CreditRisk

March 17, 2022

[1]:

```
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
from sklearn.preprocessing import MinMaxScaler
from matplotlib import pyplot as plt
from scipy import linalg
import matplotlib.pyplot as plt
from scipy import stats
import seaborn as sns
```

[2]:

```
Df = pd.read_csv("cs-training.csv", index_col = 0)
print(len(Df))
Df = Df.dropna()
print(len(Df))
X_Cols = list(Df.columns)
X_Cols.remove("SeriousDlqin2yrs")
X = Df[X_Cols].to_numpy()
Y = Df["SeriousDlqin2yrs"].to_numpy()
```

```
150000
120269
```

[3]:

```
X_Train, X_Test, Y_Train, Y_Test = train_test_split(X, Y, test_size = 0.33,␣
 ↪random_state = 42)
```

[4]:

```
len(X_Train)
```

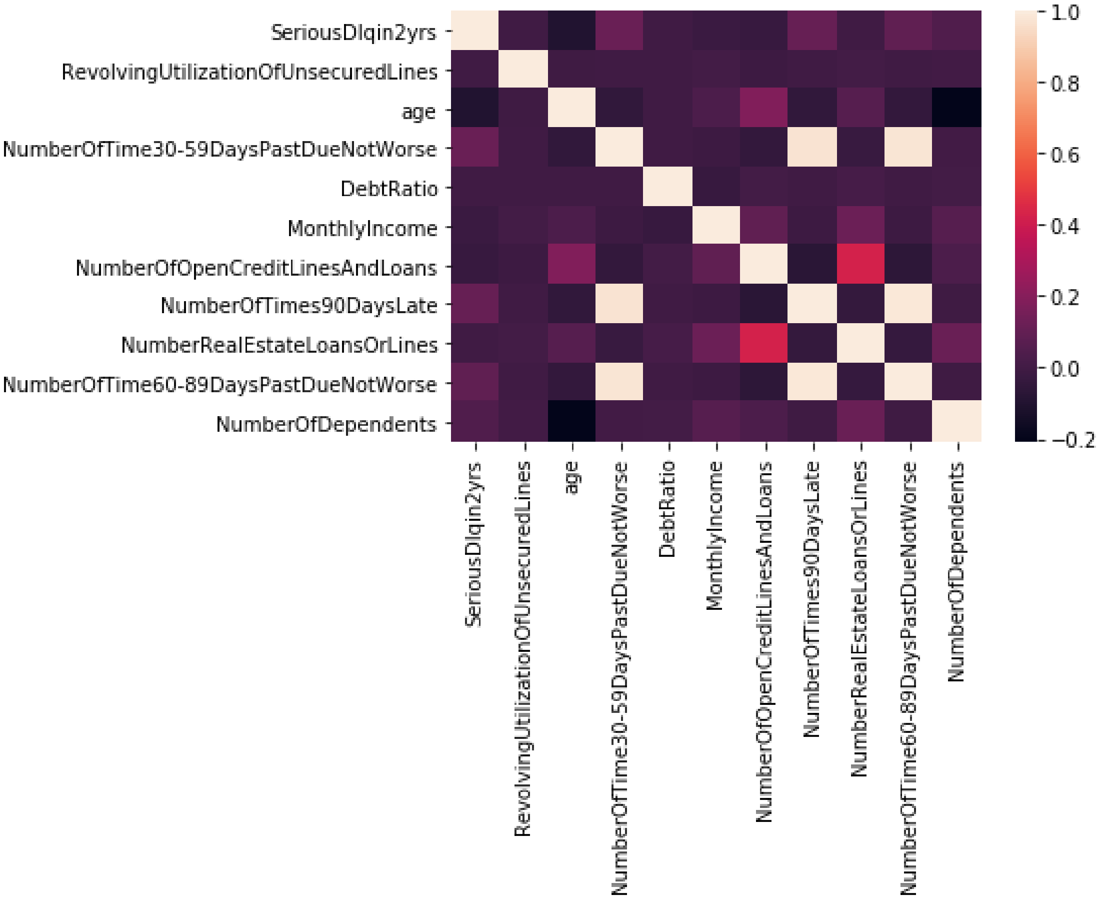
[4]:

```
80580
```

1 Premilinaries

[5]:

```
# Correlation Matrix
Corr_Matrix = Df.corr()
round(Corr_Matrix, 2)
Fig = sns.heatmap(Corr_Matrix)
Figure = Fig.get_figure()
Figure.savefig('CorrPlot.pdf', bbox_inches = "tight")
```

