Regression

Analysis of Data

8 input features and 2 columns('Y1','Y2') to be predicted. Each column contains numerical values.

Preprocessing Steps

I have checked for duplicate and null values but haven't found any.
All numerical values so no encoding required.

Information about code

I have used an object-oriented approach by creating classes. To create a particular model, I am creating an object for that respective class and then applying fit function on it to improve the model.

Code Approach:

Linear Regression closed form: w = pseudoinverse(X)*y*
Linear Regression gradient descend: w_new = *w - lr(learning rate)*gradient

Test and train errors

Algorithm	Features	Prediction	Test/Train	MSE	MAE	ARE
Univariate Linear Regression (closed form)	X1	Y1	Train	61.68250201	6.21776911	38.134117738
Univariate Linear Regression (closed form)	X1	Y1	Test	62.08100744	5.90770589	25.805453718
Multivariate Linear Regression (closed form)	X1-X8	Y1	Train	8.84171268	2.12887585	10.392177616776
Multivariate Linear Regression (closed form)	X1-X8	Y1	Test	12.38385656	2.87898823	14.85463477721
Multivariate Linear						

Regression (closed form)	X1-X8	Y2	Train	10.58086224	2.26041685	9.35429032241
Multivariate Linear Regression (closed form)	X1-X8	Y2	Test	11.85829312	2.70507949	11.75757983311
Univariate Linear Regression (gradient descend)	X1	Y1	Train	59.10982235	5.90869755	34.20721452726583
Univariate Linear Regression (gradient descend)	X1	Y1	Test	70.32569263	6.15254756	25.068907576532
Multivariate Linear Regression (gradient descend)	X1-X8	Y1	Train	21.03246453	3.53266606	19.04176185612271
Multivariate Linear Regression (gradient descend)	X1-X8	Y1	Test	27.28774608	3.92897355	19.041761856122
Multivariate Linear Regression (gradient descend)	X1-X8	Y2	Train	23.27756416	3.62355348	16.330451019673
Multivariate Linear Regression (gradient descend)	X1-X8	Y2	Test	26.56407074	3.81189368	15.612731124169

Preprocessing

Imports

In [ ]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

from sklearn.preprocessing import LabelEncoder
```

Loading data

In [ ]:
```
main_df = pd.read_excel("./ENB2012_data.xlsx")
```

Data description

In [ ]:
```
main_df.describe()
```

Out[ ]:

	X1	X2	X3	X4	X5	X6	X7	
count	768.000000	768.000000	768.000000	768.000000	768.00000	768.000000	768.000000	7
mean	0.764167	671.708333	318.500000	176.604167	5.25000	3.500000	0.234375	
std	0.105777	88.086116	43.626481	45.165950	1.75114	1.118763	0.133221	
min	0.620000	514.500000	245.000000	110.250000	3.50000	2.000000	0.000000	
25%	0.682500	606.375000	294.000000	140.875000	3.50000	2.750000	0.100000	
50%	0.750000	673.750000	318.500000	183.750000	5.25000	3.500000	0.250000	
75%	0.830000	741.125000	343.000000	220.500000	7.00000	4.250000	0.400000	
max	0.980000	808.500000	416.500000	220.500000	7.00000	5.000000	0.400000	

Checking for null/empty values

In [ ]:
```
main_df.isna().sum()
```

Out[ ]:
```
X1    0
X2    0
X3    0
X4    0
X5    0
X6    0
X7    0
X8    0
Y1    0
Y2    0
dtype: int64
```

In [ ]:
```
(main_df == "?").sum()
```

Out[ ]:
```
X1    0
X2    0
X3    0
X4    0
X5    0
X6    0
X7    0
X8    0
Y1    0
Y2    0
dtype: int64
```

Checking for duplicates

In [ ]:
```
main_df.duplicated().sum()
```

Out[ ]:
```
0
```

In [ ]:
```
main_df.nunique()
```

Out[ ]:
```
X1      12
X2      12
X3       7
X4       4
X5       2
X6       4
X7       4
X8       6
Y1     587
Y2     636
dtype: int64
```

Common Functions

Mean squared error function

In [ ]:
```
def MSE(y,ypred):
  return sum((y - ypred)**2)/ypred.shape[0]
```

Mean absolute error function

In [ ]:
```
def MAE(y,ypred):
  return sum(abs(y-ypred))/ypred.shape[0]
```

Absolute relative error function

In [ ]:
```
def ARE(y,ypred):
    return ((100/y.size)*np.sum((np.abs(y-ypred)/(np.abs(y) + 0.01))))
```

Function to split training and test data

In [ ]:
```
def train_test_split(X,y,train_size):
    a = int(X.shape[0]*train_size)
    b = X.shape[0]-a
    return X[:a],X[b:],y[:a],y[b:]
```

In [ ]:
```
def Normalize(X):
    return (X - np.mean(X,axis=0))/np.std(X,axis=0)
```

Linear Regression

Linear regression class

In [ ]:
```
from array import array
from operator import matmul


