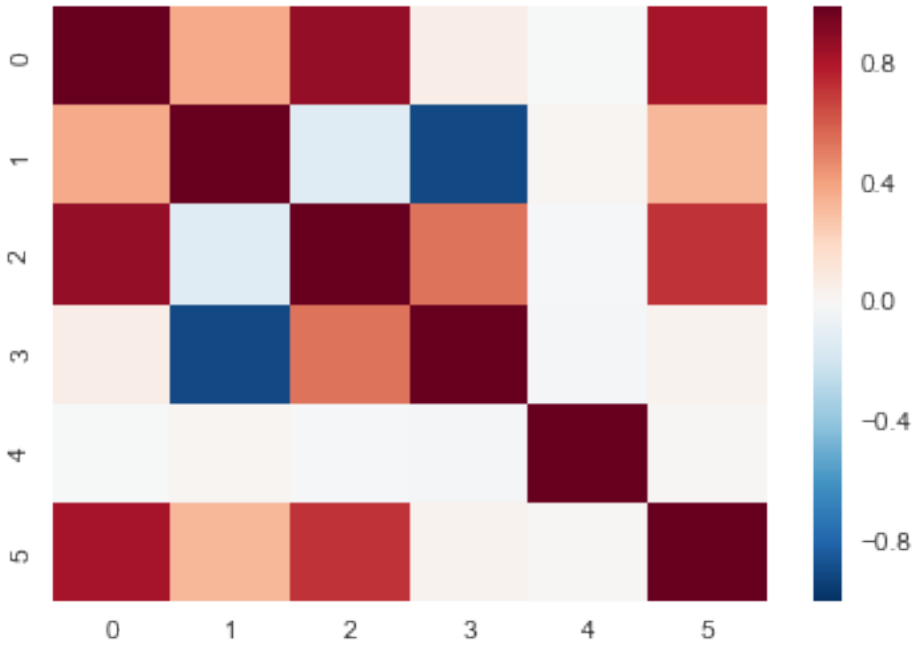
In [12]:
```
# (d) Install Seaborn if it is not already installed and import it below.
import seaborn as sns
sns.pairplot(df, hue=5)
```

Out[12]: <seaborn.axisgrid.PairGrid at 0x11d84d2b0>



In [18]:
```
# (e) Now try Seaborn's correlation plot (Heatmap).
sns.heatmap(df.corr())
```

Out[18]: <matplotlib.axes._subplots.AxesSubplot at 0x122a29908>



In [40]:
```
# (Optional) Using the first 70% of the data as a training set and the las
# and see how well it performs. You will be certainly able to do this at t
train_test_split = int(len(df) * 0.7)

train_df = df[:train_test_split]
train_X = train_df[train_df.columns[:-1]]
train_y = train_df[train_df.columns[-1]]

test_df  = df[train_test_split:]
test_X = test_df[train_df.columns[:-1]]
test_y = test_df[train_df.columns[-1]]

from sklearn.linear_model import SGDClassifier
clf = SGDClassifier(loss='hinge', penalty='l2')

clf.fit(train_X, train_y)
y_train_pred = clf.predict(train_X)
print("Training Accuracy: " + str(sum(i == j for i, j in zip(list(train_y)

y_test_pred = clf.predict(test_X)
print("Test Accuracy: " + str(sum(i == j for i, j in zip(list(test_y), lis
```

```
Training Accuracy: 0.944285714286
Test Accuracy: 0.926666666667
```

5 Question 5: Numpy Exercises

In [385]:
```
# (a) Write a function that takes in a tuple and a string that can either
# be 'zero', 'one' or 'gaussian' and correspondingly return a NumPy array
# assume sampling with mean = 0, std = 1.
def array_with_shape(shape, type_):
    if type_ == 'zero':
        return np.zeros(shape)
    elif type_ == 'one':
        return np.ones(shape)
    elif type_ == 'gaussian':
        return np.random.standard_normal(shape)
    else:
        raise NotImplementedError

print(array_with_shape((3, 10), 'zero'))
print(array_with_shape((5, 2, 3), 'one'))
print(array_with_shape((3, 3), 'gaussian'))
print(array_with_shape((4, 4, 1), 'uniform'))
```

```
[[ 0.  0.  0.  0.  0.  0.  0.  0.  0.  0.]
 [ 0.  0.  0.  0.  0.  0.  0.  0.  0.  0.]
 [ 0.  0.  0.  0.  0.  0.  0.  0.  0.  0.]]
[[[ 1.  1.  1.]
  [ 1.  1.  1.]]

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

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

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

 [[ 1.  1.  1.]
  [ 1.  1.  1.]]]
[[ 1.42420629  0.03745411  2.07203795]
 [ 0.5928345  -0.33875083  0.7768265 ]
 [-0.38344065 -1.03579055 -0.28423047]]
```

```
---------------------------------------------------------------------------
NotImplementedError                       Traceback (most recent call last)

<ipython-input-385-e14f91067560> in <module>()
```

```
     15 print(array_with_shape((5, 2, 3), 'one'))
     16 print(array_with_shape((3, 3), 'gaussian'))
---> 17 print(array_with_shape((4, 4, 1), 'uniform'))


<ipython-input-385-e14f91067560> in array_with_shape(shape, type_)
     10         return np.random.standard_normal(shape)
     11     else:
---> 12         raise NotImplementedError
     13
     14 print(array_with_shape((3, 10), 'zero'))


NotImplementedError:
```