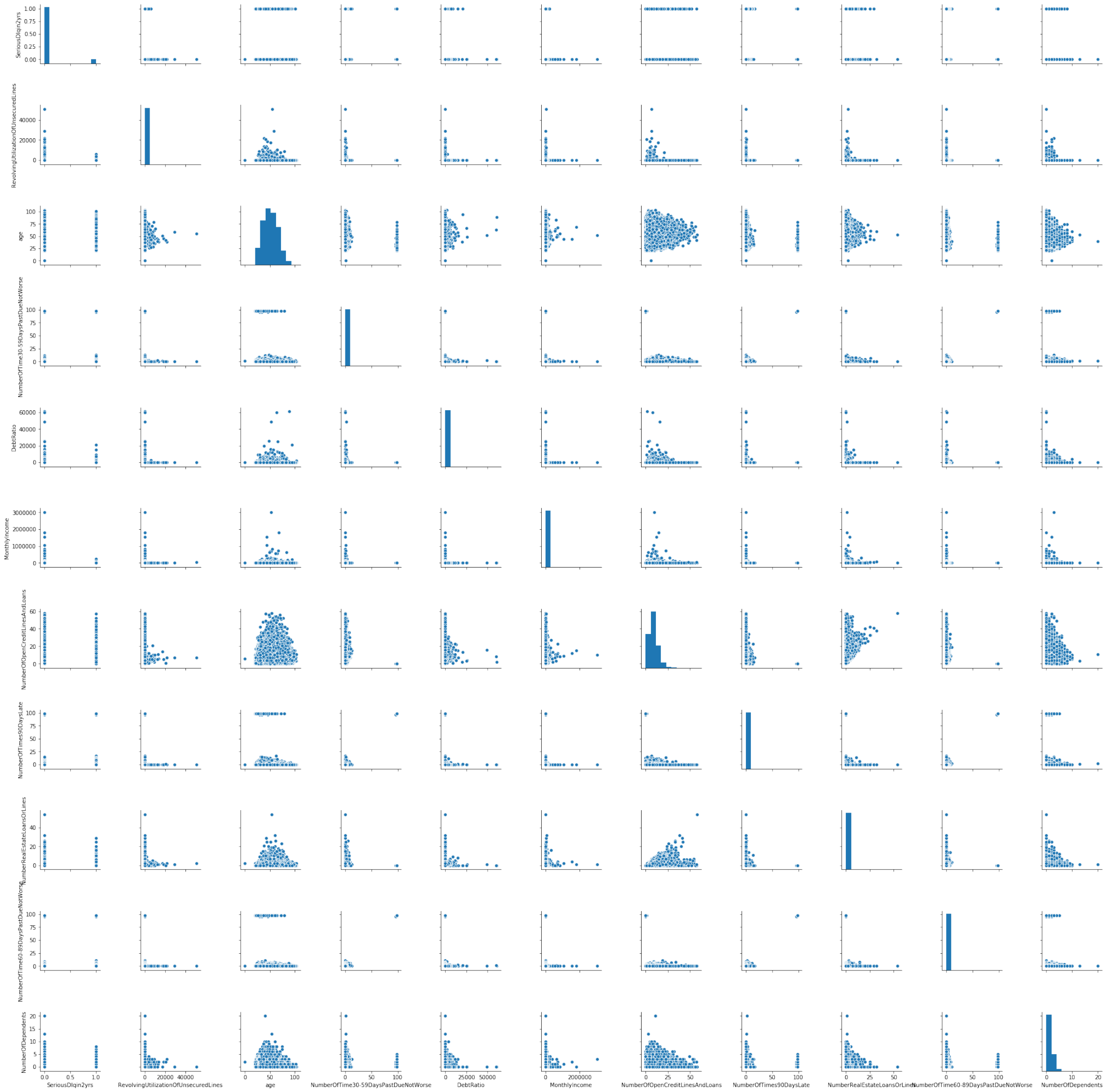


[6]:

```
### Two by Two Plots
Plt = sns.pairplot(Df)
Plt
```

[6]:

```
<seaborn.axisgrid.PairGrid at 0x7f9a9ce4f310>
```



2 Fisher LDA

[7]:
```
mu = np.mean(X_Train)
X_Train_Demeaned = (X_Train - mu).T
X_Test_Demeaned = (X_Test - mu).T
S_t = np.cov(X_Train_Demeaned)
S_w = np.zeros(S_t.shape)
for c in np.unique(Y_Train):
    S_w += np.cov(X_Train_Demeaned[:, Y_Train == c])

S_b = S_t - S_w
```

```
Vals, Vecs = linalg.eig(np.linalg.inv(S_w)@S_b)
Vecs = Vecs[:, np.argsort(Vals)]

W_lda = Vecs[:, -1:].real

X_Train_Lda = (W_lda.T@X_Train_Demeaned).T
X_Test_Lda = (W_lda.T@X_Test_Demeaned).T

print("Scores for Train Are:")
print(np.mean(X_Train_Lda[Y_Train == 0]), np.mean(X_Train_Lda[Y_Train == 1]))

print("Scores for Test Are:")
print(np.mean(X_Test_Lda[Y_Test == 0]), np.mean(X_Test_Lda[Y_Test == 1]))
```

```
Scores for Train Are:
85.44373421735314 83.43138114565562
Scores for Test Are:
85.49241455138895 83.98570707596363
```

```
[8]: Y_Train
```

```
[8]: array([0, 0, 0, …, 0, 1, 0])
```

3 Logistic Regression

```
[9]: from sklearn.linear_model import LogisticRegression
     Clf = LogisticRegression(random_state = 0, max_iter = 1000).fit(X_Train,␣
      ↪Y_Train)
     Probs = Clf.predict_proba(X_Train)

     Train_Predicted = np.zeros(len(Probs))
     for i in range(len(Probs)):
         if (Probs[i, 0] > Probs[i, 1]):
             Train_Predicted[i] = 0
         else:
             Train_Predicted[i] = 1

     Equal = 0
     for i in range(len(Y_Train)):
         if (Y_Train[i] == Train_Predicted[i]):
             Equal = Equal + 1

     Score = Probs[:, 1]/(1 - Probs[:, 1])
     print("Scores for Train Are:")
print(np.mean(Score[Y_Train == 0]), np.mean(Score[Y_Train == 1]))
```

```
Scores for Train Are:
0.09199179721400955 0.3332044933838555
```

[10]:

```
print("Classification Accuracy on Training Set is:")
print(Equal/len(Y_Train))
```

```
Classification Accuracy on Training Set is:
0.9315711094564408
```

[11]:

```
Probs = Clf.predict_proba(X_Test)