class LinReg:
    w = np.identity(1)
    cost = np.array([])
    def fit(self,x,y):
        global w
        a,b = x.shape
        x0 = np.ones((a,1))
        X = np.hstack((x0,x))
        xTx = matmul(X.transpose(),X)
        pinv = matmul(np.linalg.inv(xTx),X.transpose()) #pseudo-inverse
        w = matmul(pinv,y)
        return w

    def hypo(self,w,x):
        return matmul(w.transpose(),x)

    def gd_fit(self,w_ini,x,y,lr,itrs):
        global w,cost
        cost = np.array([])
        w = w_ini
        a,b = x.shape
        x0 = np.ones((a,1))
        X = np.hstack((x0,x))
        for k in range(itrs):
            for i in range(b+1):
                sum = 0
                for j in range(a):
                    sum += (matmul(w_ini.transpose(),X[j]) - y[j])*X[j][i
                grad = (lr*sum)/a # gradient
                w[i] = w_ini[i] - grad
            cost =   np.append(cost,MSE(y,self.predict(x)))
            w_ini = w
        return cost;

    def predict(self,x):
        global w
        a,b = x.shape
        x0 = np.ones((a,1))
        X = np.hstack((x0,x))
        return matmul(w.transpose(),X.transpose()).transpose()
```

Linear Regression (Univariate)

In [ ]:
```
X = main_df[['X1']].to_numpy().astype(np.float64)
y = main_df[['Y1']].to_numpy().astype(np.float64)

train_X, test_X, train_y, test_y = train_test_split(X, y, train_size=0.6)
```

In [ ]:
```
ulr_model = LinReg()
w = ulr_model.fit(X,y)
print(w)
train_yhat = ulr_model.predict(train_X)
test_yhat = ulr_model.predict(test_X)
```

```
[[-23.05301406]
 [ 59.35905261]]
```

In [ ]:
```
print(MSE(train_y,train_yhat))
```

```
[61.68250201]
```

In [ ]:
```
print(MAE(train_y,train_yhat))
```

```
[6.21776911]
```

In [ ]:
```
print(ARE(train_y,train_yhat))
```

```
38.13411773882514
```

In [ ]:
```
print(MSE(test_y,test_yhat))
```

```
[62.08100744]
```

In [ ]:
```
print(MAE(test_y,test_yhat))
```

```
[5.90770589]
```

In [ ]:
```
print(ARE(test_y,test_yhat))
```

```
25.805453718034787
```

Linear Regression Multivariate

Predicting 'Y1'

In [ ]:
```
X = main_df[['X1','X2','X3','X4','X5','X6','X7','X8']].to_numpy().astype(
y = main_df[['Y1']].to_numpy().astype(np.float64)
X = Normalize(X)
train_X, test_X, train_y, test_y = train_test_split(X, y, train_size=0.6)

mlr_model = LinReg()
cost = mlr_model.fit(train_X,train_y)


train_yhat = mlr_model.predict(train_X)
test_yhat = mlr_model.predict(test_X)
```

In [ ]:
```
print(MSE(train_y,train_yhat))
```

```
[8.84171268]
```

In [ ]:
```
print(MAE(train_y,train_yhat))
```

```
[2.12887585]
```

In [ ]:
```
print(ARE(train_y,train_yhat))
```

```
10.392177616776301
```

In [ ]:
```
print(MSE(test_y,test_yhat))
```

```
[12.38385656]
```

In [ ]:
```
print(MAE(test_y,test_yhat))
```

```
[2.87898823]
```

In [ ]:
```
print(ARE(test_y,test_yhat))
```

```
14.85463477721348
```

Predicting 'Y2'

In [ ]:
```
X = main_df[['X1','X2','X3','X4','X5','X6','X7','X8']].to_numpy().astype(
y = main_df[['Y2']].to_numpy().astype(np.float64)
X = Normalize(X)
train_X, test_X, train_y, test_y = train_test_split(X, y, train_size=0.6)

mlr_model = LinReg()
cost = mlr_model.fit(train_X,train_y)


train_yhat = mlr_model.predict(train_X)
test_yhat = mlr_model.predict(test_X)
```

In [ ]:
```
print(MSE(train_y,train_yhat))
```

