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1 Executive Summary

Problem Statement:

- It is difficult to identify the freshness of each of the fruits when the number of fruits is in large volume
- It is important to monitor the freshness of the fruits from time to time to ensure that the customer will come again

Scope:

- The dataset covers fruits specifically apples, bananas, and oranges

Methodology:

- Identify whether the fruit is fresh or rotten based on the RGB
- Use RMSE, MSE to identify the performance of the model

2 Importing the Libraries

[1]:
```
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
import streamlit as st

# Scaler Methods
from sklearn.preprocessing import RobustScaler, MaxAbsScaler, MinMaxScaler,␣
↪StandardScaler

# Machine Learning Models

from sklearn.model_selection import cross_val_score, train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier, AdaBoostClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.naive_bayes import GaussianNB
```

```python
from xgboost import XGBClassifier

# Metrics
from sklearn.metrics import make_scorer
from sklearn.metrics import (
    make_scorer,
    accuracy_score,
    precision_score,
    recall_score,
    f1_score,
    matthews_corrcoef,
    cohen_kappa_score,
    mean_squared_error,
    mean_absolute_error,
    confusion_matrix,
    ConfusionMatrixDisplay,
    classification_report
)
```

3 Importing the Database

[2]:
```python
df = pd.read_csv("fruits.csv")
```

[3]:
```python
df
```

[3]:
```
                                                 Image     Red   Green  \
0      rotated_by_75_Screen Shot 2018-06-08 at 5.25.0…  480016  320784
1      rotated_by_15_Screen Shot 2018-06-08 at 5.15.2…  429908  287132
2      rotated_by_15_Screen Shot 2018-06-08 at 5.26.4…  493084  503330
3      rotated_by_15_Screen Shot 2018-06-08 at 5.27.0…  398133  463717
4      rotated_by_75_Screen Shot 2018-06-08 at 5.33.4…  403308  424642
…                                                   …       …       …
10896  saltandpepper_Screen Shot 2018-06-12 at 11.46…  510687  494520
10897  rotated_by_75_Screen Shot 2018-06-12 at 11.40…  337028  264447
10898              Screen Shot 2018-06-12 at 11.46.17 PM  514385  463767
10899  rotated_by_15_Screen Shot 2018-06-12 at 11.45…  452977  368142
10900  saltandpepper_Screen Shot 2018-06-12 at 11.23…  604274  481870

         Blue     Contrast    Energy  Correlation  Homogeneity  Freshness
0      308173  1455.458367  0.091725     0.826346     0.216102          1
1      294462  1898.266122  0.089732     0.849394     0.243132          1
2      363093  1304.415102  0.298530     0.871957     0.475525          1
3      277134  1057.761224  0.087325     0.859704     0.302005          1
4      264396  2111.405306  0.109698     0.800220     0.234803          1
…         …          …         …          …           …        …
10896  443423   252.043265  0.143389     0.848958     0.359614          0
```

```
10897  225432   882.749388  0.131601     0.892012     0.216836          0
10898  426552   441.551020  0.113603     0.919746     0.324600          0
10899  305902  1738.992653  0.224891     0.850204     0.377876          0
10900  322724   222.860816  0.200812     0.926512     0.325153          0

[10901 rows x 9 columns]
```

4 Exploratory Data Analysis (EDA)

[4]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10901 entries, 0 to 10900
Data columns (total 9 columns):
 #   Column       Non-Null Count  Dtype
---  ------       --------------  -----
 0   Image        10901 non-null  object
 1   Red          10901 non-null  int64
 2   Green        10901 non-null  int64
 3   Blue         10901 non-null  int64
 4   Contrast     10901 non-null  float64
 5   Energy       10901 non-null  float64
 6   Correlation  10901 non-null  float64
 7   Homogeneity  10901 non-null  float64
 8   Freshness    10901 non-null  int64
dtypes: float64(4), int64(4), object(1)
memory usage: 766.6+ KB
```

[5]:
```
df.describe()
```

[5]:
```
                 Red          Green           Blue      Contrast  \
count   10901.000000   10901.000000   10901.000000  10901.000000
mean   466876.253646  402949.903036  337048.713788   1337.803641
std     83431.591490   85979.015033   84021.923106    777.397036
min     74212.000000   54894.000000   38685.000000     31.596735
25%    418183.000000  345000.000000  279333.000000    647.005714
50%    472741.000000  400620.000000  333381.000000   1387.058776
75%    522343.000000  460991.000000  392566.000000   1789.657143
max    633913.000000  622438.000000  571283.000000   5078.617143

             Energy   Correlation   Homogeneity     Freshness
count  10901.000000  10901.000000  10901.000000  10901.000000
mean       0.258193      0.887706      0.427981      0.434822
std        0.140672      0.043782      0.138434      0.495756
min        0.016229      0.406196      0.041493      0.000000
25%        0.159700      0.864890      0.338576      0.000000
```

```
50%       0.233098     0.888041     0.410762     0.000000
75%       0.331826     0.915210     0.502112     1.000000
max       0.788228     0.993536     0.878452     1.000000
```

[6]:
```
df.isnull().sum()
```

[6]:
```
Image          0
Red            0
Green          0
Blue           0
Contrast       0
Energy         0
Correlation    0
Homogeneity    0
Freshness      0
dtype: int64
```

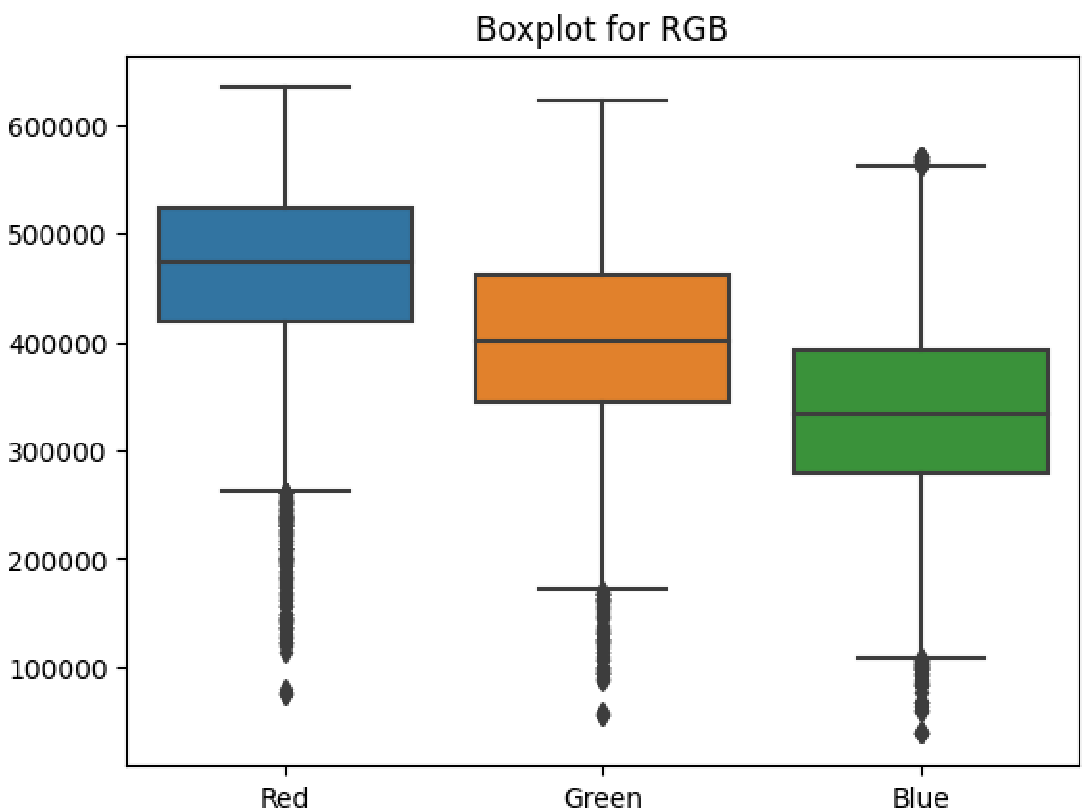
[7]:
```
df.dtypes
```

[7]:
```
Image           object
Red              int64
Green            int64
Blue             int64
Contrast       float64
Energy         float64
Correlation    float64
Homogeneity    float64
Freshness        int64
dtype: object
```

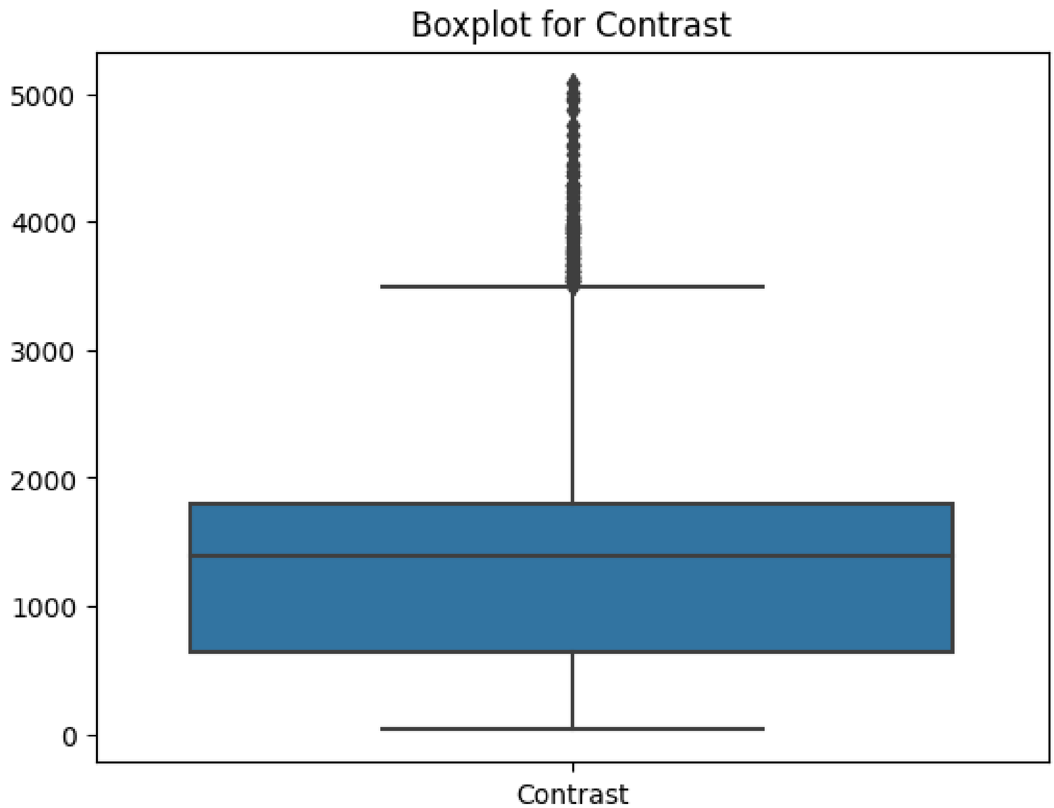
[8]:
```
df = df.drop(columns=['Image'])
```

[9]:
```
def remove_outliers(df, column):
    Q1 = df[column].quantile(0.25)
    Q3 = df[column].quantile(0.75)
    IQR = Q3 - Q1
    lower_bound = Q1 - 1.5 * IQR
    upper_bound = Q3 + 1.5 * IQR
    return df[(df[column] >= lower_bound) & (df[column] <= upper_bound)]
```

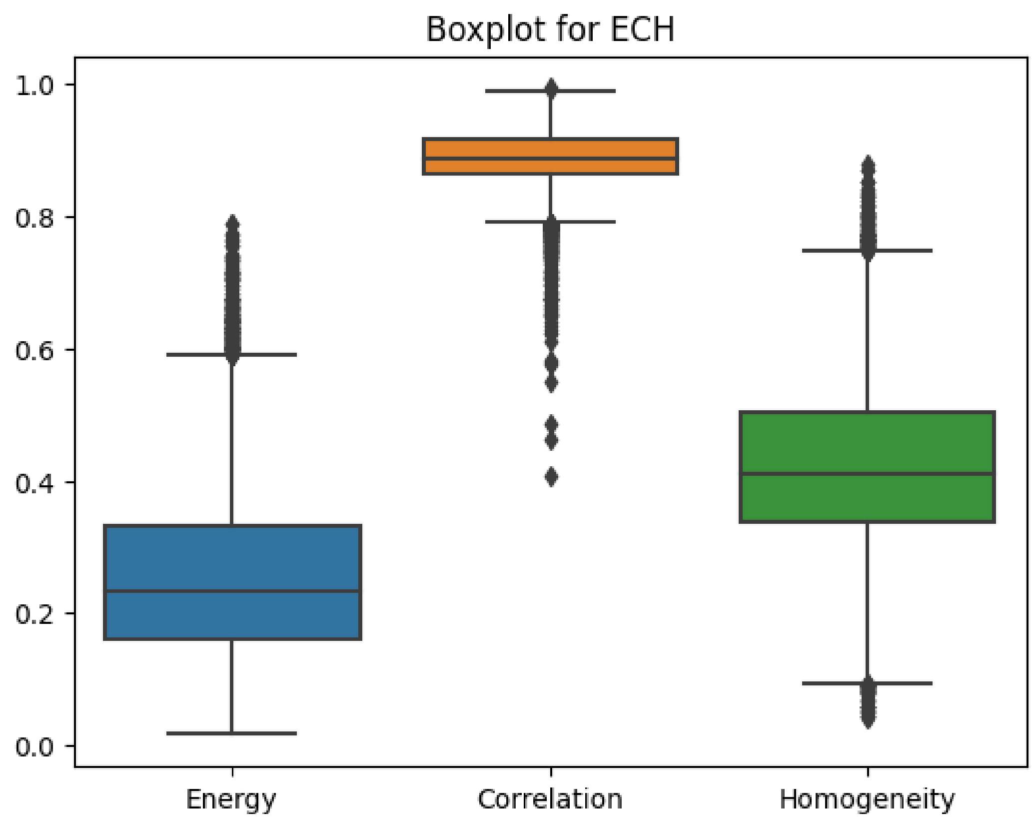
[10]:
```
columns = ['Red', 'Green', 'Blue']
df_rgb = df[columns]

sns.boxplot(data=df_rgb)
plt.title("Boxplot for RGB")
plt.show()
```



[11]:
```
columns = ['Contrast']
df_contrast = df[columns]