Test_Predicted = np.zeros(len(Probs))

for i in range(len(Probs)):
    if (Probs[i, 0] > Probs[i, 1]):
        Test_Predicted[i] = 0
    else:
        Test_Predicted[i] = 1


Equal = 0
for i in range(len(Y_Test)):
    if (Y_Test[i] == Test_Predicted[i]):
        Equal = Equal + 1

Score = Probs[:, 1]/(1 - Probs[:, 1])
print("Scores for Test Are:")
print(np.mean(Score[Y_Test == 0]), np.mean(Score[Y_Test == 1]))
```

```
Scores for Test Are:
0.08131754160975689 0.27448396478956927
```

[12]:

```
print("Classification Accuracy on Test Set is:")
Equal/len(Y_Test)
```

```
Classification Accuracy on Test Set is:
```

[12]:

```
0.9304845171206128
```

4 Random Forest

[13]:

```
from sklearn.ensemble import RandomForestClassifier
Clf = RandomForestClassifier(max_depth = 5, random_state = 0)
Clf.fit(X_Train, Y_Train)
Probs = Clf.predict_proba(X_Train)
```

```
Train_Predicted = np.zeros(len(Probs))
for i in range(len(Probs)):
    if (Probs[i, 0] > Probs[i, 1]):
        Train_Predicted[i] = 0
    else:
        Train_Predicted[i] = 1

Equal = 0
for i in range(len(Y_Train)):
    if (Y_Train[i] == Train_Predicted[i]):
        Equal = Equal + 1

Score = Probs[:, 1]/(1 - Probs[:, 1])
print("Scores for Train Are:")
print(np.mean(Score[Y_Train == 0]), np.mean(Score[Y_Train == 1]))
```

```
Scores for Train Are:
0.07023938518560487 0.39612069415283807
```

[14]:

```
print("Classification Accuracy on Training Set is:")
print(Equal/len(Y_Train))
```

```
Classification Accuracy on Training Set is:
0.9345619260362373
```

[15]:

```
Probs = Clf.predict_proba(X_Test)

Test_Predicted = np.zeros(len(Probs))

for i in range(len(Probs)):
    if (Probs[i, 0] > Probs[i, 1]):
        Test_Predicted[i] = 0
    else:
        Test_Predicted[i] = 1

Equal = 0
for i in range(len(Y_Test)):
    if (Y_Test[i] == Test_Predicted[i]):
        Equal = Equal + 1

Score = Probs[:, 1]/(1 - Probs[:, 1])
print("Scores for Test Are:")
print(np.mean(Score[Y_Test == 0]), np.mean(Score[Y_Test == 1]))
```

```
Scores for Test Are:
0.07135186453471327 0.3791356430665598
```

