Linear Regression - Penalized Model

In [ ]:
```
#Table like structure
import pandas as pd

#numerical computation
import numpy as np


#scikit learn
#Ridge regression model
from sklearn.linear_model import Ridge

from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_squared_error, r2_score

#Simple decision tree
from sklearn.tree import DecisionTreeRegressor
from math import sqrt




#import pytorch
import torch
import torch.nn as nn
import torch.optim as optim
#Need for normalizing the data
from sklearn.preprocessing import StandardScaler

#For generating graphs
import matplotlib.pyplot as plt
```

In [ ]:
```
# Load the dataset and show its first 5 rows
data = pd.read_excel('.\\Dataset #1 - Regression (Brain Age Prediction)\\Volumetric_features.xlsx')
data.head()
```

Out[ ]:

	S.No	Left-Lateral-Ventricle	Left-Inf-Lat-Vent	Left-Cerebellum-White-Matter	Left-Cerebellum-Cortex	Left-Thalamus	Left-Caudate	Left-Putamen	Left-Pallidum	3rd-Ventricle	...	rh_supramarginal_thickness	rh_frontalpole_thickness	rh_temporalpole_thickness	rh_transversetemporal_thickness	rh_insula_thickness	rh_MeanThickness
0	1	22916.9	982.7	15196.7	55796.4	6855.5	2956.4	4240.7	2223.9	2034.4	...	2.408	2.629	3.519	2.009	2.825	
1	2	22953.2	984.5	15289.7	55778.6	6835.1	3064.2	4498.6	2354.1	1927.1	...	2.417	2.640	3.488	2.111	2.720	
2	3	23320.4	1062.1	15382.1	55551.2	7566.0	3231.7	4456.2	1995.4	2064.7	...	2.374	2.601	3.342	2.146	2.684	
3	4	24360.0	1000.5	14805.4	54041.8	8004.6	3137.3	4262.2	1983.4	2017.7	...	2.366	2.639	3.361	2.056	2.700	
4	5	25769.4	1124.4	16331.1	54108.6	6677.4	2964.4	4204.6	2409.7	2251.8	...	2.381	2.555	3.450	2.052	2.574	

5 rows × 141 columns

In [ ]:
```
# Split the data into training and testing sets. The output label of the data is the age
#80% data is for training and 20% for testing
X_train, X_test, y_train, y_test = train_test_split(data.drop('Age', axis=1), data['Age'], test_size=0.2, random_state=0)
X_train.head() # print the first 5 records
```

Out[ ]:

	S.No	Left-Lateral-Ventricle	Left-Inf-Lat-Vent	Left-Cerebellum-White-Matter	Left-Cerebellum-Cortex	Left-Thalamus	Left-Caudate	Left-Putamen	Left-Pallidum	3rd-Ventricle	...	rh_superiortemporal_thickness	rh_supramarginal_thickness	rh_frontalpole_thickness	rh_temporalpole_thickness	rh_transversetemporal_thickness	rh
883	884	18276.2	488.6	15488.8	60165.9	6753.3	3973.9	5154.7	2247.5	2230.6	...	2.531	2.323	2.423	3.351	2.447	
2404	2405	19564.2	1550.6	11636.4	50535.2	5335.3	3155.9	3791.9	1453.2	1918.1	...	2.708	2.330	2.502	2.974	2.195	
1699	1700	14076.8	718.0	17377.2	54915.0	7591.1	3143.6	4072.2	1816.3	1710.6	...	2.872	2.436	2.518	3.961	2.571	
3380	3381	9147.3	274.4	14968.5	55712.8	7974.4	3665.7	6010.0	2108.9	981.6	...	2.807	2.555	2.814	3.612	2.269	
2284	2285	16839.5	1651.2	12847.5	41962.7	4724.7	3129.7	3110.3	1389.7	1917.6	...	2.184	2.076	2.528	2.447	2.080	

5 rows × 140 columns

In [ ]:
```
#Number of data points and number of features for each data point
print(X_train.shape)
```

```
(3380, 140)
```

In [ ]:
```
# Fit the model
#Penalty
regularization_strength = 0.5
model_ridge = Ridge(alpha=regularization_strength)
model_ridge.fit(X_train, y_train)

# Calculate the mean squared error on train data
y_pred = model_ridge.predict(X_train)
mse_train = mean_squared_error(y_train, y_pred)
rmse_train = sqrt(mse_train)
r2_score_train = r2_score(y_train, y_pred)

print('Ridge regression: Train')
print('Train Mean squared error (MSE): ', mse_train)
print('Train Root Mean squared error (RMSE): ', rmse_train)
print('Train R2 Score: ', r2_score_train)
```

```
Ridge regression: Train
Train Mean squared error (MSE):  54.36301773508804
Train Root Mean squared error (RMSE):  7.373486405595985
Train R2 Score:  0.8633872637090052
```