sns.boxplot(data=df_contrast)
plt.title("Boxplot for Contrast")
plt.show()
```

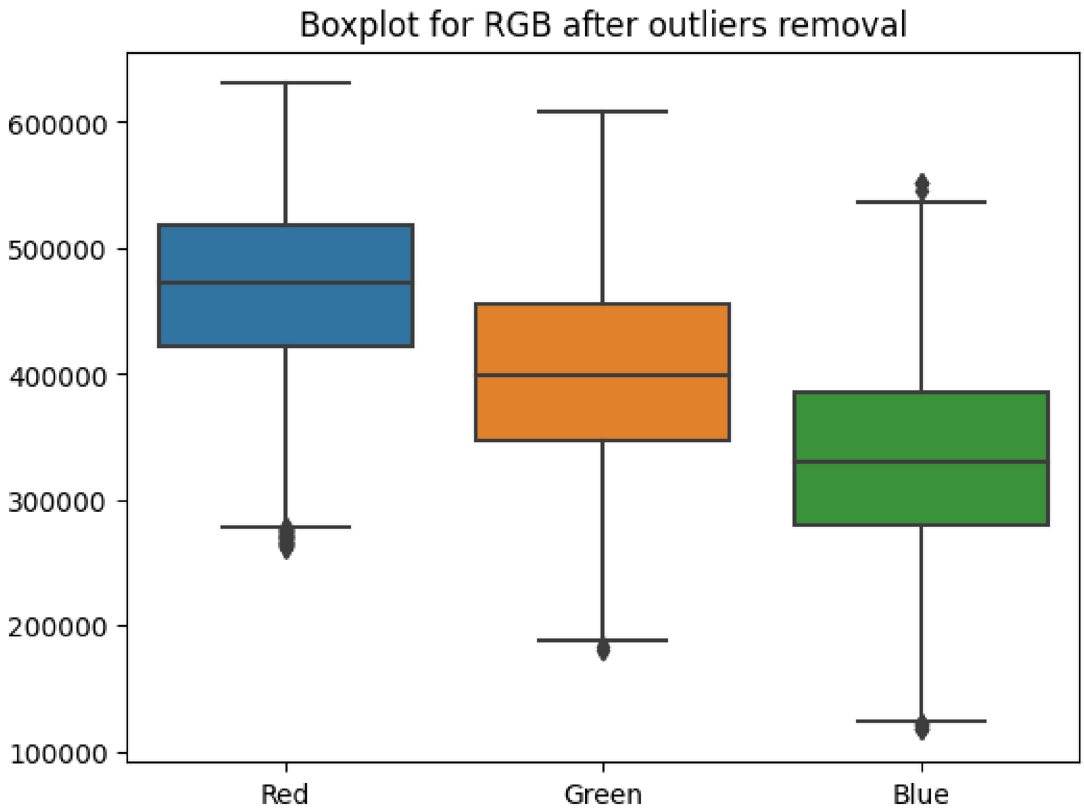


[12]:
```
columns = ['Energy', 'Correlation', 'Homogeneity']
df_ech = df[columns]

sns.boxplot(data=df_ech)
plt.title("Boxplot for ECH")
plt.show()
```

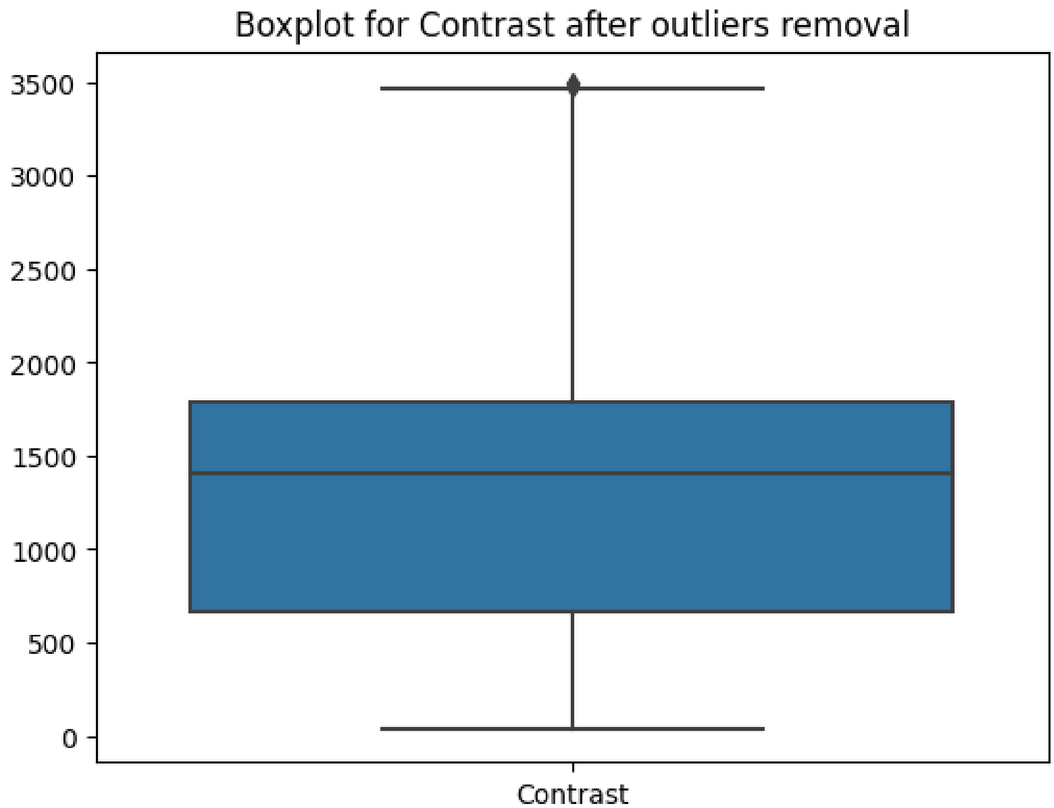


[13]:
```
for col in df.columns:
    df = remove_outliers(df, col)
```

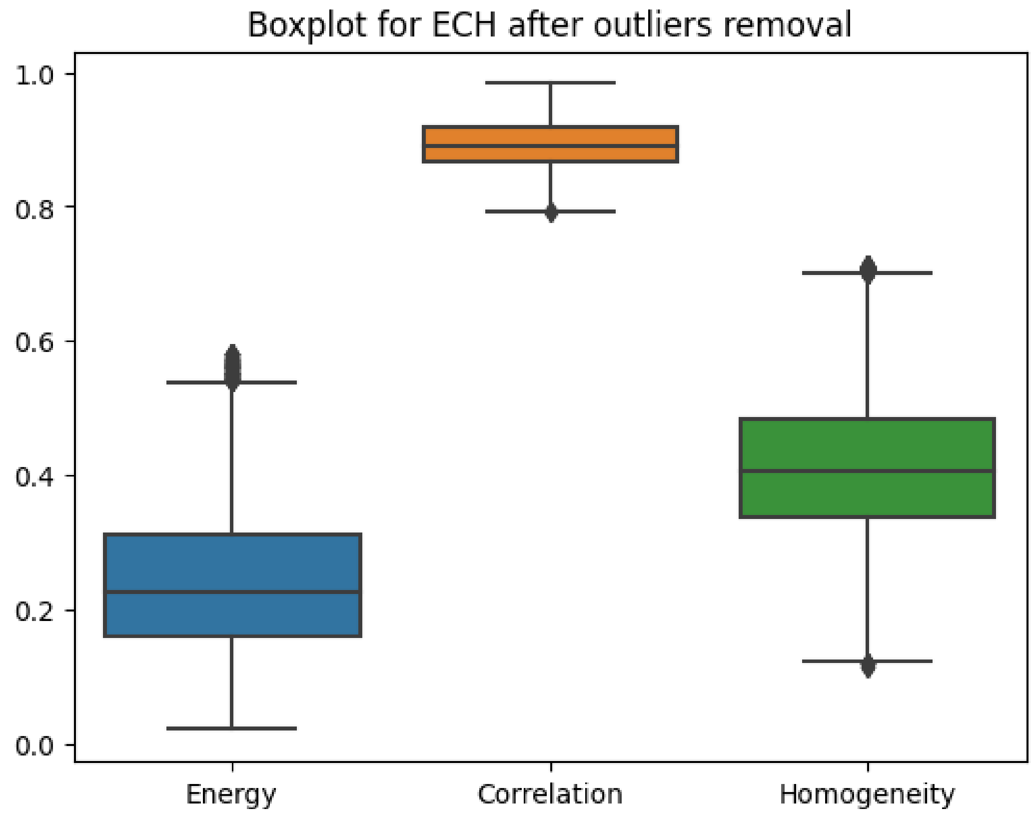
[14]:
```
columns = ['Red', 'Green', 'Blue']
df_rgb = df[columns]

sns.boxplot(data=df_rgb)
plt.title("Boxplot for RGB after outliers removal")
plt.show()
```



[15]:
```
columns = ['Contrast']
df_contrast = df[columns]

sns.boxplot(data=df_contrast)
plt.title("Boxplot for Contrast after outliers removal")
plt.show()
```



[16]:
```
columns = ['Energy', 'Correlation', 'Homogeneity']
df_ech = df[columns]

sns.boxplot(data=df_ech)
plt.title("Boxplot for ECH after outliers removal")
plt.show()
```

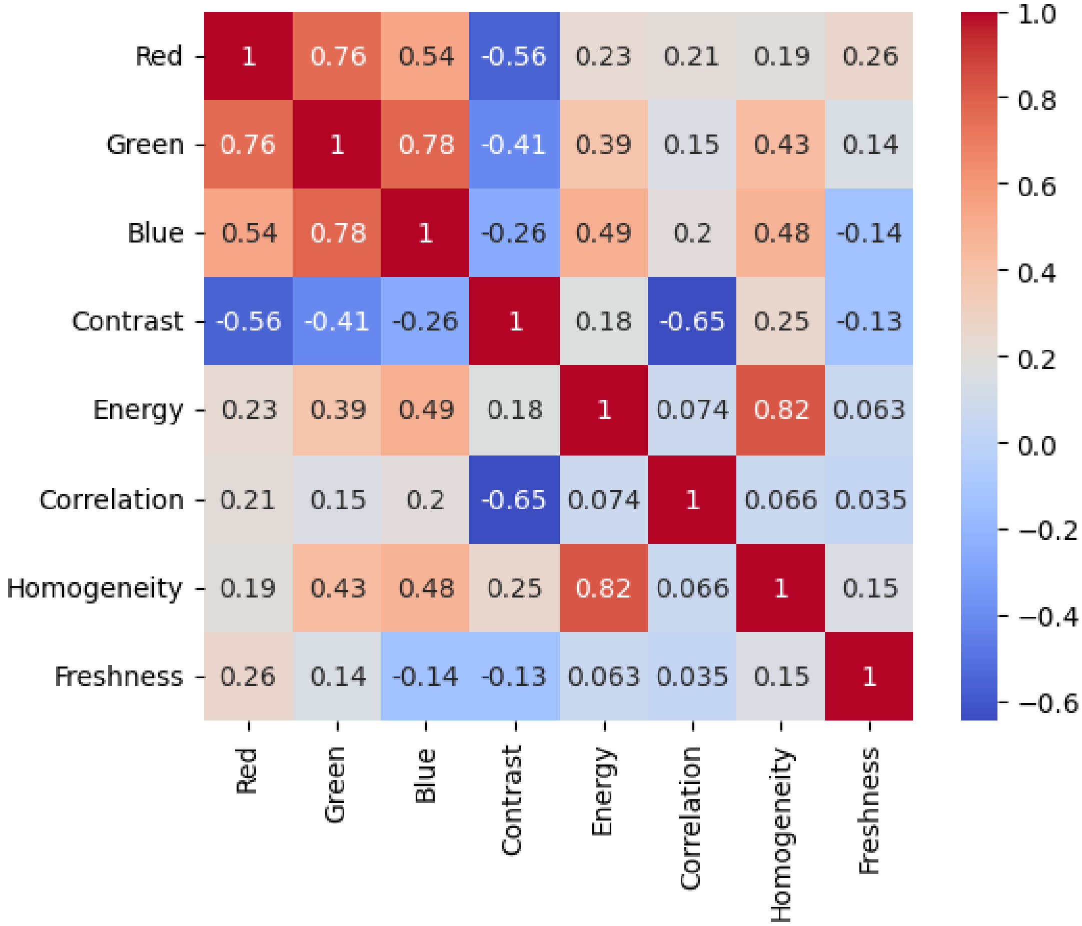


[17]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 9764 entries, 0 to 10900
Data columns (total 8 columns):
 #   Column       Non-Null Count  Dtype
---  ------       --------------  -----
 0   Red          9764 non-null   int64
 1   Green        9764 non-null   int64
 2   Blue         9764 non-null   int64
 3   Contrast     9764 non-null   float64
 4   Energy       9764 non-null   float64
 5   Correlation  9764 non-null   float64
 6   Homogeneity  9764 non-null   float64
 7   Freshness    9764 non-null   int64
dtypes: float64(4), int64(4)
memory usage: 686.5 KB
```

5 Correlation Matrix

[18]:
```
corr_matrix = df.corr()
sns.heatmap(corr_matrix, annot=True, cmap='coolwarm', square=True)
plt.figure(figsize=(10, 8))
plt.show()
```



	Red	Green	Blue	Contrast	Energy	Correlation	Homogeneity	Freshness
Red	1	0.76	0.54	-0.56	0.23	0.21	0.19	0.26
Green	0.76	1	0.78	-0.41	0.39	0.15	0.43	0.14
Blue	0.54	0.78	1	-0.26	0.49	0.2	0.48	-0.14
Contrast	-0.56	-0.41	-0.26	1	0.18	-0.65	0.25	-0.13
Energy	0.23	0.39	0.49	0.18	1	0.074	0.82	0.063
Correlation	0.21	0.15	0.2	-0.65	0.074	1	0.066	0.035
Homogeneity	0.19	0.43	0.48	0.25	0.82	0.066	1	0.15
Freshness	0.26	0.14	-0.14	-0.13	0.063	0.035	0.15	1

```
<Figure size 1000x800 with 0 Axes>
```