[16]:

```
print("Classification Accuracy on Test Set is:")
Equal/len(Y_Test)
```

```
Classification Accuracy on Test Set is:
```

[16]:

```
0.9323994053768047
```

[17]:

```
X_Train.shape
```

[17]:

```
(80580, 10)
```

[18]:

```
np.sum(Y_Train)
```

[18]:

```
5575
```

[19]:

```
Y_Train.shape
X_Train.shape
# len(Y_Train)
```

[19]:

```
(80580, 10)
```

[20]:

```
Default = []
for i in range(len(X_Train)):
    if(Y_Train[i] == 1):
        Default.append(X_Train[i])
Default = np.asarray(Default)

Resampled = []
Resampled_y = []
Target = X_Train.shape[0]/2
Current = np.sum(Y_Train)

while(Current <= Target):
    Index = np.random.choice(Default.shape[0], 1)
    Resampled.append(Default[Index].squeeze())
    Resampled_y.append(1)
    Current += 1
    Target += .498

X_Train = np.concatenate((X_Train, np.asarray(Resampled)))
Y_Train = np.concatenate((Y_Train, np.asarray(Resampled_y)))
```

5 Dense NN

[21]:

```python
# Class_Weight = {1: 0.95,0: 0.05}
import random
random.seed(1)
Model_in = keras.Input(shape = (10, ))
X = layers.Dense(10, activation = "relu")(Model_in)
X2 = layers.Dense(10, activation= "relu")(X)
X3 = layers.Dense(10, activation= "relu")(X2)
X4 = layers.Dense(10, activation= "relu")(X3)

Out = layers.Dense(1, activation= "sigmoid")(X4)

Model = keras.Model(Model_in, Out)
Model.compile(optimizer = 'adam', loss = 'binary_crossentropy')
Model.fit(X_Train, Y_Train, epochs = 100,
                batch_size = 128,
                shuffle = True)
```

```
Epoch 1/100
1170/1170 [==============================] - 2s 987us/step - loss: 1.7073
Epoch 2/100
1170/1170 [==============================] - 1s 918us/step - loss: 1.0539
Epoch 3/100
1170/1170 [==============================] - 2s 1ms/step - loss: 0.9618
Epoch 4/100
1170/1170 [==============================] - 2s 2ms/step - loss: 0.7582
Epoch 5/100
1170/1170 [==============================] - 2s 1ms/step - loss: 0.7611
Epoch 6/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.8066
Epoch 7/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.7324
Epoch 8/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5777
Epoch 9/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.6036
Epoch 10/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.6342
Epoch 11/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.6488
Epoch 12/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5655
Epoch 13/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.6054
Epoch 14/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5910
```

```
Epoch 15/100
1170/1170 [==============================] - 1s 969us/step - loss: 0.5565
Epoch 16/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5606
Epoch 17/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5559
Epoch 18/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5822A: 0s -
loss: 0.58
Epoch 19/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5539
Epoch 20/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5663
Epoch 21/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5541
Epoch 22/100
1170/1170 [==============================] - 1s 950us/step - loss: 0.5500
Epoch 23/100
1170/1170 [==============================] - 1s 922us/step - loss: 0.5474
Epoch 24/100
1170/1170 [==============================] - 1s 949us/step - loss: 0.5413
Epoch 25/100
1170/1170 [==============================] - 1s 954us/step - loss: 0.5410
Epoch 26/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5340
Epoch 27/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5315A: 1s -
lo - ETA: 0s - loss
Epoch 28/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5598
Epoch 29/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5632
Epoch 30/100
1170/1170 [==============================] - 2s 1ms/step - loss: 0.5354A: 0s -
loss: 0.5
Epoch 31/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5378
Epoch 32/100
1170/1170 [==============================] - 1s 926us/step - loss: 0.5353
Epoch 33/100
1170/1170 [==============================] - 1s 979us/step - loss: 0.5515
Epoch 34/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5252
Epoch 35/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5176
Epoch 36/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5134
Epoch 37/100
```

```
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5150
Epoch 38/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5115
Epoch 39/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5113
Epoch 40/100
1170/1170 [==============================] - 1s 942us/step - loss: 0.5098 0s -
loss: 0.508
Epoch 41/100
1170/1170 [==============================] - 1s 980us/step - loss: 0.5066 0s -
lo
Epoch 42/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5069
Epoch 43/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5083A: 0s -
loss
Epoch 44/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5096
Epoch 45/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5032
Epoch 46/100
1170/1170 [==============================] - 1s 946us/step - loss: 0.4985
Epoch 47/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5028A: 0s -
Epoch 48/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4964
Epoch 49/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.5005
Epoch 50/100
1170/1170 [==============================] - 1s 950us/step - loss: 0.4994
Epoch 51/100
1170/1170 [==============================] - 1s 977us/step - loss: 0.5023 0s -
loss: 0.501
Epoch 52/100
1170/1170 [==============================] - 1s 958us/step - loss: 0.4971
Epoch 53/100
1170/1170 [==============================] - 1s 986us/step - loss: 0.5013
Epoch 54/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4941
Epoch 55/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4943
Epoch 56/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4934
Epoch 57/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4936
Epoch 58/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4904
Epoch 59/100
```

```
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4930A
Epoch 60/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4902
Epoch 61/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4916
Epoch 62/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4945
Epoch 63/100
1170/1170 [==============================] - 2s 1ms/step - loss: 0.4963
Epoch 64/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4948
Epoch 65/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4948
Epoch 66/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4939
Epoch 67/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4941
Epoch 68/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4934A: 0s
Epoch 69/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4929A: 0s -
loss: 0
Epoch 70/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4944
Epoch 71/100
1170/1170 [==============================] - 1s 983us/step - loss: 0.4913
Epoch 72/100
1170/1170 [==============================] - 1s 977us/step - loss: 0.4911
Epoch 73/100
1170/1170 [==============================] - 1s 985us/step - loss: 0.4912
Epoch 74/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4893A: 0s -
los
Epoch 75/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4934A: 0s -
Epoch 76/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4899
Epoch 77/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4893
Epoch 78/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4909A: 0s -
loss: 0.
Epoch 79/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4886
Epoch 80/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4890
Epoch 81/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4889
```

```
Epoch 82/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4886
Epoch 83/100
1170/1170 [==============================] - 2s 1ms/step - loss: 0.4891A: 0s
Epoch 84/100
1170/1170 [==============================] - 1s 931us/step - loss: 0.4894
Epoch 85/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4909
Epoch 86/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4894
Epoch 87/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4905
Epoch 88/100
1170/1170 [==============================] - 2s 2ms/step - loss: 0.4886
Epoch 89/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4882
Epoch 90/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4907
Epoch 91/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4931
Epoch 92/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4880
Epoch 93/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4877
Epoch 94/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4860
Epoch 95/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4879
Epoch 96/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4863A: 0s -
Epoch 97/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4888
Epoch 98/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4874
Epoch 99/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4870
Epoch 100/100
1170/1170 [==============================] - 1s 1ms/step - loss: 0.4866
```