In [ ]:
```
# Calculate the test mean squared error
y_pred = model_ridge.predict(X_test)
mse_test = mean_squared_error(y_test, y_pred)

rmse_test = sqrt(mse_test)
r2_score_test = r2_score(y_test, y_pred)

print('Ridge regression: Test')
print('Test Mean squared error (MSE): ', mse_test)
print('Test Root Mean squared error (RMSE): ', rmse_test)
print('R2 Score: ', r2_score_test)
```

```
Ridge regression: Test
Test Mean squared error (MSE):  62.92794690818672
Test Root Mean squared error (RMSE):  7.932714977117652
R2 Score:  0.8501465123979921
```

In [ ]:
```
print('Ridge regression: Sample predictions')
# Make predictions on the test set
y_pred = model_ridge.predict(X_test)[:20]
#Print first 20 actual and predicted values
print('  Actual labels:  {} \n Predicted labels: {}'.format(np.array(y_test)[:20], y_pred))
```

```
Ridge regression: Sample predictions
  Actual labels:  [27 58 81 53 80 30 60 27 19 90 54 26 74 81 76 77 24 94 23 86]
 Predicted labels: [23.56209146 48.59179565 67.93996086 49.69093248 86.89987233 30.10547221
 64.27179457 27.82982003 33.91326673 87.09330768 29.86808956 26.70476231
 75.02546906 67.7584405  65.67257159 82.93490117 30.04493486 84.79482934
 29.55680278 73.23445662]
```

Non-Linear Regression - Neural Nets Model

In [ ]:
```
#Reloading the data. Not necessary
# Load the dataset
data = pd.read_excel('.\\Dataset #1 - Regression (Brain Age Prediction)\\Volumetric_features.xlsx')

# Split the data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(data.drop('Age', axis=1), data['Age'], test_size=0.2, random_state=0)
```

In [ ]:
```
# Scale the input data
scaler = StandardScaler()

#Scale the data
X_train = scaler.fit_transform(X_train)
X_test = scaler.transform(X_test)

# Convert the data to tensors: train
inputs = torch.tensor(X_train, dtype=torch.float32)
targets = torch.tensor(y_train.values, dtype=torch.float32).unsqueeze(1)

inputs_test = torch.tensor(X_test, dtype=torch.float32)
targets_test = torch.tensor(y_test.values, dtype=torch.float32).unsqueeze(1)
```

In [ ]:
```
# Four layers Neural network model
#ReLu is the activation function
class NonLinearRegressionNet(nn.Module):
    def __init__(self, Input, Output):
        super(NonLinearRegressionNet, self).__init__()

        self.fc1 = nn.Linear(Input, 64)
        self.fc2 = nn.Linear(64, 32)
        self.fc3 = nn.Linear(32, 16)
        self.fc4 = nn.Linear(16, Output)

    def forward(self, x):
        x = torch.relu(self.fc1(x))
        x = torch.relu(self.fc2(x))
        x = torch.relu(self.fc3(x))
        x = self.fc4(x)
        return x
```

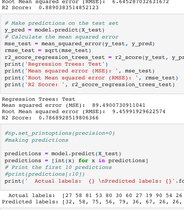
In [ ]:
```
# Create an instance of the model with input dimensions
model = NonLinearRegressionNet(Input=140, Output=1) # Input_dimension is 140 (140 features)

# Define the loss function and optimizer
criterion = nn.MSELoss()
learning_rate = 0.001
optimizer = optim.Adam(model.parameters(), lr=learning_rate)
num_epochs = 2000
```

In [ ]:
```
# Train the model
Loss = []
for epoch in range(num_epochs):
    #-----------------------Forward pass--------------------------
    outputs = model(inputs)
    loss = criterion(outputs, targets)
    #-----------------Backward and optimize-------------------
    optimizer.zero_grad()
    loss.backward()
    optimizer.step()
    Loss.append(loss)
    # Print progress
    if (epoch+1) % 200 == 0:
        print(f'----------Epoch {(}/{}----------- \n Train Loss: {:.2f}'
              .format(epoch+1, num_epochs, loss.item()))
```

```
----------Epoch 200/2000----------
Train Loss: 308.09
----------Epoch 400/2000----------
Train Loss: 81.62
----------Epoch 600/2000----------
Train Loss: 39.02
----------Epoch 800/2000----------
Train Loss: 21.73
----------Epoch 1000/2000----------
Train Loss: 12.67
----------Epoch 1200/2000----------
Train Loss: 8.01
----------Epoch 1400/2000----------
Train Loss: 5.30
----------Epoch 1600/2000----------
Train Loss: 3.76
----------Epoch 1800/2000----------
Train Loss: 2.84
----------Epoch 2000/2000----------
Train Loss: 2.15
```