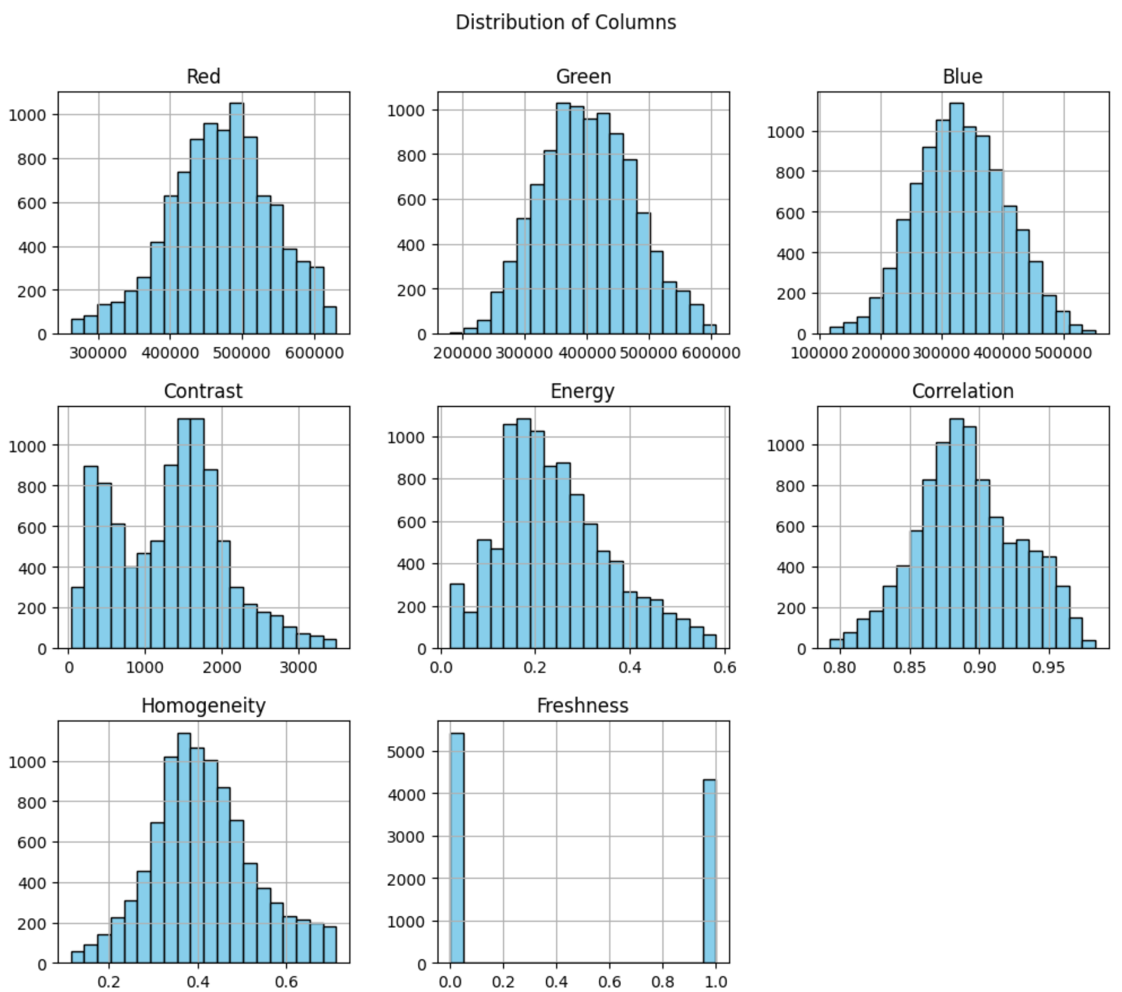
** Since the correlation between the features and freshness are not relatively storng, considering to use non-linear maching learning models here.

6 Distribution for Each Columns

[19]:
```
skewness = df.skew()

print("Skewness for each column:")
print(skewness)
```

```
Skewness for each column:
Red            -0.219872
Green           0.120736
Blue            0.051449
Contrast        0.238257
Energy          0.553582
Correlation     0.059359
Homogeneity     0.300997
Freshness       0.227631
dtype: float64
```

[20]:
```
# Assuming df is your DataFrame
df.hist(figsize=(12, 10), bins=20, color='skyblue', edgecolor='black')
plt.suptitle('Distribution of Columns', y=0.95)
plt.show()
```



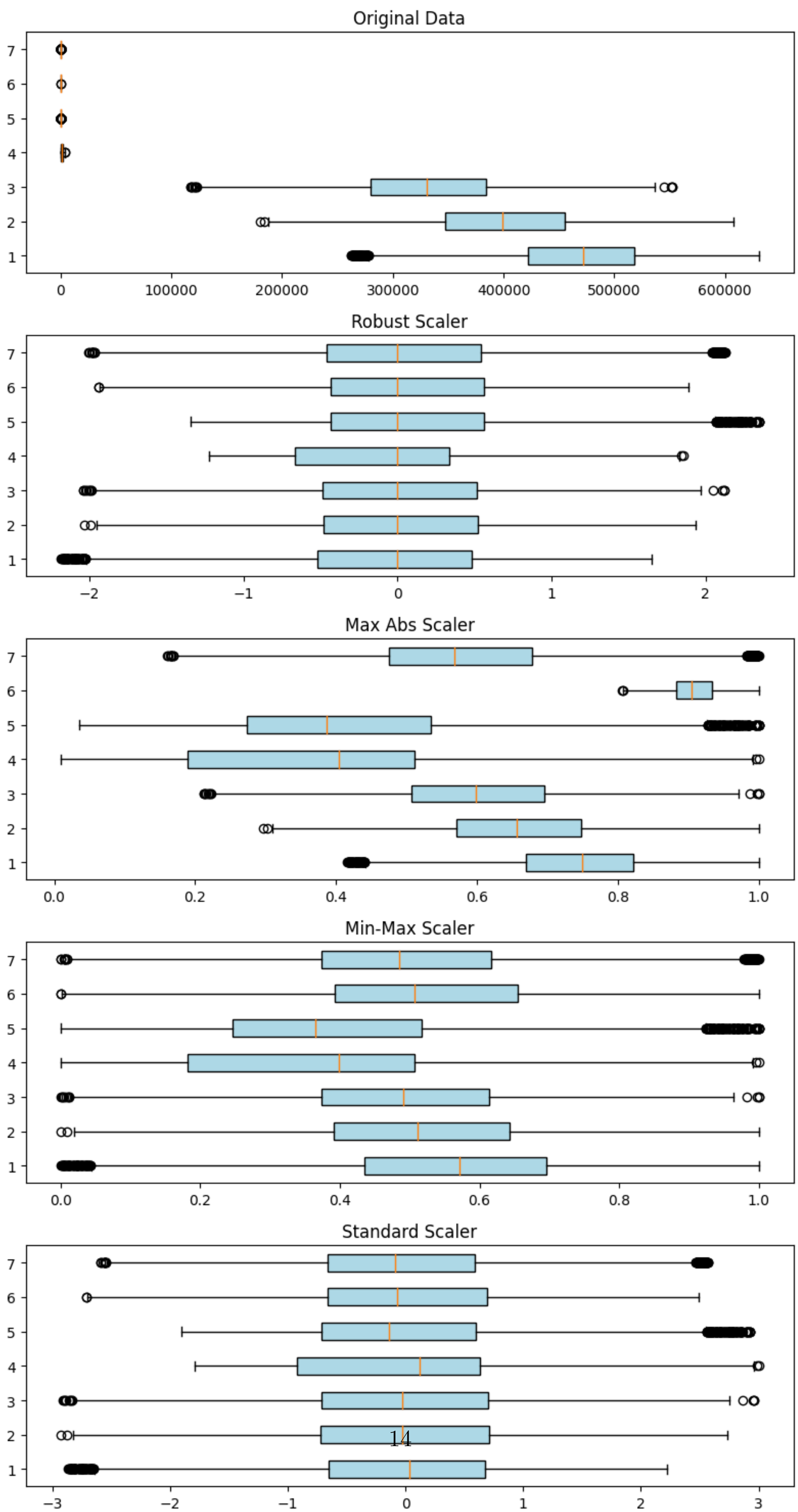
** Only Energy is relatively left-skewed

7 Feature Extraction

[21]:
```python
x = df.drop(columns=['Freshness'])
y = df['Freshness']
```

8 Scaling the Data

[22]:
```python
scalers = {
    'Robust Scaler': RobustScaler(),
    'Max Abs Scaler': MaxAbsScaler(),
    'Min-Max Scaler': MinMaxScaler(),
    'Standard Scaler': StandardScaler()
}

x_robust_scale = scalers['Robust Scaler'].fit_transform(x)
x_max_abs_scale = scalers['Max Abs Scaler'].fit_transform(x)
x_min_max_scale = scalers['Min-Max Scaler'].fit_transform(x)
x_standard_scale = scalers['Standard Scaler'].fit_transform(x)

fig, axs = plt.subplots(5, 1, figsize=(8, 15))
axs[0].boxplot(x.values, vert=False, patch_artist=True,␣
↪boxprops=dict(facecolor='lightblue'))
axs[0].set_title('Original Data')

scaling_results = {
    'Robust Scaler': x_robust_scale,
    'Max Abs Scaler': x_max_abs_scale,
    'Min-Max Scaler': x_min_max_scale,
    'Standard Scaler': x_standard_scale
}

for idx, (scaler_name, scaled_data) in enumerate(scaling_results.items(),␣
↪start=1):
    axs[idx].boxplot(scaled_data, vert=False, patch_artist=True,␣
↪boxprops=dict(facecolor='lightblue'))
    axs[idx].set_title(scaler_name)

plt.tight_layout()
plt.show()
```


Original Data
Robust Scaler
Max Abs Scaler
Min-Max Scaler
Standard Scaler

** Although there are significant difference for each of the scaler methods, it is important to know which scaler should be paired with which type of machine learning models ** Max Abs Scaler is suitable when the data has positive and negative values, since the data here are all in postiive, this option may not be required ** Min-max Scaler is suitable for Neural Network Models

9 Model Selection & Training

Linear - 1. Logistic Regression

Non-linear - 2. Support Vector Machine (SVC) - 3. Decision Tree - 4. Random Forest - 5. K Neighbors (KNN) - 6. Naive Bayes - 7. XGBoost - 8. AdaBoost

Neural Network

[23]:
```
x_train, x_test, y_train, y_test = train_test_split(x_standard_scale, y,␣
↪test_size=0.3, random_state=42)
```

9.1 Logistic Regression Classifier

[24]:
```
logisticModel = LogisticRegression()
logisticModel.fit(x_train, y_train)
```

[24]:
```
LogisticRegression()
```

[25]:
```
logisticModelAccuracy = np.mean(cross_val_score(logisticModel, x_train,␣
↪y_train, scoring=make_scorer(accuracy_score), cv=30))*100
logisticModelPrecision = np.mean(cross_val_score(logisticModel, x_train,␣
↪y_train, scoring=make_scorer(precision_score), cv=30))*100
logisticModelSenstivity = np.mean(cross_val_score(logisticModel, x_train,␣
↪y_train, scoring=make_scorer(recall_score), cv=30))*100
logisticModelF1Score = np.mean(cross_val_score(logisticModel, x_train, y_train,␣
↪scoring=make_scorer(f1_score), cv=30))*100
logisticModelMCCScore = np.mean(cross_val_score(logisticModel, x_train,␣
↪y_train, scoring=make_scorer(matthews_corrcoef), cv=30))*100
logisticModelKappaCoeff = np.mean(cross_val_score(logisticModel, x_train,␣
↪y_train, scoring=make_scorer(cohen_kappa_score), cv=30))*100
```

[26]:
```
print("Train Accuracy: ", logisticModelAccuracy*100)
print("Train Precision: ", logisticModelPrecision*100)
print("Train Senstivity: ", logisticModelSenstivity*100)
print("Train F1 Score: ", logisticModelF1Score*100)
print("Train MCC Score: ", logisticModelMCCScore*100)
print("Train Kappa Coefficiet: ", logisticModelKappaCoeff*100)
```

```
Train Accuracy:  7464.15230440271
Train Precision:  7330.641377848939
Train Senstivity:  6717.392739273927
Train F1 Score:  7006.104903835823
Train MCC Score:  4832.6411592484965
Train Kappa Coefficiet:  4814.645663003126
```

[27]:
```python
y_pred_logistic = logisticModel.predict(x_test)
```

[28]:
```python
mse_logistic = mean_squared_error(y_test, y_pred_logistic)
rmse_logistic = np.sqrt(mse_logistic)
mae_logistic = mean_absolute_error(y_test, y_pred_logistic)

print(f"MSE: {mse_logistic}")
print(f"RMSE: {rmse_logistic}")
print(f"MAE: {mae_logistic}")
```

```
MSE: 0.26348122866894197
RMSE: 0.5133042262332758
MAE: 0.26348122866894197
```

[29]:
```python
logisticModelTestAccuracy = accuracy_score(y_test, y_pred_logistic)*100
logisticModelTestPrecision = precision_score(y_test, y_pred_logistic)*100
logisticModelTestSenstivity = recall_score(y_test, y_pred_logistic)*100
logisticModelTestF1Score = f1_score(y_test, y_pred_logistic)*100
logisticModelTestMCCScore = matthews_corrcoef(y_test, y_pred_logistic)*100
logisticModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_logistic)*100

print(f"Test Accuracy: {logisticModelTestAccuracy*100}")
print(f"Test Precision: {logisticModelPrecision*100}")
print(f"Test Senstivity: {logisticModelSenstivity*100}")
print(f"Test F1 Score: {logisticModelF1Score*100}")
print(f"Test MCC Score: {logisticModelMCCScore*100}")
print(f"Test Kappa Coefficiet: {logisticModelKappaCoeff*100}")
```

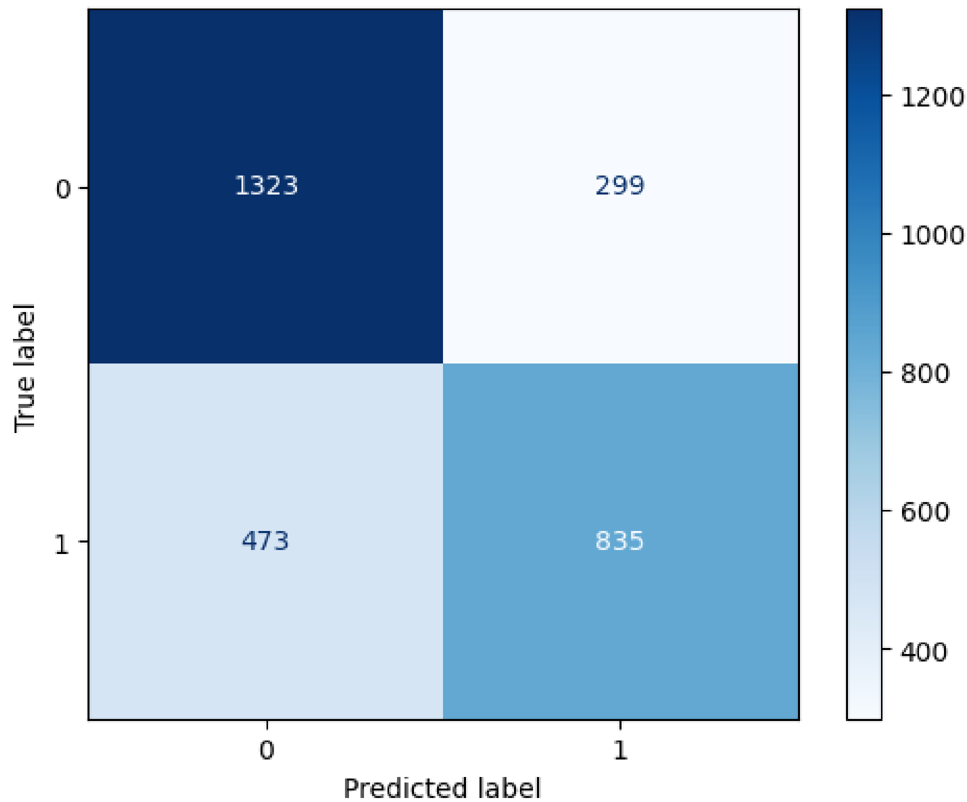
```
Test Accuracy: 7365.18771331058
Test Precision: 7330.641377848939
Test Senstivity: 6717.392739273927
Test F1 Score: 7006.104903835823
Test MCC Score: 4832.6411592484965
Test Kappa Coefficiet: 4814.645663003126
```