```
[10.58086224]
```

In [ ]:
```
print(MAE(train_y,train_yhat))
```

```
[2.26041685]
```

In [ ]:
```
print(ARE(train_y,train_yhat))
```

```
9.354290322412705
```

In [ ]:
```
print(MSE(test_y,test_yhat))
```

```
[11.85829312]
```

In [ ]:
```
print(MAE(test_y,test_yhat))
```

```
[2.70507949]
```

In [ ]:
```
print(ARE(test_y,test_yhat))
```

```
11.757579833118074
```

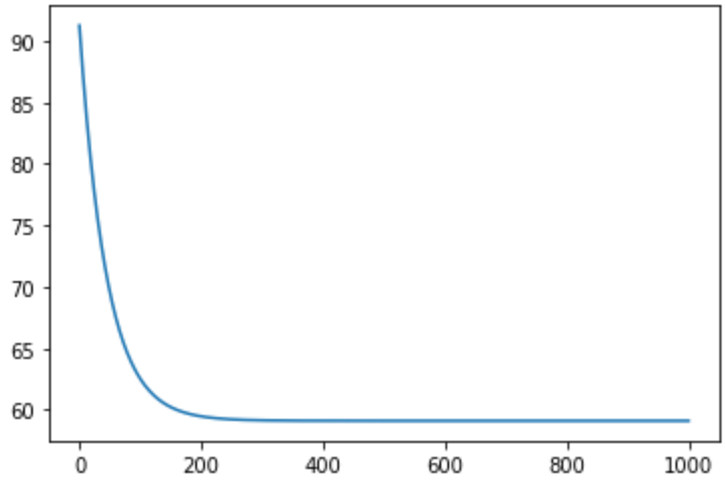
Linear Regression (Gradient descend) - Univariate

In [ ]:
```
X = main_df[['X1']].to_numpy().astype(np.float64)
y = main_df[['Y1']].to_numpy().astype(np.float64)

train_X, test_X, train_y, test_y = train_test_split(X, y, train_size=0.6)

ulr_gd_model = LinReg()
cost = ulr_gd_model.gd_fit(np.ones((train_X.shape[1]+1,1)),train_X,train_

train_yhat = ulr_gd_model.predict(train_X)
test_yhat = ulr_gd_model.predict(test_X)
```

Plotting cost vs iterations

In [ ]:
```
plt.plot(cost)
```

Out[ ]: [<matplotlib.lines.Line2D at 0x7f6a423ecdf0>]



In [ ]:
```
print(MSE(train_y,train_yhat))
```
```
[59.10982235]
```

In [ ]:
```
print(MAE(train_y,train_yhat))
```
```
[5.90869755]
```

In [ ]:
```
print(ARE(train_y,train_yhat))
```
```
34.20721452726583
```

In [ ]:
```
print(MSE(test_y,test_yhat))
```
```
[70.32569263]
```

In [ ]:
```
print(MAE(test_y,test_yhat))
```
```
[6.15254756]
```

In [ ]:
```
print(ARE(test_y,test_yhat))
```
```
25.068907576532233
```

Linear Regression (Gradient descend) - Multivariate

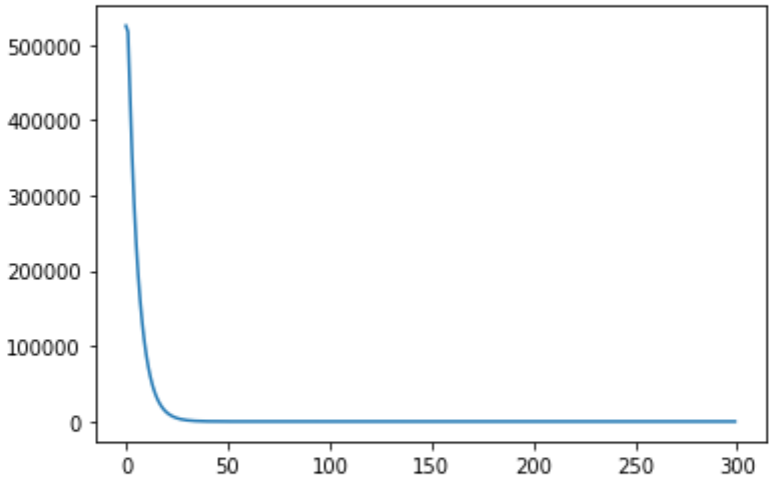
Predicting Y1

In [ ]:
```
X = main_df[['X1','X2','X3','X4','X5','X6','X7','X8']].to_numpy().astype(
y = main_df[['Y1']].to_numpy().astype(np.float64)