[21]:
```
<tensorflow.python.keras.callbacks.History at 0x7f9a976faa50>
```

[22]:
```
Probs = Model.predict(X_Train)
Probs
```

[22]:
```
array([[0.11589515],
       [0.19759074],
       [0.14599547],
       …,
       [0.85877407],
       [0.4121329 ],
       [0.5329002 ]], dtype=float32)
```

[23]:
```
Probs.shape
```

[23]:
```
(149734, 1)
```

[24]:
```
Train_Predicted = np.zeros(len(Probs))
for i in range(len(Probs)):
    if (Probs[i] < 0.5):
        Train_Predicted[i] = 0
    else:
        Train_Predicted[i] = 1

Equal = 0
Default = 0
Non_Default = 0
for i in range(len(Y_Train)):
    if(Y_Train[i] == 1):
        if(Y_Train[i] == Train_Predicted[i]):
            Equal += 1
            Default += 1
    else:
        if(Y_Train[i] == Train_Predicted[i]):
            Equal += 1
            Non_Default += 1

Probs

Score = Probs/(1 - Probs)
print("Scores for Train Are:")
print(np.mean(Score[Y_Train == 0]), np.mean(Score[Y_Train == 1]))
```

```
Scores for Train Are:
1.0912266 6.80118
```

[25]:
```
np.sum(Train_Predicted)
```

[25]:
```
65379.0
```

[26]:
```
print("Classification Accuracy on Training Set is:")
print(Equal/len(Y_Train))
print("Classification Accuracy on Non-Default Training Set is:")
print(Non_Default/(len(Y_Train) - np.sum(Y_Train)))
print("Classification Accuracy on Default Training Set is:")
print(Default/np.sum(Y_Train))
```

```
Classification Accuracy on Training Set is:
0.7684961331427732
Classification Accuracy on Non-Default Training Set is:
0.8312512499166722
Classification Accuracy on Default Training Set is:
0.705509240054062
```