[30]:
```python
report_logistic = classification_report(y_test, y_pred_logistic)
print(report_logistic)
```

```
              precision    recall  f1-score   support

           0       0.74      0.82      0.77      1622
```

```
           1       0.74      0.64      0.68      1308

    accuracy                           0.74      2930
   macro avg       0.74      0.73      0.73      2930
weighted avg       0.74      0.74      0.73      2930
```

[31]:
```
cm_logistic = confusion_matrix(y_test, y_pred_logistic)

disp = ConfusionMatrixDisplay(confusion_matrix=cm_logistic)
disp.plot(cmap=plt.cm.Blues)
plt.show()
```



9.2 Support Vector Machine Classifier (SVM)

[32]:
```
svmModel = SVC()
svmModel.fit(x_train, y_train)
```

[32]: SVC()

[33]:
```
svmModelAccuracy = np.mean(cross_val_score(svmModel, x_train, y_train,␣
 ↪scoring=make_scorer(accuracy_score), cv=30))*100
svmModelPrecision = np.mean(cross_val_score(svmModel, x_train, y_train,␣
 ↪scoring=make_scorer(precision_score), cv=30))*100
svmModelSenstivity = np.mean(cross_val_score(svmModel, x_train, y_train,␣
 ↪scoring=make_scorer(recall_score), cv=30))*100
svmModelF1Score = np.mean(cross_val_score(svmModel, x_train, y_train,␣
 ↪scoring=make_scorer(f1_score), cv=30))*100
svmModelMCCScore = np.mean(cross_val_score(svmModel, x_train, y_train,␣
 ↪scoring=make_scorer(matthews_corrcoef), cv=30))*100
svmModelKappaCoeff = np.mean(cross_val_score(svmModel, x_train, y_train,␣
 ↪scoring=make_scorer(cohen_kappa_score), cv=30))*100
```

[34]:
```
print("Train Accuracy: ", svmModelAccuracy*100)
print("Train Precision: ", svmModelPrecision*100)
print("Train Senstivity: ", svmModelSenstivity*100)
print("Train F1 Score: ", svmModelF1Score*100)
print("Train MCC Score: ", svmModelMCCScore*100)
print("Train Kappa Coefficiet: ", svmModelKappaCoeff*100)
```

```
Train Accuracy:  8637.671638714995
Train Precision:  8668.024385395693
Train Senstivity:  8183.201320132013
Train F1 Score:  8414.73474776269
Train MCC Score:  7236.169269154683
Train Kappa Coefficiet:  7222.311133050082
```

[35]:
```
y_pred_svm = svmModel.predict(x_test)
```

[36]:
```
mse_svm = mean_squared_error(y_test, y_pred_svm)
rmse_svm = np.sqrt(mse_svm)
mae_svm = mean_absolute_error(y_test, y_pred_svm)

print(f"MSE: {mse_svm}")
print(f"RMSE: {rmse_svm}")
print(f"MAE: {mae_svm}")
```

```
MSE: 0.15187713310580206
RMSE: 0.38971416846940793
MAE: 0.15187713310580206
```

[37]:
```
svmModelTestAccuracy = accuracy_score(y_test, y_pred_svm)*100
svmModelTestPrecision = precision_score(y_test, y_pred_svm)*100
svmModelTestSenstivity = recall_score(y_test, y_pred_svm)*100
svmModelTestF1Score = f1_score(y_test, y_pred_svm)*100
svmModelTestMCCScore = matthews_corrcoef(y_test, y_pred_svm)*100
svmModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_svm)*100
```

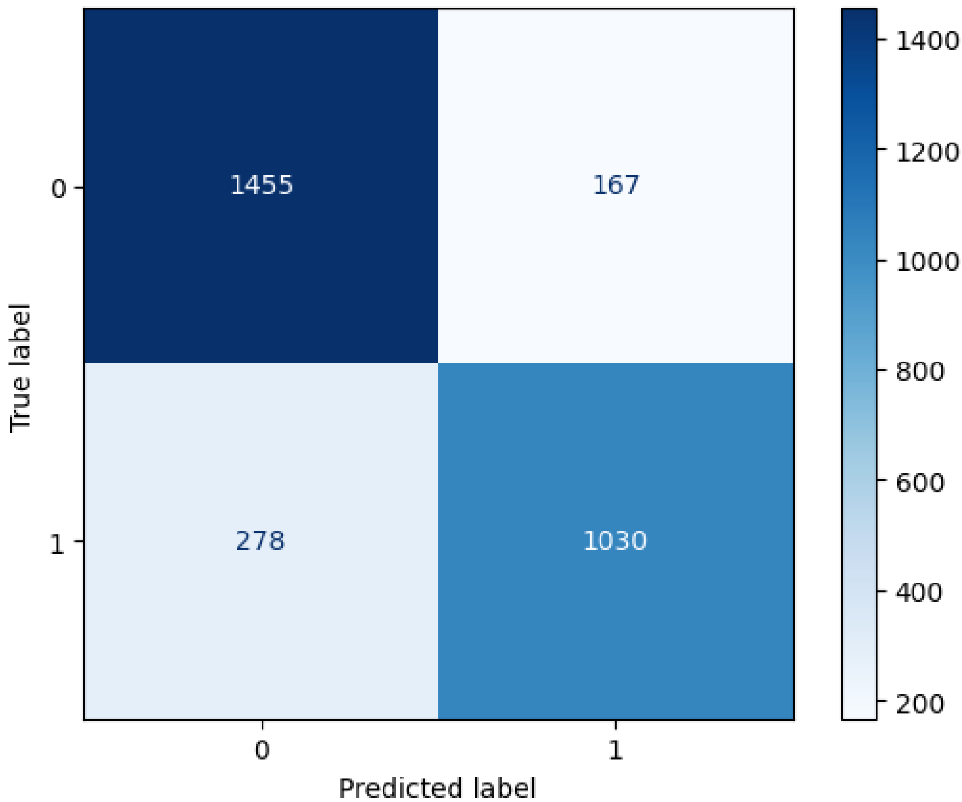
```
print(f"Test Accuracy: {svmModelTestAccuracy*100}")
print(f"Test Precision: {svmModelTestPrecision*100}")
print(f"Test Senstivity: {svmModelTestSenstivity*100}")
print(f"Test F1 Score: {svmModelTestF1Score*100}")
print(f"Test MCC Score: {svmModelTestMCCScore*100}")
print(f"Test Kappa Coefficiet: {svmModelTestKappaCoeff*100}")
```

```
Test Accuracy: 8481.22866894198
Test Precision: 8604.845446950709
Test Senstivity: 7874.617737003058
Test F1 Score: 8223.552894211576
Test MCC Score: 6922.42017288289
Test Kappa Coefficiet: 6901.716560946968
```

[38]:
```
report_svm = classification_report(y_test, y_pred_svm)
print(report_svm)
```

```
              precision    recall  f1-score   support

           0       0.84      0.90      0.87      1622
           1       0.86      0.79      0.82      1308

    accuracy                           0.85      2930
   macro avg       0.85      0.84      0.84      2930
weighted avg       0.85      0.85      0.85      2930
```

[39]:
```
cm_svm = confusion_matrix(y_test, y_pred_svm)

disp = ConfusionMatrixDisplay(confusion_matrix=cm_svm)
disp.plot(cmap=plt.cm.Blues)
plt.show()
```



9.3 Decision Tree Classifier

[40]:
```
decisionTreeModel = DecisionTreeClassifier()
decisionTreeModel.fit(x_train, y_train)
```

[40]: DecisionTreeClassifier()

[41]:
```
decisionTreeModelAccuracy = np.mean(cross_val_score(decisionTreeModel, x_train,␣
 ↪y_train, scoring=make_scorer(accuracy_score), cv=30))*100
decisionTreeModelPrecision = np.mean(cross_val_score(decisionTreeModel,␣
 ↪x_train, y_train, scoring=make_scorer(precision_score), cv=30))*100
decisionTreeModelSenstivity = np.mean(cross_val_score(decisionTreeModel,␣
 ↪x_train, y_train, scoring=make_scorer(recall_score), cv=30))*100
decisionTreeModelF1Score = np.mean(cross_val_score(decisionTreeModel, x_train,␣
 ↪y_train, scoring=make_scorer(f1_score), cv=30))*100
decisionTreeModelMCCScore = np.mean(cross_val_score(decisionTreeModel, x_train,␣
 ↪y_train, scoring=make_scorer(matthews_corrcoef), cv=30))*100
decisionTreeModelKappaCoeff = np.mean(cross_val_score(decisionTreeModel,␣
 ↪x_train, y_train, scoring=make_scorer(cohen_kappa_score), cv=30))*100
```

[42]:
```
print("Train Accuracy: ", decisionTreeModelAccuracy*100)
print("Train Precision: ", decisionTreeModelPrecision*100)
print("Train Senstivity: ", decisionTreeModelSenstivity*100)
print("Train F1 Score: ", decisionTreeModelF1Score*100)
print("Train MCC Score: ", decisionTreeModelMCCScore*100)
print("Train Kappa Coefficiet: ", decisionTreeModelKappaCoeff*100)
```

```
Train Accuracy:  8552.728186104026
Train Precision:  8435.649099361057
Train Senstivity:  8312.178217821784
Train F1 Score:  8379.177184541539
Train MCC Score:  7087.360954712037
Train Kappa Coefficiet:  7064.231567262482
```

[43]:
```
y_pred_decision_tree = decisionTreeModel.predict(x_test)
```

[44]:
```
mse_decision_tree = mean_squared_error(y_test, y_pred_decision_tree)
rmse_decision_tree = np.sqrt(mse_decision_tree)
mae_decision_tree = mean_absolute_error(y_test, y_pred_decision_tree)

print(f"MSE: {mse_decision_tree}")
print(f"RMSE: {rmse_decision_tree}")
print(f"MAE: {mae_decision_tree}")
```

```
MSE: 0.1477815699658703
RMSE: 0.3844236854902027
MAE: 0.1477815699658703
```

[45]:
```
decisionTreeModelTestAccuracy = accuracy_score(y_test, y_pred_decision_tree)*100
decisionTreeModelTestPrecision = precision_score(y_test,␣
 ↪y_pred_decision_tree)*100
decisionTreeModelTestSenstivity = recall_score(y_test, y_pred_decision_tree)*100
decisionTreeModelTestF1Score = f1_score(y_test, y_pred_decision_tree)*100
decisionTreeModelTestMCCScore = matthews_corrcoef(y_test,␣
 ↪y_pred_decision_tree)*100
decisionTreeModelTestKappaCoeff = cohen_kappa_score(y_test,␣
 ↪y_pred_decision_tree)*100

print(f"Test Accuracy: {decisionTreeModelTestAccuracy*100}")
print(f"Test Precision: {decisionTreeModelTestPrecision*100}")
print(f"Test Senstivity: {decisionTreeModelTestSenstivity*100}")
print(f"Test F1 Score: {decisionTreeModelTestF1Score*100}")
print(f"Test MCC Score: {decisionTreeModelTestMCCScore*100}")
print(f"Test Kappa Coefficiet: {decisionTreeModelTestKappaCoeff*100}")
```

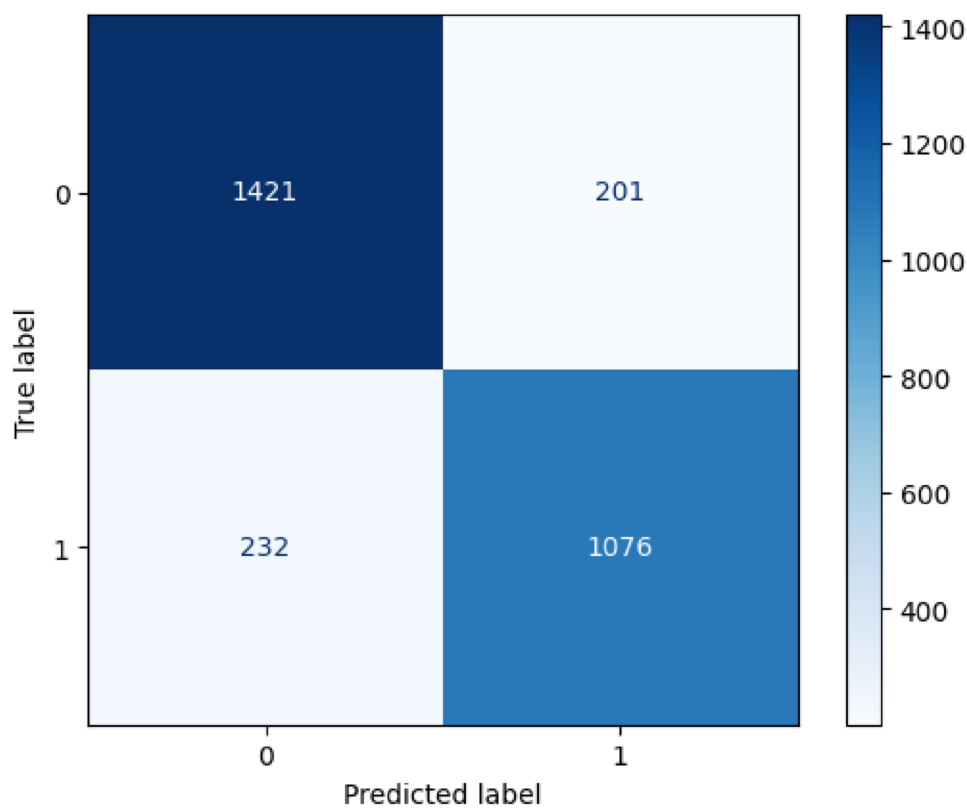
```
Test Accuracy: 8522.184300341298
Test Precision: 8425.998433829287
```

```
Test Senstivity: 8226.299694189604
Test F1 Score: 8324.95164410058
Test MCC Score: 7004.766889016804
Test Kappa Coefficiet: 7003.154425100474
```

[46]:
```python
report_decision_tree = classification_report(y_test, y_pred_decision_tree)
print(report_decision_tree)
```

```
              precision    recall  f1-score   support

           0       0.86      0.88      0.87      1622
           1       0.84      0.82      0.83      1308

    accuracy                           0.85      2930
   macro avg       0.85      0.85      0.85      2930
weighted avg       0.85      0.85      0.85      2930
```

[47]:
```python
cm_decision_tree = confusion_matrix(y_test, y_pred_decision_tree)

disp = ConfusionMatrixDisplay(confusion_matrix=cm_decision_tree)
disp.plot(cmap=plt.cm.Blues)
plt.show()
```



9.4 Random Forest Classifier

[48]:
```
randomForestModel = RandomForestClassifier()
randomForestModel.fit(x_train, y_train)
```