train_X, test_X, train_y, test_y = train_test_split(X, y, train_size=0.6)

mlr_gd_model = LinReg()
cost = mlr_gd_model.gd_fit(np.ones((train_X.shape[1]+1,1)),train_X,train_


train_yhat = mlr_gd_model.predict(train_X)
test_yhat = mlr_gd_model.predict(test_X)
```

graph of cost vs iterations

In [ ]:
```
plt.plot(cost)
```

Out[ ]: [<matplotlib.lines.Line2D at 0x7f6a42290a30>]



In [ ]:
```
print(MSE(train_y,train_yhat))
```

[21.03246453]

In [ ]:
```
print(MAE(train_y,train_yhat))
```

[3.53266606]

In [ ]:
```
print(ARE(train_y,train_yhat))
```

19.04176185612271

In [ ]:
```
print(MSE(test_y,test_yhat))
```

[27.28774608]

In [ ]:
```
print(MAE(test_y,test_yhat))
```

[3.92897355]

In [ ]:
```
print(ARE(train_y,train_yhat))
```

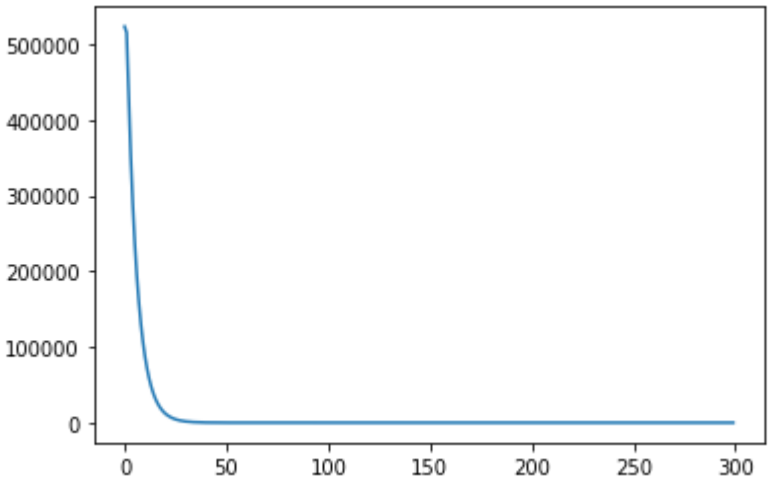
19.04176185612271

Predicting 'Y2'

In [ ]:
```
X = main_df[['X1','X2','X3','X4','X5','X6','X7','X8']].to_numpy().astype(
y = main_df[['Y2']].to_numpy().astype(np.float64)

train_X, test_X, train_y, test_y = train_test_split(X, y, train_size=0.6)

mlr_gd_model = LinReg()
cost = mlr_gd_model.gd_fit(np.ones((train_X.shape[1]+1,1)),train_X,train_


train_yhat = mlr_gd_model.predict(train_X)
test_yhat = mlr_gd_model.predict(test_X)
```

In [ ]:
```
plt.plot(cost)
```

Out[ ]: [<matplotlib.lines.Line2D at 0x7f6a422adc90>]



In [ ]:
```
print(MSE(train_y,train_yhat))
```
```
[23.27756416]
```

In [ ]:
```
print(MAE(train_y,train_yhat))
```
```
[3.62355348]
```

In [ ]:
```
print(ARE(train_y,train_yhat))
```
```
16.330451019673554
```

In [ ]:
```
print(MSE(test_y,test_yhat))
```
```
[26.56407074]
```

In [ ]:
```
print(MAE(test_y,test_yhat))
```
```
[3.81189368]
```

In [ ]:
```
print(ARE(test_y,test_yhat))
```
```
15.61273112416903
```