Linear Regression

May 13, 2019

Linear Regression with one variable

[1]:
```
import numpy as np
import matplotlib.pyplot as plt
from numpy.linalg import pinv
%matplotlib inline
```

Let us define our hypothesis, costFunction and implementaion of gradient Descent in a vectorised way..

[2]:
```
def hypothesis(Theta,X):
    return X@Theta     #Vectorised Implementation
```

[3]:
```
def costFunction(Theta,X,Y):
    m,n = X.shape
    return ((0.5/m)*((hypothesis(Theta,X) - Y).T @ (hypothesis(Theta,X) - Y))).
 ↪item()    #Vectorised Implementation
```

[4]:
```
def gradientDescent(Theta,X,Y,alpha,iterations):
    m,n = X.shape
    for count in range(0,iterations):
        Theta = Theta - (alpha * (1/m)*(X.T @ (hypothesis(Theta,X)-Y)))    ␣
 ↪#Vectorised Implementation
    return Theta
```

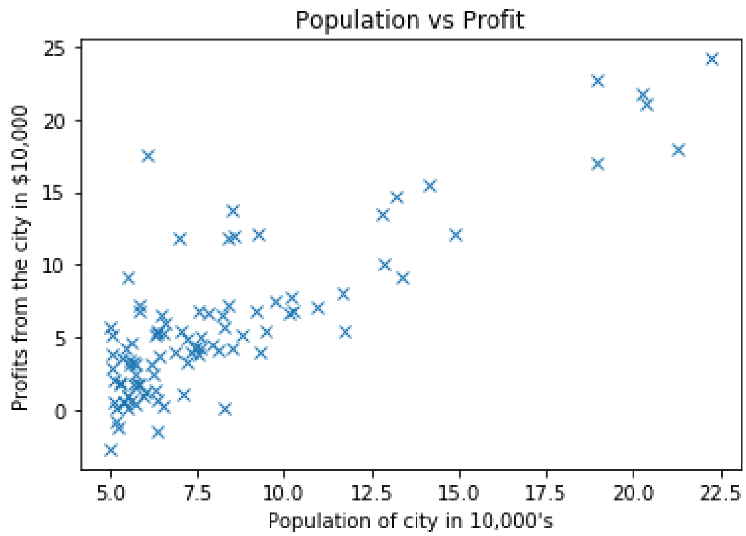
We have the data in csv format as population,profit

[5]:
```
data = np.loadtxt("Data/ex1data1.txt", delimiter=",")
X =  data[:,:-1]
Y =  data[:,-1:]
```

Visualizing data: Population vs Profit

[6]:
```
fig, ax = plt.subplots()
ax.plot(X,Y,ls='', marker = 'x', label='Population vs Profit')
ax.set(xlabel="Population of city in 10,000's", ylabel="Profits from the city␣
 ↪in $10,000", title='Population vs Profit')
```

[6]:
```
[Text(0, 0.5, 'Profits from the city in $10,000'),
 Text(0.5, 0, "Population of city in 10,000's"),
 Text(0.5, 1.0, 'Population vs Profit')]
```



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Converting data into matrices as adding column of ones to X

[7]:
```
X = np.matrix(X)
Y = np.matrix(Y)
m,n = X.shape
X_new = np.hstack((np.ones((m,1)),X))
n = n+1
```

Let us take, theta initially as zeros and set learning rate (alpha) and number of iterations

[8]:
```
initialTheta = np.zeros((n,1))
alpha = 0.01     #Learning rate
iterations = 1500
```

Cost when initial parameters are zero.

[9]:
```
print("Cost when theta is\n",initialTheta,"\nis:␣
↪",costFunction(initialTheta,X_new,Y))
```

```
Cost when theta is
 [[0.]
 [0.]]
is:  32.072733877455676
```

Running Gradient Descent:

[10]:
```
finalTheta = gradientDescent(initialTheta,X_new,Y,alpha,iterations)
print("Optimized parameters after running gradient Descent are: \n",finalTheta)
```

```
Optimized parameters after running gradient Descent are:
 [[-3.63029144]
 [ 1.16636235]]
```

Cost after running Gradient Descent:

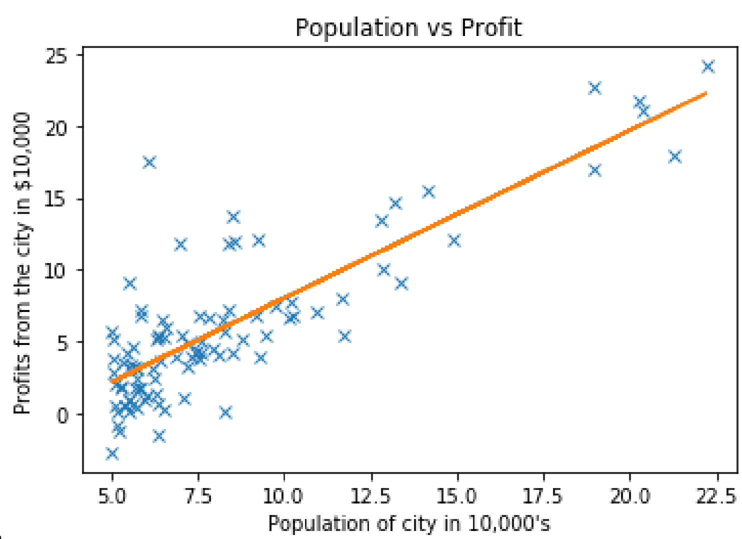
[11]:
```
print("Cost after running gradient Descent is:␣
↪",costFunction(finalTheta,X_new,Y))
```

```
Cost after running gradient Descent is:  4.483388256587725
```