[48]:
```
RandomForestClassifier()
```

[49]:
```
randomForestModelAccuracy = np.mean(cross_val_score(randomForestModel, x_train,␣
 ↪y_train, scoring=make_scorer(accuracy_score), cv=30))*100
randomForestModelPrecision = np.mean(cross_val_score(randomForestModel,␣
 ↪x_train, y_train, scoring=make_scorer(precision_score), cv=30))*100
randomForestModelSenstivity = np.mean(cross_val_score(randomForestModel,␣
 ↪x_train, y_train, scoring=make_scorer(recall_score), cv=30))*100
randomForestModelF1Score = np.mean(cross_val_score(randomForestModel, x_train,␣
 ↪y_train, scoring=make_scorer(f1_score), cv=30))*100
randomForestModelMCCScore = np.mean(cross_val_score(randomForestModel, x_train,␣
 ↪y_train, scoring=make_scorer(matthews_corrcoef), cv=30))*100
randomForestModelKappaCoeff = np.mean(cross_val_score(randomForestModel,␣
 ↪x_train, y_train, scoring=make_scorer(cohen_kappa_score), cv=30))*100
```

[50]:
```
print("Accuracy: ", randomForestModelAccuracy*100)
print("Precision: ", randomForestModelPrecision*100)
print("Senstivity: ", randomForestModelSenstivity*100)
print("F1 Score: ", randomForestModelF1Score*100)
print("MCC Score: ", randomForestModelMCCScore*100)
print("Kappa Coefficiet: ", randomForestModelKappaCoeff*100)
```

```
Accuracy:  9029.83228997604
Precision:  9052.871420333931
Senstivity:  8696.435643564357
F1 Score:  8881.699977780247
MCC Score:  8043.4712083279155
Kappa Coefficiet:  8024.307977072654
```

[51]:
```
y_pred_random_forest = randomForestModel.predict(x_test)
```

[52]:
```
mse_random_forest = mean_squared_error(y_test, y_pred_random_forest)
rmse_random_forest = np.sqrt(mse_random_forest)
mae_random_forest = mean_absolute_error(y_test, y_pred_random_forest)

print(f"MSE: {mse_random_forest}")
print(f"RMSE: {rmse_random_forest}")
print(f"MAE: {mae_random_forest}")
```

```
MSE: 0.09931740614334471
RMSE: 0.31514664228473815
MAE: 0.09931740614334471
```

[53]:

```python
randomForestModelTestAccuracy = accuracy_score(y_test, y_pred_random_forest)*100
randomForestModelTestPrecision = precision_score(y_test,␣
↪y_pred_random_forest)*100
randomForestModelTestSenstivity = recall_score(y_test, y_pred_random_forest)*100
randomForestTestModelF1Score = f1_score(y_test, y_pred_random_forest)*100
randomForestModelTestMCCScore = matthews_corrcoef(y_test,␣
↪y_pred_random_forest)*100
randomForestModelTestKappaCoeff = cohen_kappa_score(y_test,␣
↪y_pred_random_forest)*100

print(f"Test Accuracy: {randomForestModelTestAccuracy*100}")
print(f"Test Precision: {randomForestModelTestPrecision*100}")
print(f"Test Senstivity: {randomForestModelTestSenstivity*100}")
print(f"Test F1 Score: {randomForestTestModelF1Score*100}")
print(f"Test MCC Score: {randomForestModelTestMCCScore*100}")
print(f"Test Kappa Coefficiet: {randomForestModelTestKappaCoeff*100}")
```

```
Test Accuracy: 9006.825938566553
Test Precision: 9110.751818916733
Test Senstivity: 8616.207951070337
Test F1 Score: 8856.581532416503
Test MCC Score: 7989.670339895791
Test Kappa Coefficiet: 7979.960472491613
```

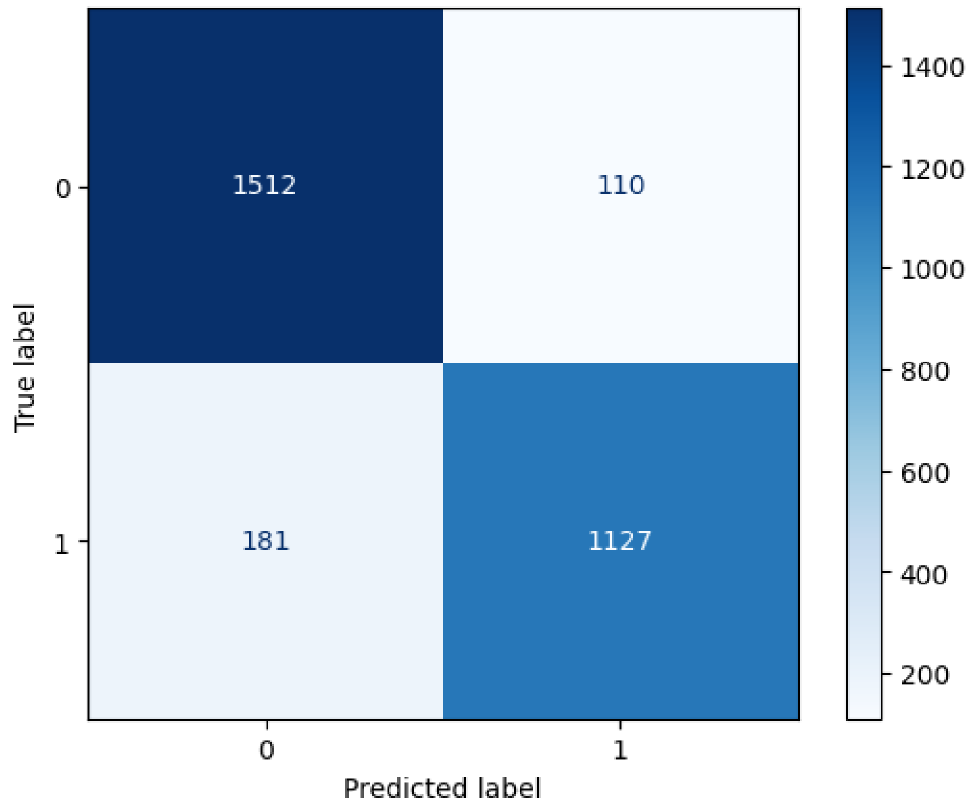
[54]:

```python
report_random_forest = classification_report(y_test, y_pred_random_forest)
print(report_random_forest)
```

```
              precision    recall  f1-score   support

           0       0.89      0.93      0.91      1622
           1       0.91      0.86      0.89      1308

    accuracy                           0.90      2930
   macro avg       0.90      0.90      0.90      2930
weighted avg       0.90      0.90      0.90      2930
```

[55]:

```python
cm_random_forest = confusion_matrix(y_test, y_pred_random_forest)

disp = ConfusionMatrixDisplay(confusion_matrix=cm_random_forest)
disp.plot(cmap=plt.cm.Blues)
plt.show()
```



9.5 K Neighbors Classifier (KNN)

[56]:
```
KNNModel = KNeighborsClassifier()
KNNModel.fit(x_train, y_train)
```

[56]: KNeighborsClassifier()

[57]:
```
KNNModelAccuracy = np.mean(cross_val_score(KNNModel, x_train, y_train,␣
 ↪scoring=make_scorer(accuracy_score), cv=30))*100
KNNModelPrecision = np.mean(cross_val_score(KNNModel, x_train, y_train,␣
 ↪scoring=make_scorer(precision_score), cv=30))*100
KNNModelSenstivity = np.mean(cross_val_score(KNNModel, x_train, y_train,␣
 ↪scoring=make_scorer(recall_score), cv=30))*100
KNNModelF1Score = np.mean(cross_val_score(KNNModel, x_train, y_train,␣
 ↪scoring=make_scorer(f1_score), cv=30))*100
KNNModelMCCScore = np.mean(cross_val_score(KNNModel, x_train, y_train,␣
 ↪scoring=make_scorer(matthews_corrcoef), cv=30))*100
KNNModelKappaCoeff = np.mean(cross_val_score(KNNModel, x_train, y_train,␣
 ↪scoring=make_scorer(cohen_kappa_score), cv=30))*100
```

[58]:
```python
print("Train Accuracy: ", KNNModelAccuracy*100)
print("Train Precision: ", KNNModelPrecision*100)
print("Train Senstivity: ", KNNModelSenstivity*100)
print("Train F1 Score: ", KNNModelF1Score*100)
print("Train MCC Score: ", KNNModelMCCScore*100)
print("Train Kappa Coefficiet: ", KNNModelKappaCoeff*100)
```

```
Train Accuracy:  8858.580003606667
Train Precision:  8740.52925782226
Train Senstivity:  8672.805280528053
Train F1 Score:  8704.611245895627
Train MCC Score:  7687.380728186296
Train Kappa Coefficiet:  7684.529384091519
```

[59]:
```python
y_pred_knn = KNNModel.predict(x_test)
```

[60]:
```python
mse_knn = mean_squared_error(y_test, y_pred_knn)
rmse_knn = np.sqrt(mse_knn)
mae_knn = mean_absolute_error(y_test, y_pred_knn)

print(f"MSE: {mse_knn}")
print(f"RMSE: {rmse_knn}")
print(f"MAE: {mae_knn}")
```

```
MSE: 0.11569965870307167
RMSE: 0.3401465253432286
MAE: 0.11569965870307167
```

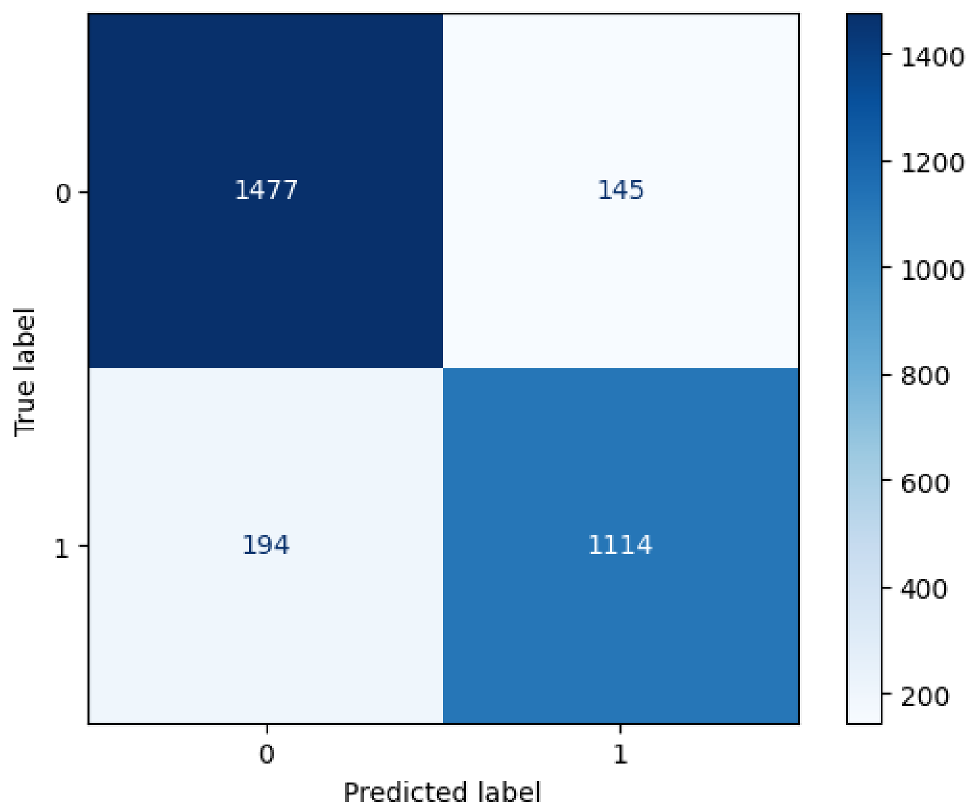
[61]:
```python
KNNModelTestAccuracy = accuracy_score(y_test, y_pred_knn)*100
KNNModelTestPrecision = precision_score(y_test, y_pred_knn)*100
KNNModelTestSenstivity = recall_score(y_test, y_pred_knn)*100
KNNModelTestF1Score = f1_score(y_test, y_pred_knn)*100
KNNModelTestMCCScore = matthews_corrcoef(y_test, y_pred_knn)*100
KNNModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_knn)*100

print(f"Test Accuracy: {KNNModelTestAccuracy*100}")
print(f"Test Precision: {KNNModelTestPrecision*100}")
print(f"Test Senstivity: {KNNModelTestSenstivity*100}")
print(f"Test F1 Score: {KNNModelTestF1Score*100}")
print(f"Test MCC Score: {KNNModelTestMCCScore*100}")
print(f"Test Kappa Coefficiet: {KNNModelTestKappaCoeff*100}")
```

```
Test Accuracy: 8843.003412969285
Test Precision: 8848.292295472598
Test Senstivity: 8516.819571865442
Test F1 Score: 8679.39228671601
Test MCC Score: 7655.0183448969665
Test Kappa Coefficiet: 7650.603179078502
```

[62]:
```
report_knn = classification_report(y_test, y_pred_knn)
print(report_knn)
```

```
              precision    recall  f1-score   support

           0       0.88      0.91      0.90      1622
           1       0.88      0.85      0.87      1308

    accuracy                           0.88      2930
   macro avg       0.88      0.88      0.88      2930
weighted avg       0.88      0.88      0.88      2930
```

[63]:
```
cm_knn = confusion_matrix(y_test, y_pred_knn)

disp = ConfusionMatrixDisplay(confusion_matrix=cm_knn)
disp.plot(cmap=plt.cm.Blues)
plt.show()
```



9.6 Naive Bayes Classifier

[64]:
```
naiveBayesModel = GaussianNB()
naiveBayesModel.fit(x_train, y_train)
```

[64]:
```
GaussianNB()
```

[65]:
```
naiveBayesModelAccuracy = np.mean(cross_val_score(naiveBayesModel, x_train,␣
 ↪y_train, scoring=make_scorer(accuracy_score), cv=30))*100
naiveBayesModelPrecision = np.mean(cross_val_score(naiveBayesModel, x_train,␣
 ↪y_train, scoring=make_scorer(precision_score), cv=30))*100
naiveBayesModelSenstivity = np.mean(cross_val_score(naiveBayesModel, x_train,␣
 ↪y_train, scoring=make_scorer(recall_score), cv=30))*100
naiveBayesModelF1Score = np.mean(cross_val_score(naiveBayesModel, x_train,␣
 ↪y_train, scoring=make_scorer(f1_score), cv=30))*100
naiveBayesModelMCCScore = np.mean(cross_val_score(naiveBayesModel, x_train,␣
 ↪y_train, scoring=make_scorer(matthews_corrcoef), cv=30))*100
naiveBayesModelKappaCoeff = np.mean(cross_val_score(naiveBayesModel, x_train,␣
 ↪y_train, scoring=make_scorer(cohen_kappa_score), cv=30))*100
```