In [389]:
```
# (b) Write a function that returns a n x n identity matrix with n as a p
def identity(n):
    return np.eye(n)

print(identity(1))
print(identity(5))
print(identity(5) * 3.1415926535)
```

```
[[ 1.]]
[[ 1.  0.  0.  0.  0.]
 [ 0.  1.  0.  0.  0.]
 [ 0.  0.  1.  0.  0.]
 [ 0.  0.  0.  1.  0.]
 [ 0.  0.  0.  0.  1.]]
[[ 3.14159265  0.          0.          0.          0.        ]
 [ 0.          3.14159265  0.          0.          0.        ]
 [ 0.          0.          3.14159265  0.          0.        ]
 [ 0.          0.          0.          3.14159265  0.        ]
 [ 0.          0.          0.          0.          3.14159265]]
```

In [400]:
```
# (c) Write a function that normalizes a matrix to [0, 1] and returns the
def normalizer(arr):
    return arr if arr.max() == arr.min() else (arr - arr.min()) / (arr.ma

print(normalizer(array_with_shape((5, 5), 'one'))) # Note: Without the i
print(normalizer(array_with_shape((3, 2, 3), 'gaussian')))
```

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

```
[[[ 0.67485502  0.89618789  0.33424507]
  [ 0.50204285  0.46854452  0.86743627]]

 [[ 0.46105389  0.25583353  0.26624085]
  [ 1.          0.56813732  0.4275101 ]]

 [[ 0.          0.4454402   0.63184115]
  [ 0.49166951  0.34849142  0.40069063]]]
```

```
In [75]: # (d) Write code that creates a NumPy array and makes it immutable.
         def make_immutable(arr):
             arr.flags.writeable = False

         arr = np.array([0, 0, 0])
         make_immutable(arr)
         arr[0] = 1
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)

<ipython-input-75-7125da517e91> in <module>()
  5 arr = np.array([0, 0, 0])
  6 make_immutable(arr)
----> 7 arr[0] = 1


ValueError: assignment destination is read-only
```

```
In [407]: # (e) Write a function that finds the closest value to a given scalar s.
          def closest_element(arr, scalar):
              return arr[np.abs(arr - scalar).argmin()]

          print(closest_element(np.array([-10, 0, 10]), 40))
          print(closest_element(np.array([-10, 0, 10]), -40))
          print(closest_element(np.array([-10, 0, 10]), 0))
          print(closest_element(np.array([-10, 0, 10]), 5.5))
          print(closest_element(np.array([-10, 0, 10]), -5.5))
          print(closest_element(np.array([-10, 0, 10]), 3.5))
          print(closest_element(np.array([-10, 0, 10]), -3.5))
```

```
10
-10
0
10
-10
```

```
0
0
```

```
In [411]: # (f) Write a function that subtracts the mean of each row from a matrix
          def subtract_row_means(arr):
              return arr - arr.mean(axis=1, keepdims=True)

          print(subtract_row_means(np.array([[2, 2], [-1, 1]])))
          print(subtract_row_means(np.array([[1.3, 2.4, 5.6], [5.6, 7.8, 8.9]])))
```

```
[[ 0.  0.]
 [-1.  1.]]
[[-1.8        -0.7         2.5       ]
 [-1.83333333  0.36666667  1.46666667]]
```

```
In [414]: # (g) Write a function that sorts an array by the nth column and returns
          def sort_by_column(arr, n):
              return arr[arr[:, n].argsort()]
          print(sort_by_column(np.array([[-1, 5, 3], [7, 10, -1], [-1, -2, -5]]), 0
          print(sort_by_column(np.array([[-1, 5, 3], [7, 10, -1], [-1, -2, -5]]), 1
          print(sort_by_column(np.array([[-1, 5, 3], [7, 10, -1], [-1, -2, -5]]), 2
```

```
[[-1  5  3]
 [-1 -2 -5]
 [ 7 10 -1]]
[[-1 -2 -5]
 [-1  5  3]
 [ 7 10 -1]]
[[-1 -2 -5]
 [ 7 10 -1]
 [-1  5  3]]
```

6 Question 6: Numpy + First ML algorithm!

```
In [3]: # (a) Write a function that implements Ordinary Least Squares given an inpu
        # We will go over the method in the forthcoming lecture, but the equation i
        # https://en.wikipedia.org/wiki/Linear_regression#Estimation_methods
        # Note: Use NumPy here, but do NOT make use of library functions that do th
```

```
In [290]: def OLS(X_, y_):
              return np.dot(np.linalg.inv(np.dot(X_.T, X_)), np.dot(X_.T, y_))
```

```
In [370]: from sklearn.datasets import make_regression
          X, y = make_regression(1000, n_features=1, noise=20, random_state=0)
```

In [371]:
```
# (b) Run your function on the above data and plot the data as well as th
# generated by your classifer using matplotlib.
```

In [378]:
```
beta1, beta2 = OLS(np.concatenate((np.ones((len(X), 1)), X.reshape((len(X

from matplotlib import pyplot as plt
plt.plot(X, y, 'o', color='turquoise', linewidth=5)

space = np.linspace(min(X), max(X))
plt.plot(space, (beta1 + beta2 * space).squeeze(), 'r-', linewidth=5)
```

Out[378]:
```
[<matplotlib.lines.Line2D at 0x1491652b0>]
```