Linear fit after obtaining the values of theta:

[12]:
```
fig, ax = plt.subplots()
ax.plot(X,Y,ls='', marker = 'x', label='Population vs Profit')
ax.plot(X,hypothesis(finalTheta,X_new))
ax.set(xlabel="Population of city in 10,000's", ylabel="Profits from the city␣
↪in $10,000", title='Population vs Profit')
```

[12]:
```
[Text(0, 0.5, 'Profits from the city in $10,000'),
 Text(0.5, 0, "Population of city in 10,000's"),
 Text(0.5, 1.0, 'Population vs Profit')]
```



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Predicting profits for given population using our model:

[13]:
```
print("Profits in $10,000's when the city population is 35,000: ",[1, 3.
↪5]*finalTheta)
print("Profits in $10,000's when the city population is 70,000: ",[1,␣
↪7]*finalTheta)
```

```
Profits in $10,000's when the city population is 35,000:  [[0.45197679]]
Profits in $10,000's when the city population is 70,000:  [[4.53424501]]
```

Linear Regreesion with multivariable
Note: hypothesis, costFunction, gradientDescent are same as above.
Feature Normalization:

[14]:
```
def featureNormalization(X):
    m, n = X.shape
    means = []
    stds = []
    for column in range(1,n):
        mean = X[:,column].mean()
        std = X[:,column].std()
        means.append(mean)
        stds.append(std)
        X[:,column] = (X[:,column] - mean)/std
    return X, means, stds
```

[15]:
```
def predict(X,theta,means,stds):
    X = np.matrix(X)
    m,n = X.shape
    for column in range(1,n):
        X[0:,column] = (X[0:,column] - means[column-1])/stds[column-1]
    return X@theta
```

Loading Data:

[16]:
```
data = np.loadtxt("Data/ex1data2.txt", delimiter=',')
X =  data[:,:-1]
Y =  data[:,-1:]
```

Converting data into matrices, adding column of ones to X and normalizing features:

[17]:
```
X = np.matrix(X)
Y = np.matrix(Y)
m,n = X.shape
X_new = np.hstack((np.ones((m,1)),X))
X_new,means,stds = featureNormalization(X_new)
n = n+1
```

Intializing theta, learning rate and number of iterations:

[18]:
```
initialTheta = np.zeros((n,1))
alpha = 0.01     #Learning rate
iterations = 400
```

Cost when initial parameters are zero.

[19]:
```
print("Cost when theta is\n",initialTheta,"\nis:␣
↪",costFunction(initialTheta,X_new,Y))
```

```
Cost when theta is
 [[0.]
 [0.]
 [0.]]
is:  65591548106.45744
```

Running Gradient Descent:

[20]:
```
finalTheta = gradientDescent(initialTheta,X_new,Y,alpha,iterations)
print("Optimized parameters after running gradient Descent are: \n",finalTheta)
```

```
Optimized parameters after running gradient Descent are:
 [[334302.06399328]
 [ 99411.44947359]
 [  3267.01285407]]
```

Cost after running Gradient Descent:

[21]:
```
print("Cost after running gradient Descent is:␣
↪",costFunction(finalTheta,X_new,Y))
```

```
Cost after running gradient Descent is:  2105448288.6292472
```

Predicting cost of the houses using our model:

[22]:
```
print("Predicted price of a 1650 sq-ft, 3 br house (using gradient descent):␣
↪",predict([1.,1650.,3.],finalTheta,means,stds).item())
```

```
Predicted price of a 1650 sq-ft, 3 br house (using gradient descent):
289221.5473712181
```

Normal equation Method

[23]:
```
def normalEqn(X,y):
    return pinv(X.T@X)@X.T@y
```

Loading Data

[24]:
```
data = np.loadtxt("Data/ex1data2.txt", delimiter=',')
X =  data[:,:-1]
Y =  data[:,-1:]
```

[25]:
```
X = np.matrix(X)
Y = np.matrix(Y)
m,n = X.shape
X_new = np.hstack((np.ones((m,1)),X))
n = n+1
```

Applying normal equation to get theta

[26]:
```
theta = normalEqn(X_new,Y)
```

Predicting values:

[27]:
```
print("Predicted price of a 1650 sq-ft, 3 br house (using normal eqn): ",[1.
↪,1650.,3.]*theta)
```

```
Predicted price of a 1650 sq-ft, 3 br house (using normal eqn):
[[293081.46433497]]
```