[66]:
```
print("Train Accuracy: ", naiveBayesModelAccuracy*100)
print("Train Precision: ", naiveBayesModelPrecision*100)
print("Train Senstivity: ", naiveBayesModelSenstivity*100)
print("Train F1 Score: ", naiveBayesModelF1Score*100)
print("Train MCC Score: ", naiveBayesModelMCCScore*100)
print("Train Kappa Coefficiet: ", naiveBayesModelKappaCoeff*100)
```

```
Train Accuracy:  6504.25071489296
Train Precision:  6121.97007194838
Train Senstivity:  5724.521452145214
Train F1 Score:  5911.964772987255
Train MCC Score:  2873.2972384627788
Train Kappa Coefficiet:  2865.5846455036053
```

[67]:
```
y_pred_naive_bayes = naiveBayesModel.predict(x_test)
```

[68]:
```
mse_naive_bayes = mean_squared_error(y_test, y_pred_naive_bayes)
rmse_naive_bayes = np.sqrt(mse_naive_bayes)
mae_naive_bayes = mean_absolute_error(y_test, y_pred_naive_bayes)

print(f"MSE: {mse_naive_bayes}")
print(f"RMSE: {rmse_naive_bayes}")
print(f"MAE: {mae_naive_bayes}")
```

```
MSE: 0.36928327645051195
RMSE: 0.6076868243186715
MAE: 0.36928327645051195
```

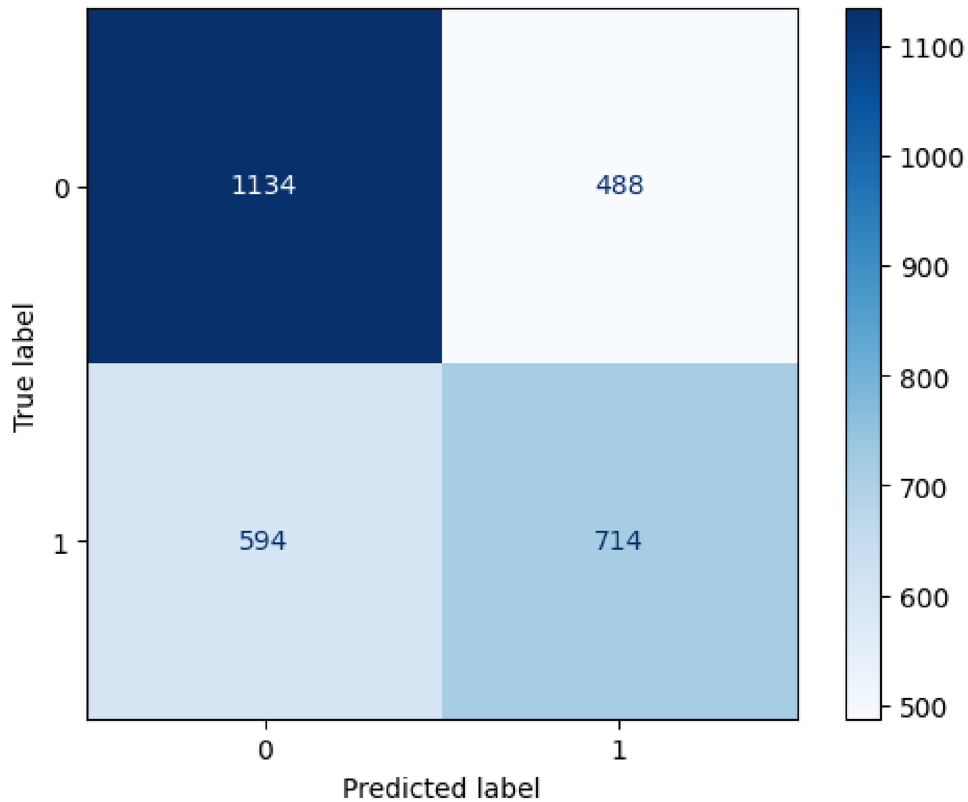
```
[69]: naiveBayesModelTestAccuracy = accuracy_score(y_test, y_pred_naive_bayes)*100
naiveBayesModelTestPrecision = precision_score(y_test, y_pred_naive_bayes)*100
naiveBayesModelTestSenstivity = recall_score(y_test, y_pred_naive_bayes)*100
naiveBayesModelTestF1Score = f1_score(y_test, y_pred_naive_bayes)*100
naiveBayesModelTestMCCScore = matthews_corrcoef(y_test, y_pred_naive_bayes)*100
naiveBayesModelTestKappaCoeff = cohen_kappa_score(y_test,␣
 ↪y_pred_naive_bayes)*100

print(f"Test Accuracy: {naiveBayesModelTestAccuracy*100}")
print(f"Test Precision: {naiveBayesModelTestPrecision*100}")
print(f"Test Senstivity: {naiveBayesModelTestSenstivity*100}")
print(f"Test F1 Score: {naiveBayesModelTestF1Score*100}")
print(f"Test MCC Score: {naiveBayesModelTestMCCScore*100}")
print(f"Test Kappa Coefficiet: {naiveBayesModelTestKappaCoeff*100}")
```

```
Test Accuracy: 6307.1672354948805
Test Precision: 5940.099833610649
Test Senstivity: 5458.715596330275
Test F1 Score: 5689.243027888446
Test MCC Score: 2476.202839809542
Test Kappa Coefficiet: 2469.455099304776
```

```
[70]: report_naive_bayes = classification_report(y_test, y_pred_naive_bayes)
print(report_naive_bayes)
```

```
              precision    recall  f1-score   support

           0       0.66      0.70      0.68      1622
           1       0.59      0.55      0.57      1308

    accuracy                           0.63      2930
   macro avg       0.63      0.62      0.62      2930
weighted avg       0.63      0.63      0.63      2930
```

```
[71]: cm_naive_bayes = confusion_matrix(y_test, y_pred_naive_bayes)

disp = ConfusionMatrixDisplay(confusion_matrix=cm_naive_bayes)
disp.plot(cmap=plt.cm.Blues)
plt.show()
```



9.7 XGBoost

[72]:
```
xgboostModel = XGBClassifier()
xgboostModel.fit(x_train, y_train)
```

[72]:
```
XGBClassifier(base_score=None, booster=None, callbacks=None,
              colsample_bylevel=None, colsample_bynode=None,
              colsample_bytree=None, device=None, early_stopping_rounds=None,
              enable_categorical=False, eval_metric=None, feature_types=None,
              gamma=None, grow_policy=None, importance_type=None,
              interaction_constraints=None, learning_rate=None, max_bin=None,
              max_cat_threshold=None, max_cat_to_onehot=None,
              max_delta_step=None, max_depth=None, max_leaves=None,
              min_child_weight=None, missing=nan, monotone_constraints=None,
              multi_strategy=None, n_estimators=None, n_jobs=None,
              num_parallel_tree=None, random_state=None, …)
```

[73]:
```
xgboostModelAccuracy = np.mean(cross_val_score(xgboostModel, x_train, y_train,␣
 ↪scoring=make_scorer(accuracy_score), cv=30))*100
xgboostModelPrecision = np.mean(cross_val_score(xgboostModel, x_train, y_train,␣
 ↪scoring=make_scorer(precision_score), cv=30))*100
```

```
xgboostModelSenstivity = np.mean(cross_val_score(xgboostModel, x_train,␣
↪y_train, scoring=make_scorer(recall_score), cv=30))*100
xgboostModelF1Score = np.mean(cross_val_score(xgboostModel, x_train, y_train,␣
↪scoring=make_scorer(f1_score), cv=30))*100
xgboostModelMCCScore = np.mean(cross_val_score(xgboostModel, x_train, y_train,␣
↪scoring=make_scorer(matthews_corrcoef), cv=30))*100
xgboostModelKappaCoeff = np.mean(cross_val_score(xgboostModel, x_train,␣
↪y_train, scoring=make_scorer(cohen_kappa_score), cv=30))*100
```

[74]:
```
print("Train Accuracy: ", xgboostModelAccuracy*100)
print("Train Precision: ", xgboostModelPrecision*100)
print("Train Senstivity: ", xgboostModelSenstivity*100)
print("Train F1 Score: ", xgboostModelF1Score*100)
print("Train MCC Score: ", xgboostModelMCCScore*100)
print("Train Kappa Coefficiet: ", xgboostModelKappaCoeff*100)
```

```
Train Accuracy:  9035.654481283975
Train Precision:  8957.006657981545
Train Senstivity:  8855.016501650167
Train F1 Score:  8902.46176778782
Train MCC Score:  8047.776539230777
Train Kappa Coefficiet:  8042.6945113056245
```

[75]:
```
y_pred_xgboost = xgboostModel.predict(x_test)
```

[76]:
```
mse_xgboost = mean_squared_error(y_test, y_pred_xgboost)
rmse_xgboost = np.sqrt(mse_xgboost)
mae_xgboost = mean_absolute_error(y_test, y_pred_xgboost)

print(f"MSE: {mse_xgboost}")
print(f"RMSE: {rmse_xgboost}")
print(f"MAE: {mae_xgboost}")
```

```
MSE: 0.09488054607508532
RMSE: 0.308026859340359
MAE: 0.09488054607508532
```

[77]:
```
xgboostModelTestAccuracy = accuracy_score(y_test, y_pred_xgboost)*100
xgboostModelTestPrecision = precision_score(y_test, y_pred_xgboost)*100
xgboostModelTestSenstivity = recall_score(y_test, y_pred_xgboost)*100
xgboostModelTestF1Score = f1_score(y_test, y_pred_xgboost)*100
xgboostModelTestMCCScore = matthews_corrcoef(y_test, y_pred_xgboost)*100
xgboostModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_xgboost)*100

print(f"Test Accuracy: {xgboostModelTestAccuracy*100}")
print(f"Test Precision: {xgboostModelTestPrecision*100}")
print(f"Test Senstivity: {xgboostModelTestSenstivity*100}")
```

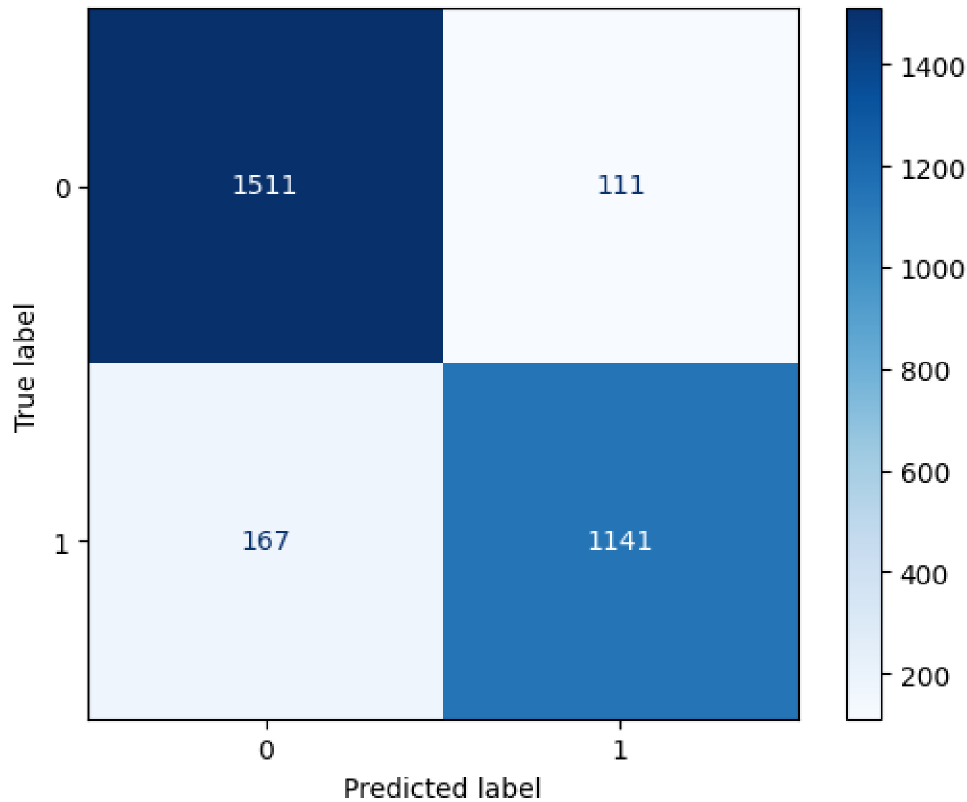
```
print(f"Test F1 Score: {xgboostModelTestF1Score*100}")
print(f"Test MCC Score: {xgboostModelTestMCCScore*100}")
print(f"Test Kappa Coefficiet: {xgboostModelTestKappaCoeff*100}")
```

```
Test Accuracy: 9051.194539249147
Test Precision: 9113.418530351439
Test Senstivity: 8723.241590214067
Test F1 Score: 8914.0625
Test MCC Score: 8078.446424478811
Test Kappa Coefficiet: 8072.353823201994
```

[78]:
```
report_xgboost = classification_report(y_test, y_pred_xgboost)
print(report_xgboost)
```

```
              precision    recall  f1-score   support

           0       0.90      0.93      0.92      1622
           1       0.91      0.87      0.89      1308

    accuracy                           0.91      2930
   macro avg       0.91      0.90      0.90      2930
weighted avg       0.91      0.91      0.90      2930
```

[79]:
```
cm_xgboost = confusion_matrix(y_test, y_pred_xgboost)

disp = ConfusionMatrixDisplay(confusion_matrix=cm_xgboost)
disp.plot(cmap=plt.cm.Blues)
plt.show()
```



9.8 AdaBoost

[80]:
```
adaboostModel = AdaBoostClassifier()
adaboostModel.fit(x_train, y_train)
```

```
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-
packages/sklearn/ensemble/_weight_boosting.py:519: FutureWarning: The SAMME.R
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algorithm to circumvent this warning.
  warnings.warn(
```

[80]:
```
AdaBoostClassifier()
```

[81]:
```
adaboostModelAccuracy = np.mean(cross_val_score(adaboostModel, x_train,␣
↪y_train, scoring=make_scorer(accuracy_score), cv=30))*100
adaboostModelPrecision = np.mean(cross_val_score(adaboostModel, x_train,␣
↪y_train, scoring=make_scorer(precision_score), cv=30))*100
adaboostModelSenstivity = np.mean(cross_val_score(adaboostModel, x_train,␣
↪y_train, scoring=make_scorer(recall_score), cv=30))*100
adaboostModelF1Score = np.mean(cross_val_score(adaboostModel, x_train, y_train,␣
↪scoring=make_scorer(f1_score), cv=30))*100
```

```python
adaboostModelMCCScore = np.mean(cross_val_score(adaboostModel, x_train,␣
↪y_train, scoring=make_scorer(matthews_corrcoef), cv=30))*100
adaboostModelKappaCoeff = np.mean(cross_val_score(adaboostModel, x_train,␣
↪y_train, scoring=make_scorer(cohen_kappa_score), cv=30))*100
```