In [ ]:
```
with torch.no_grad():
    plt.plot(Loss)
    plt.xlabel('Epochs')
    plt.ylabel('MSE')
    plt.legend('train')
```



In [ ]:
```
#----------------------Make predictions on training data----------------------
with torch.no_grad():
    predicted = model(inputs)
    mse_train = criterion(predicted, targets)
    rmse_train = sqrt(train_loss)
    r2_score_train = r2_score(targets, predicted)



    print('Nonlinear Regression: NNet: Train')
    print('Test Mean squared error (MSE): ', mse_train)
    print('Test Root Mean squared error (RMSE): ', rmse_train)
    print('R2 Score: ', r2_score_train)
```

```
Nonlinear Regression: NNet: Train
Test Mean squared error (MSE):  tensor(2.1176)
Test Root Mean squared error (RMSE):  1.4551131896599676
R2 Score:  0.9946796644538853
```

In [ ]:
```
with torch.no_grad():
    test_predictions = model(inputs_test)
    mse_test = criterion(test_predictions, targets_test)
    rmse_test = sqrt(mse_test)
    r2_score_test = r2_score(targets_test, test_predictions)



    print('Nonlinear Regression: NNet: Test')
    print('Test Mean squared error (MSE): ', mse_test)
    print('Test Root Mean squared error (RMSE): ', rmse_test)
    print('R2 Score: ', r2_score_test)
```

```
Nonlinear Regression: NNet: Test
Test Mean squared error (MSE):  tensor(77.7614)
Test Root Mean squared error (RMSE):  8.818242259757964
R2 Score:  0.8148229551275514
```

In [ ]:
```
# Print the first 20 predictions
test_predictions = [int(x) for x in test_predictions]
print('test_predictions: {} \n  Actual output : {}'.format(np.array(y_test)[:20],(test_predictions[:20])))
```

```
test_predictions: [27 58 81 53 80 30 60 27 19 90 54 26 74 81 76 77 24 94 23 86]
  Actual output : [26, 61, 70, 54, 89, 33, 71, 26, 26, 83, 61, 37, 67, 68, 73, 74, 25, 91, 29, 78]
```

In [ ]:
```

```

Regression Trees

In [ ]:
```
# Load the dataset
# Reloading as it has been updated in the previous cells
data = pd.read_excel('.\\Dataset #1 - Regression (Brain Age Prediction)\\Volumetric_features.xlsx')

# Split the data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(data.drop('Age', axis=1), data['Age'], test_size=0.2, random_state=0)
```

In [ ]:
```
# Fit the model
model = DecisionTreeRegressor(criterion='squared_error', splitter='best',max_depth=7)
model.fit(X_train, y_train)
```

Out[ ]:
```
DecisionTreeRegressor(max_depth=7)
```

In [ ]:
```
# Make predictions on the train set
y_pred = model.predict(X_train)
# Calculate the mean squared error
mse_train = mean_squared_error(y_train, y_pred)
rmse_train = sqrt(mse_train)
r2_score_regression_trees_train = r2_score(y_train, y_pred)
print('Regression Trees: Train')
print('Mean squared error (MSE) : ', mse_train)
print('Root Mean squared error (RMSE): ', rmse_train)
print('R2 Score: ', r2_score_regression_trees_train)
```

```
Regression Trees: Train
Mean squared error (MSE):  44.15983974606266
Root Mean squared error (RMSE):  6.645287032631672
R2 Score:  0.8899382514852112
```

In [ ]:
```
# Make predictions on the test set
y_pred = model.predict(X_test)
# Calculate the mean squared error
mse_test = mean_squared_error(y_test, y_pred)
rmse_test = sqrt(mse_test)
r2_score_regression_trees_test = r2_score(y_test, y_pred)
print('Regression Trees: Test')
print('Mean squared error (MSE) : ', mse_test)
print('Root Mean squared error (RMSE): ', rmse_test)
print('R2 Score: ', r2_score_regression_trees_test)
```

```
Regression Trees: Test
Mean squared error (MSE):  89.49007309310941
Root Mean squared error (RMSE):  9.459919296225274
R2 Score:  0.7868928519983686
```

In [ ]:
```
#np.set_printoptions(precision=0)
#making predictions

predictions = model.predict(X_test)
predictions = [int(x) for x in predictions]
# Print the first 10 predictions
#print(predictions[:10])
print('  Actual labels:  {} \nPredicted labels: {}'.format(np.array(y_test)[:20]), predictions[:20]))
```

```
  Actual labels:  [27 58 81 53 80 30 60 27 19 90 54 26 74 81 76 77 24 94 23 86]
Predicted labels: [32, 59, 75, 54, 79, 36, 67, 26, 26, 88, 51, 32, 72, 75, 75, 76, 26, 88, 42, 72]
```

In [ ]:
```

```