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algorithm (the default) is deprecated and will be removed in 1.6. Use the SAMME
algorithm to circumvent this warning.
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/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-
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```

```
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```
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algorithm to circumvent this warning.
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/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-
packages/sklearn/ensemble/_weight_boosting.py:519: FutureWarning: The SAMME.R
algorithm (the default) is deprecated and will be removed in 1.6. Use the SAMME
algorithm to circumvent this warning.
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-
packages/sklearn/ensemble/_weight_boosting.py:519: FutureWarning: The SAMME.R
algorithm (the default) is deprecated and will be removed in 1.6. Use the SAMME
algorithm to circumvent this warning.
  warnings.warn(
```

[82]:

```
print("Train Accuracy: ", adaboostModelAccuracy*100)
print("Train Precision: ", adaboostModelPrecision*100)
print("Train Senstivity: ", adaboostModelSenstivity*100)
print("Train F1 Score: ", adaboostModelF1Score*100)
```

```
print("Train MCC Score: ", adaboostModelMCCScore*100)
print("Train Kappa Coefficiet: ", adaboostModelKappaCoeff*100)
```

```
Train Accuracy:  7598.771156967309
Train Precision:  7406.424561327721
Train Senstivity:  7051.782178217822
Train F1 Score:  7220.2349716214485
Train MCC Score:  5119.103407721856
Train Kappa Coefficiet:  5109.373352783182
```

[83]:
```
y_pred_adaboost = adaboostModel.predict(x_test)
```

[84]:
```
mse_adaboost = mean_squared_error(y_test, y_pred_adaboost)
rmse_adaboost = np.sqrt(mse_adaboost)
mae_adaboost = mean_absolute_error(y_test, y_pred_adaboost)

print(f"MSE: {mse_adaboost}")
print(f"RMSE: {rmse_adaboost}")
print(f"MAE: {mae_adaboost}")
```

```
MSE: 0.2614334470989761
RMSE: 0.511305629833054
MAE: 0.2614334470989761
```

[85]:
```
adaboostModelTestAccuracy = accuracy_score(y_test, y_pred_adaboost)*100
adaboostModelTestPrecision = precision_score(y_test, y_pred_adaboost)*100
adaboostModelTestSenstivity = recall_score(y_test, y_pred_adaboost)*100
adaboostModelTestF1Score = f1_score(y_test, y_pred_adaboost)*100
adaboostModelTestMCCScore = matthews_corrcoef(y_test, y_pred_adaboost)*100
adaboostModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_adaboost)*100

print(f"Test Accuracy: {adaboostModelTestAccuracy*100}")
print(f"Test Precision: {adaboostModelTestPrecision*100}")
print(f"Test Senstivity: {adaboostModelTestSenstivity*100}")
print(f"Test F1 Score: {adaboostModelTestF1Score*100}")
print(f"Test MCC Score: {adaboostModelTestMCCScore*100}")
print(f"Test Kappa Coefficiet: {adaboostModelTestKappaCoeff*100}")
```

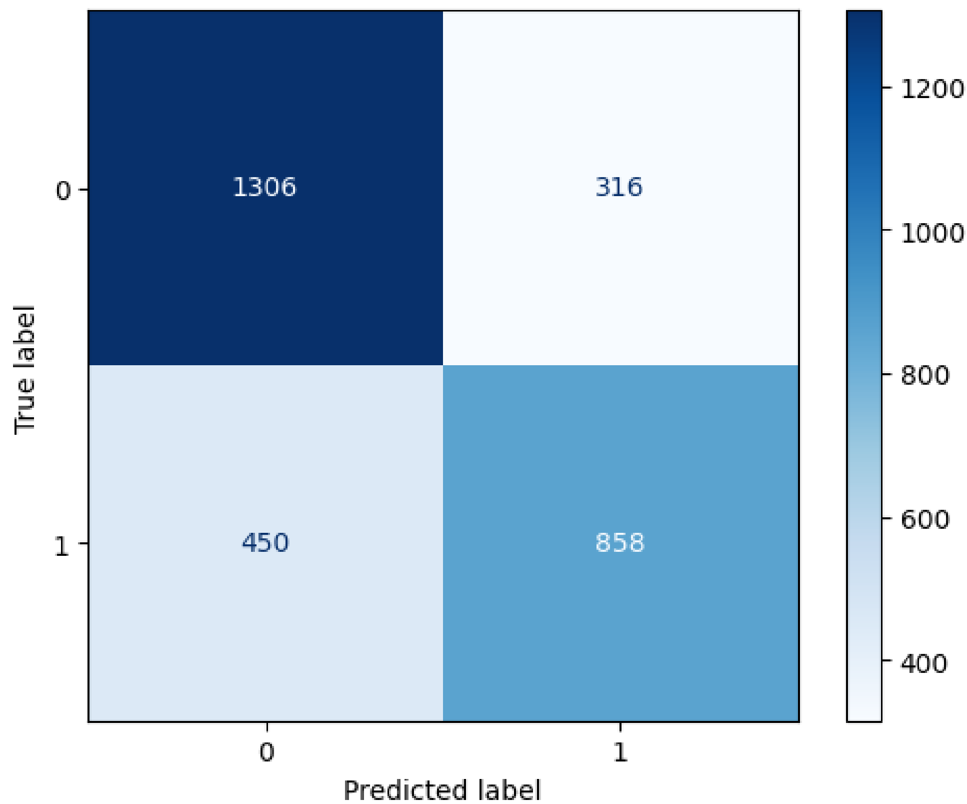
```
Test Accuracy: 7385.66552901024
Test Precision: 7308.347529812606
Test Senstivity: 6559.633027522935
Test F1 Score: 6913.779210314263
Test MCC Score: 4678.081248865522
Test Kappa Coefficiet: 4657.606765504837
```

[86]:
```
report_adaboost = classification_report(y_test, y_pred_adaboost)
print(report_adaboost)
```

```
              precision    recall  f1-score   support

           0       0.74      0.81      0.77      1622
           1       0.73      0.66      0.69      1308

    accuracy                           0.74      2930
   macro avg       0.74      0.73      0.73      2930
weighted avg       0.74      0.74      0.74      2930
```

[87]:

```
cm_adaboost = confusion_matrix(y_test, y_pred_adaboost)

disp = ConfusionMatrixDisplay(confusion_matrix=cm_adaboost)
disp.plot(cmap=plt.cm.Blues)
plt.show()
```



10 Model Comparison

10.1 Metrics Comparison on Train Data

10.1.1 Classification Performance Metrics

[88]:
```
arr_train = np.array([["Logistic Regression", logisticModelAccuracy,␣
↪logisticModelPrecision, logisticModelSenstivity, logisticModelF1Score,␣
↪logisticModelMCCScore, logisticModelKappaCoeff]])
arr_train = np.insert(arr_train, 0, ["SVM", svmModelAccuracy,␣
↪svmModelPrecision, svmModelSenstivity, svmModelF1Score, svmModelMCCScore,␣
↪svmModelKappaCoeff], axis=0)
arr_train = np.insert(arr_train, 0, ["Decision Tree",␣
↪decisionTreeModelAccuracy, decisionTreeModelPrecision,␣
↪decisionTreeModelSenstivity, decisionTreeModelF1Score,␣
↪decisionTreeModelMCCScore, decisionTreeModelKappaCoeff], axis=0)
arr_train = np.insert(arr_train, 0, ["Random Forest",␣
↪randomForestModelAccuracy, randomForestModelPrecision,␣
↪randomForestModelSenstivity, randomForestModelF1Score,␣
↪randomForestModelMCCScore, randomForestModelKappaCoeff], axis=0)
arr_train = np.insert(arr_train, 0, ["KNN", KNNModelAccuracy,␣
↪KNNModelPrecision, KNNModelSenstivity, KNNModelF1Score, KNNModelMCCScore,␣
↪KNNModelKappaCoeff], axis=0)
arr_train = np.insert(arr_train, 0, ["Naive Bayes", naiveBayesModelAccuracy,␣
↪naiveBayesModelPrecision, naiveBayesModelSenstivity, naiveBayesModelF1Score,␣
↪naiveBayesModelMCCScore, naiveBayesModelKappaCoeff], axis=0)
arr_train = np.insert(arr_train, 0, ["XGBoost", xgboostModelAccuracy,␣
↪xgboostModelPrecision, xgboostModelSenstivity, xgboostModelF1Score,␣
↪xgboostModelMCCScore, xgboostModelKappaCoeff], axis=0)
arr_train = np.insert(arr_train, 0, ["AdaBoost", adaboostModelAccuracy,␣
↪adaboostModelPrecision, adaboostModelSenstivity, adaboostModelF1Score,␣
↪adaboostModelMCCScore, adaboostModelKappaCoeff], axis=0)
```

[89]:
```
arr_train = pd.DataFrame(arr_train, columns=['Model', 'Accuracy', 'Precision',␣
↪'Senstivity', 'F1 Score', 'MCC Score', 'Kappa Coeff'])
```

[90]:
```
arr_train
```

[90]:
```
                 Model            Accuracy           Precision  \
0             AdaBoost    75.9877115696731   74.06424561327721
1              XGBoost   90.35654481283974   89.57006657981545
2          Naive Bayes    65.0425071489296    61.2197007194838
3                  KNN   88.58580003606667    87.4052925782226
4        Random Forest   90.29832289976041   90.52871420333932
5        Decision Tree   85.52728186104027   84.35649099361058
6                  SVM   86.37671638714995   86.68024385395692
7  Logistic Regression    74.6415230440271   73.30641377848939
```

```
          Senstivity           F1 Score           MCC Score  \
0  70.51782178217822  72.20234971621448   51.19103407721855
1  88.55016501650167   89.0246176778782   80.47776539230777
2  57.24521452145215  59.11964772987255  28.732972384627786
3  86.72805280528053  87.04611245895627   76.87380728186297
4  86.96435643564357  88.81699977780247   80.43471208327915
5  83.12178217821783  83.79177184541538   70.87360954712037
6  81.83201320132014   84.1473474776269   72.36169269154684
7  67.17392739273927  70.06104903835823  48.326411592484966

          Kappa Coeff
0  51.093733527831816
1   80.42694511305625
2  28.655846455036055
3   76.84529384091519
4   80.24307977072654
5   70.64231567262482
6   72.22311133050083
7   48.14645663003126
```

** Random Forest and XG Boost classifier are very close to each other. Hence I am going to use both of them with different hyperameters to see which one performs better.

10.2 Metrics Comparison on Test Data

10.2.1 Classification Performance Metrics

[91]:

```
arr_test = np.array([["Logistic Regression", logisticModelTestAccuracy,␣
 ↪logisticModelTestPrecision, logisticModelTestSenstivity,␣
 ↪logisticModelTestF1Score, logisticModelTestMCCScore,␣
 ↪logisticModelTestKappaCoeff]])
arr_test = np.insert(arr_test, 0, ["SVM", svmModelTestAccuracy,␣
 ↪svmModelTestPrecision, svmModelTestSenstivity, svmModelTestF1Score,␣
 ↪svmModelTestMCCScore, svmModelTestKappaCoeff], axis=0)
arr_test = np.insert(arr_test, 0, ["Decision Tree",␣
 ↪decisionTreeModelTestAccuracy, decisionTreeModelTestPrecision,␣
 ↪decisionTreeModelTestSenstivity, decisionTreeModelTestF1Score,␣
 ↪decisionTreeModelTestMCCScore, decisionTreeModelTestKappaCoeff], axis=0)
arr_test = np.insert(arr_test, 0, ["Random Forest",␣
 ↪randomForestModelTestAccuracy, randomForestModelTestPrecision,␣
 ↪randomForestModelTestSenstivity, randomForestTestModelF1Score,␣
 ↪randomForestModelTestMCCScore, randomForestModelTestKappaCoeff], axis=0)
arr_test = np.insert(arr_test, 0, ["KNN", KNNModelTestAccuracy,␣
 ↪KNNModelTestPrecision, KNNModelTestSenstivity, KNNModelTestF1Score,␣
 ↪KNNModelTestMCCScore, KNNModelTestKappaCoeff], axis=0)
```

```
arr_test = np.insert(arr_test, 0, ["Naive Bayes", naiveBayesModelTestAccuracy,␣
↪naiveBayesModelTestPrecision, naiveBayesModelTestSenstivity,␣
↪naiveBayesModelTestF1Score, naiveBayesModelTestMCCScore,␣
↪naiveBayesModelTestKappaCoeff], axis=0)
arr_test = np.insert(arr_test, 0, ["XGBoost", xgboostModelTestAccuracy,␣
↪xgboostModelTestPrecision, xgboostModelTestSenstivity,␣
↪xgboostModelTestF1Score, xgboostModelTestMCCScore,␣
↪xgboostModelTestKappaCoeff], axis=0)
arr_test = np.insert(arr_test, 0, ["AdaBoost", adaboostModelTestAccuracy,␣
↪adaboostModelTestPrecision, adaboostModelTestSenstivity,␣
↪adaboostModelTestF1Score, adaboostModelTestMCCScore,␣
↪adaboostModelTestKappaCoeff], axis=0)
```

[92]:
```
arr_test = pd.DataFrame(arr_test, columns=['Model', 'Accuracy', 'Precision',␣
↪'Senstivity', 'F1 Score', 'MCC Score', 'Kappa Coeff'])
```

[93]:
```
arr_test
```

[93]:
```
                 Model           Accuracy         Precision  \
0             AdaBoost   73.8566552901024  73.08347529812606
1              XGBoost  90.51194539249147  91.13418530351439
2          Naive Bayes   63.0716723549488  59.40099833610649
3                  KNN  88.43003412969284  88.48292295472598
4        Random Forest  90.06825938566553  91.10751818916734
5        Decision Tree  85.22184300341297  84.25998433829287
6                  SVM  84.81228668941979  86.04845446950709
7  Logistic Regression   73.6518771331058   73.6331569664903

          Senstivity          F1 Score         MCC Score        Kappa Coeff
0  65.59633027522935 69.13779210314263 46.78081248865522  46.57606765504837
1  87.23241590214067         89.140625 80.78446424478811  80.72353823201993
2  54.58715596330275 56.89243027888446 24.76202839809542  24.69455099304776
3  85.16819571865443  86.7939228671601 76.55018344896966  76.50603179078502
4  86.16207951070336 88.56581532416503 79.89670339895791  79.79960472491612
5  82.26299694189603  83.2495164410058 70.04766889016804  70.03154425100475
6  78.74617737003058 82.23552894211576  69.2242017288289  69.01716560946967
7  63.83792048929664 68.38656838656838 46.34070656930576  45.99614756157073
```

10.2.2 Regression Performance Metrics

[94]:
```
arr_regression = np.array([["Logistic Regression", mse_logistic, rmse_logistic,␣
↪mae_logistic]])
arr_regression = np.insert(arr_regression, 0, ["SVM", mse_svm, rmse_svm,␣
↪mae_svm], axis=0)
arr_regression = np.insert(arr_regression, 0, ["Decision Tree",␣
↪mse_decision_tree, rmse_decision_tree, mae_decision_tree], axis=0)
```

```
arr_regression = np.insert(arr_regression, 0, ["Random Forest",␣
↪mse_random_forest, rmse_random_forest, mae_random_forest], axis=0)
arr_regression = np.insert(arr_regression, 0, ["KNN", mse_knn, rmse_knn,␣
↪mae_knn], axis=0)
arr_regression = np.insert(arr_regression, 0, ["Naive Bayes", mse_naive_bayes,␣
↪rmse_naive_bayes, mae_naive_bayes], axis=0)
arr_regression = np.insert(arr_regression, 0, ["XGBoost", mse_xgboost,␣
↪rmse_xgboost, mae_xgboost], axis=0)
arr_regression = np.insert(arr_regression, 0, ["AdaBoost", mse_adaboost,␣
↪rmse_adaboost, mae_adaboost], axis=0)
```

[95]:
```
arr_regression = pd.DataFrame(arr_regression, columns=['Model', 'MSE', 'RMSE',␣
↪'MAE'])
```

[96]:
```
arr_regression
```

[96]:
```
                 Model                  MSE                 RMSE  \
0             AdaBoost   0.2614334470989761    0.511305629833054
1              XGBoost  0.09488054607508532    0.308026859340359
2          Naive Bayes  0.36928327645051195   0.6076868243186715
3                  KNN  0.11569965870307167   0.3401465253432286
4        Random Forest  0.09931740614334471  0.31514664228473815
5        Decision Tree   0.1477815699658703   0.3844236854902027
6                  SVM  0.15187713310580206  0.38971416846940793
7  Logistic Regression  0.26348122866894197   0.5133042262332758

                   MAE
0   0.2614334470989761
1  0.09488054607508532
2  0.36928327645051195
3  0.11569965870307167
4  0.09931740614334471
5   0.1477815699658703
6  0.15187713310580206
7  0.26348122866894197
```

11 Neural Network Attempt (IGNORE)

[97]:
```
'''
Artificial Neural Network Class
'''
class ANN:
    np.random.seed(10)

    '''
    Initialize the ANN;
```

```
    HiddenLayer vector : will contain the Layers' info
    w, b, phi = (empty) arrays that will contain all the w, b and activation␣
↪functions for all the Layers
    mu = cost function
    eta = a standard learning rate initialization. It can be modified by the␣
↪'set_learning_rate' method
    '''
    def __init__(self) :
        self.HiddenLayer = []
        self.w = []
        self.b = []
        self.phi = []
        self.mu = []
        self.eta = 1 #set up the proper Learning Rate!!

    '''
    add method: to add layers to the network
    '''
    def add(self, lay = (4, 'ReLU') ):
        self.HiddenLayer.append(lay)

    '''
    FeedForward method: as explained before.
    '''
    @staticmethod
    def FeedForward(w, b, phi, x):
        return phi(np.dot(w, x) + b)

    '''
    BackPropagation algorithm implementing the Gradient Descent
    '''
    def BackPropagation(self, x, z, Y, w, b, phi):
        self.delta = []

        # We initialize ausiliar w and b that are used only inside the␣
↪backpropagation algorithm once called
        self.W = []
        self.B = []

        # We start computing the LAST error, the one for the OutPut Layer
        self.delta.append(  (z[len(z)-1] - Y) * phi[len(z)-1](z[len(z)-1],␣
↪der=True) )

        '''Now we BACKpropagate'''
        # We thus compute from next-to-last to first
        for i in range(0, len(z)-1):
```

```
            self.delta.append( np.dot( self.delta[i], w[len(z)- 1 - i] ) *
phi[len(z)- 2 - i](z[len(z)- 2 - i], der=True) )

        # We have the error array ordered from last to first; we flip it to
order it from first to last
        self.delta = np.flip(self.delta, 0)

        # Now we define the delta as the error divided by the number of
training samples
        self.delta = self.delta/self.X.shape[0]

        '''GRADIENT DESCENT'''
        # We start from the first layer that is special, since it is connected
to the Input Layer
        self.W.append( w[0] - self.eta * np.kron(self.delta[0], x).reshape(
len(z[0]), x.shape[0] ) )
        self.B.append( b[0] - self.eta * self.delta[0] )

        # We now descend for all the other Hidden Layers + OutPut Layer
        for i in range(1, len(z)):
            self.W.append( w[i] - self.eta * np.kron(self.delta[i], z[i-1]).
reshape(len(z[i]), len(z[i-1])) )
            self.B.append( b[i] - self.eta * self.delta[i] )

        # We return the descended parameters w, b
        return np.array(self.W), np.array(self.B)


    '''
    Fit method: it calls FeedForward and Backpropagation methods
    '''
    def Fit(self, x_train, y_train):
        print('Start fitting...')
        '''
        Input layer
        '''
        self.X = x_train
        self.Y = y_train

        '''
        We now initialize the Network by retrieving the Hidden Layers and
concatenating them
        '''
        print('Model recap: \n')
        print('You are fitting an ANN with the following amount of layers: ',
len(self.HiddenLayer))
```

```
        for i in range(0, len(self.HiddenLayer)) :
            print('Layer ', i+1)
            print('Number of neurons: ', self.HiddenLayer[i][0])
            if i==0:
                # We now try to use the He et al. Initialization from ArXiv:
↪1502.01852
                self.w.append( np.random.randn(self.HiddenLayer[i][0] , self.X.
↪shape[1])/np.sqrt(2/self.X.shape[1]) )
                self.b.append( np.random.randn(self.HiddenLayer[i][0])/np.
↪sqrt(2/self.X.shape[1]))
                # Old initialization
                #self.w.append(2 * np.random.rand(self.HiddenLayer[i][0] , self.
↪X.shape[1]) - 0.5)
                #self.b.append(np.random.rand(self.HiddenLayer[i][0]))

                # Initialize the Activation function
                for act in Activation_function.list_act():
                    if self.HiddenLayer[i][1] == act :
                        self.phi.append(Activation_function.get_act(act))
                        print('\tActivation: ', act)

            else :
                # We now try to use the He et al. Initialization from ArXiv:
↪1502.01852
                self.w.append( np.random.randn(self.HiddenLayer[i][0] , self.
↪HiddenLayer[i-1][0] )/np.sqrt(2/self.HiddenLayer[i-1][0]))
                self.b.append( np.random.randn(self.HiddenLayer[i][0])/np.
↪sqrt(2/self.HiddenLayer[i-1][0]))
                # Old initialization
                #self.w.append(2*np.random.rand(self.HiddenLayer[i][0] , self.
↪HiddenLayer[i-1][0] ) - 0.5)
                #self.b.append(np.random.rand(self.HiddenLayer[i][0]))

                # Initialize the Activation function
                for act in Activation_function.list_act():
                    if self.HiddenLayer[i][1] == act :
                        self.phi.append(Activation_function.get_act(act))
                        print('\tActivation: ', act)

        '''
        Now we start the Loop over the training dataset
        '''
        for I in range(0, self.X.shape[0]): # loop over the training set
            '''
            Now we start the feed forward
```

```
            '''
            self.z = []

            self.z.append( self.FeedForward(self.w[0], self.b[0], self.phi[0],␣
↪self.X[I]) ) # First layers

            for i in range(1, len(self.HiddenLayer)): #Looping over layers
                self.z.append( self.FeedForward(self.w[i] , self.b[i], self.
↪phi[i], self.z[i-1] ) )


            '''
            Here we backpropagate
            '''
            self.w, self.b  = self.BackPropagation(self.X[I], self.z, self.
↪Y[I], self.w, self.b, self.phi)

            '''
            Compute cost function
            '''
            self.mu.append(
                (1/2) * np.dot(self.z[len(self.z)-1] - self.Y[I], self.
↪z[len(self.z)-1] - self.Y[I])
            )

        print('Fit done. \n')



    '''
    predict method
    '''
    def predict(self, x_test):

        print('Starting predictions...')

        self.pred = []
        self.XX = x_test

        for I in range(0, self.XX.shape[0]): # loop over the training set

            '''
            Now we start the feed forward
            '''
            self.z = []
```

```
            self.z.append(self.FeedForward(self.w[0] , self.b[0], self.phi[0],␣
↪self.XX[I])) #First layer

            for i in range(1, len(self.HiddenLayer)) : # loop over the layers
                self.z.append( self.FeedForward(self.w[i] , self.b[i], self.
↪phi[i], self.z[i-1]))

            # Append the prediction;
            # We now need a binary classifier; we this apply an Heaviside Theta␣
↪and we set to 0.5 the threshold
            # if y < 0.5 the output is zero, otherwise is zero
            self.pred.append( np.heaviside(  self.z[-1] - 0.5, 1)[0] ) # NB:␣
↪self.z[-1]  is the last element of the self.z list

        print('Predictions done. \n')

        return np.array(self.pred)

    '''
    We need a method to retrieve the accuracy for each training data to follow␣
↪the learning of the ANN
    '''
    def get_accuracy(self):
        return np.array(self.mu)
    # This is the averaged version
    def get_avg_accuracy(self):
        import math
        self.batch_loss = []
        for i in range(0, 10):
            self.loss_avg = 0
            # To set the batch in 10 element/batch we use math.ceil method
            # int(math.ceil((self.X.shape[0]-10) / 10.0))    - 1
            for m in range(0, (int(math.ceil((self.X.shape[0]-10) / 10.0))  ␣
↪)-1):
                #self.loss_avg += self.mu[60*i+m]/60
                self.loss_avg += self.mu[(int(math.ceil((self.X.shape[0]-10) /␣
↪10.0)) )*i + m]/(int(math.ceil((self.X.shape[0]-10) / 10.0)) )
            self.batch_loss.append(self.loss_avg)
        return np.array(self.batch_loss)

    '''
    Method to set the learning rate
    '''
    def set_learning_rate(self, et=1):
        self.eta = et
```

```
'''
layers class
'''
class layers :
    '''
    Layer method: used to call standar layers to add.
    Easily generalizable to more general layers (Pooling and Convolutional␣
 ↪layers)
    '''
    def layer(p=4, activation = 'ReLU'):
        return (p, activation)

'''
Activation functions class
'''
class Activation_function(ANN):

    def __init__(self) :
        super().__init__()

    '''
    Define the sigmoid activator; we ask if we want the sigmoid or its␣
 ↪derivative
    '''
    def sigmoid_act(x, der=False):
        if (der==True) : #derivative of the sigmoid
            f = 1/(1+ np.exp(- x))*(1-1/(1+ np.exp(- x)))
        else : # sigmoid
            f = 1/(1+ np.exp(- x))
        return f

    '''
    Define the Rectifier Linear Unit (ReLU)
    '''
    def reLU_act(x, der=False):
        if (der == True): # the derivative of the ReLU is the Heaviside Theta
            f = np.heaviside(x, 1)
        else :
            f = np.maximum(x, 0)
        return f

    def list_act():
        return ['sigmoid', 'ReLU']

    def get_act(string = 'ReLU'):
        if string == 'ReLU':
```

```
            return Activation_function.reLU_act
        elif string == 'sigmoid':
            return Activation_function.sigmoid_act
        else :
            return Activation_function.sigmoid_act
```

[98]:
```
model = ANN()

model.add(layers.layer(8, 'ReLU'))
model.add(layers.layer(4, 'ReLU'))
model.add(layers.layer(1, 'sigmoid'))

model.set_learning_rate(0.8)

model.Fit(x_train, y_train)
acc_val = model.get_accuracy()
acc_avg_val = model.get_avg_accuracy()

predictions = model.predict(x_test)
```

```
Start fitting…
Model recap:

You are fitting an ANN with the following amount of layers:  3
Layer  1
Number of neurons:  8
        Activation:  ReLU
Layer  2
Number of neurons:  4
        Activation:  ReLU
Layer  3
Number of neurons:  1
        Activation:  sigmoid
```

```
---------------------------------------------------------------------------
KeyError                                  Traceback (most recent call last)
File ~/anaconda3/envs/capstone/lib/python3.10/site-packages/pandas/core/indexes/
 ↪base.py:3805, in Index.get_loc(self, key)
   3804 try:
-> 3805     return self._engine.get_loc(casted_key)
   3806 except KeyError as err:

File index.pyx:167, in pandas._libs.index.IndexEngine.get_loc()

File index.pyx:196, in pandas._libs.index.IndexEngine.get_loc()
```

```
File pandas/_libs/hashtable_class_helper.pxi:2606, in pandas._libs.hashtable.
↪Int64HashTable.get_item()

File pandas/_libs/hashtable_class_helper.pxi:2630, in pandas._libs.hashtable.
↪Int64HashTable.get_item()

KeyError: 0

The above exception was the direct cause of the following exception:

KeyError                                  Traceback (most recent call last)
Cell In[98], line 9
      5 model.add(layers.layer(1, 'sigmoid'))
      7 model.set_learning_rate(0.8)
----> 9 model.Fit(x_train, y_train)
     10 acc_val = model.get_accuracy()
     11 acc_avg_val = model.get_avg_accuracy()

Cell In[97], line 139, in ANN.Fit(self, x_train, y_train)
    133     self.z.append( self.FeedForward(self.w[i] , self.b[i], self.phi[i],
↪self.z[i-1] ) )
    136 '''
    137 Here we backpropagate
    138 '''
--> 139 self.w, self.b  = self.BackPropagation(self.X[I], self.z, self.Y[I],
↪self.w, self.b, self.phi)
    141 '''
    142 Compute cost function
    143 '''
    144 self.mu.append(
    145     (1/2) * np.dot(self.z[len(self.z)-1] - self.Y[I], self.z[len(self.
↪z)-1] - self.Y[I])
    146 )

File ~/anaconda3/envs/capstone/lib/python3.10/site-packages/pandas/core/series.
↪py:1112, in Series.__getitem__(self, key)
   1109     return self._values[key]
   1111 elif key_is_scalar:
-> 1112     return self._get_value(key)
   1114 # Convert generator to list before going through hashable part
   1115 # (We will iterate through the generator there to check for slices)
   1116 if is_iterator(key):

File ~/anaconda3/envs/capstone/lib/python3.10/site-packages/pandas/core/series.
↪py:1228, in Series._get_value(self, label, takeable)
   1225     return self._values[label]
   1227 # Similar to Index.get_value, but we do not fall back to positional
-> 1228 loc = self.index.get_loc(label)
```

```
   1230 if is_integer(loc):
   1231     return self._values[loc]

File ~/anaconda3/envs/capstone/lib/python3.10/site-packages/pandas/core/indexes/
 ↪base.py:3812, in Index.get_loc(self, key)
   3807     if isinstance(casted_key, slice) or (
   3808         isinstance(casted_key, abc.Iterable)
   3809         and any(isinstance(x, slice) for x in casted_key)
   3810     ):
   3811         raise InvalidIndexError(key)
-> 3812     raise KeyError(key) from err
   3813 except TypeError:
   3814     # If we have a listlike key, _check_indexing_error will raise
   3815     #  InvalidIndexError. Otherwise we fall through and re-raise
   3816     #  the TypeError.
   3817     self._check_indexing_error(key)

KeyError: 0
```