[CAPSTONE] Fruits Freshness Classifier based on Comprehensive Image Features using XG Boost Classifier

Executive Summary

Problem Statement:

- It is difficult to identify the freshness of the fruits one by one when the number of fruits is in large volumes
- It is important to monitor the freshness of the fruits from time to time to ensure good customer satisfaction and retention

Scope:

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

Definitions:

- Total RGB Color Composition: The cumulative measurement of color distribution across the red, green, and blue channels within each image.
  - Red: Total Colour on the Red Channel
  - Green: Total colour on the Green Channel
  - Blue: Total colour on the Blue Channel
- Picture Intensity (Contrast): A component of texture analysis, indicating the degree of brightness or darkness in the image.
- Pixel Correlation: An assessment of the interdependence and relationship between adjacent pixels in the image.
- Homogeneity: An evaluation of the uniformity and consistency of visual elements throughout the image.
- Overall Energy: A measure of the aggregate visual intensity and vibrancy present in the image.

Methodology:

- Use Accuracy, Precision, Recall (Sensitivity), F1, MCC and Kappa to evaluate the classification performance of the models
- Use RMSE, MSE, MAE to evaluate the regression performance of the models

Importing the Libraries

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

from imblearn.over_sampling import SMOTE

# Scaler Methods
from sklearn.preprocessing import RobustScaler, MaxAbsScaler, MinMaxScale

# Machine Learning Models

from sklearn.model_selection import cross_val_score, train_test_split, Gr
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
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
)

import pickle
```

Importing the Database

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

In [ ]:
```
df
```

Out[ ]:

	Image	Red	Green	Blue	Contrast	Energy	Co
0	rotated_by_75_Screen Shot 2018-06-08 at 5.25.0...	480016	320784	308173	1455.458367	0.091725	
1	rotated_by_15_Screen Shot 2018-06-08 at 5.15.2...	429908	287132	294462	1898.266122	0.089732	
2	rotated_by_15_Screen Shot 2018-06-08 at 5.26.4...	493084	503330	363093	1304.415102	0.298530	
3	rotated_by_15_Screen Shot 2018-06-08 at 5.27.0...	398133	463717	277134	1057.761224	0.087325	
4	rotated_by_75_Screen Shot 2018-06-08 at 5.33.4...	403308	424642	264396	2111.405306	0.109698	
...	...	...	...	...	...	...	
10896	saltandpepper_Screen Shot 2018-06-12 at 11.46....	510687	494520	443423	252.043265	0.143389	
10897	rotated_by_75_Screen Shot 2018-06-12 at 11.40....	337028	264447	225432	882.749388	0.131601	
10898	Screen Shot 2018-06-12 at 11.46.17 PM	514385	463767	426552	441.551020	0.113603	
10899	rotated_by_15_Screen Shot 2018-06-12 at 11.45....	452977	368142	305902	1738.992653	0.224891	
10900	saltandpepper_Screen Shot 2018-06-12 at 11.23....	604274	481870	322724	222.860816	0.200812	

10901 rows × 9 columns

Exploratory Data Analysis (EDA)

In [ ]:

```
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
```

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

Out[ ]:

	Red	Green	Blue	Contrast	Energ
count	10901.000000	10901.000000	10901.000000	10901.000000	10901.00000
mean	466876.253646	402949.903036	337048.713788	1337.803641	0.25819
std	83431.591490	85979.015033	84021.923106	777.397036	0.14067
min	74212.000000	54894.000000	38685.000000	31.596735	0.01622
25%	418183.000000	345000.000000	279333.000000	647.005714	0.15970
50%	472741.000000	400620.000000	333381.000000	1387.058776	0.23309
75%	522343.000000	460991.000000	392566.000000	1789.657143	0.33182
max	633913.000000	622438.000000	571283.000000	5078.617143	0.78822

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

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

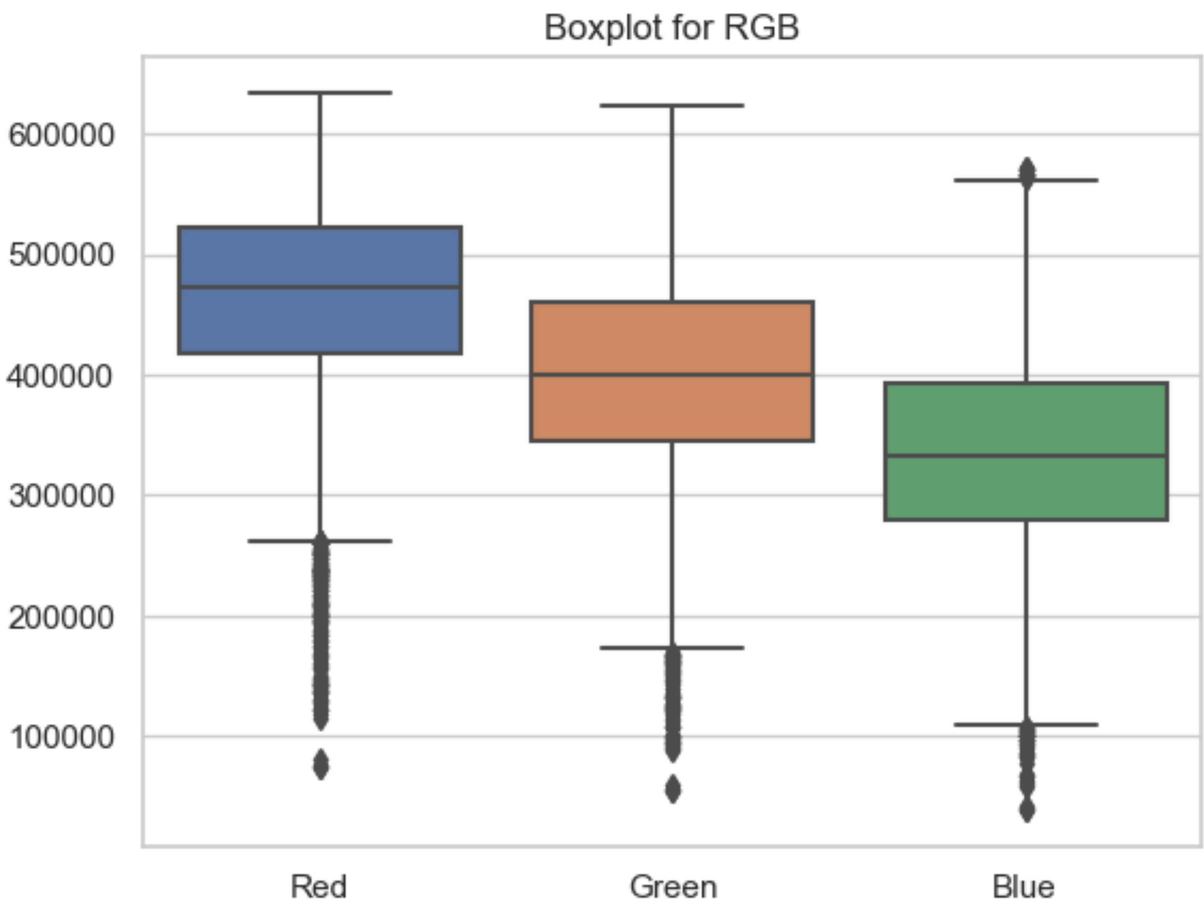
In [ ]:
```
df.dtypes
```

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

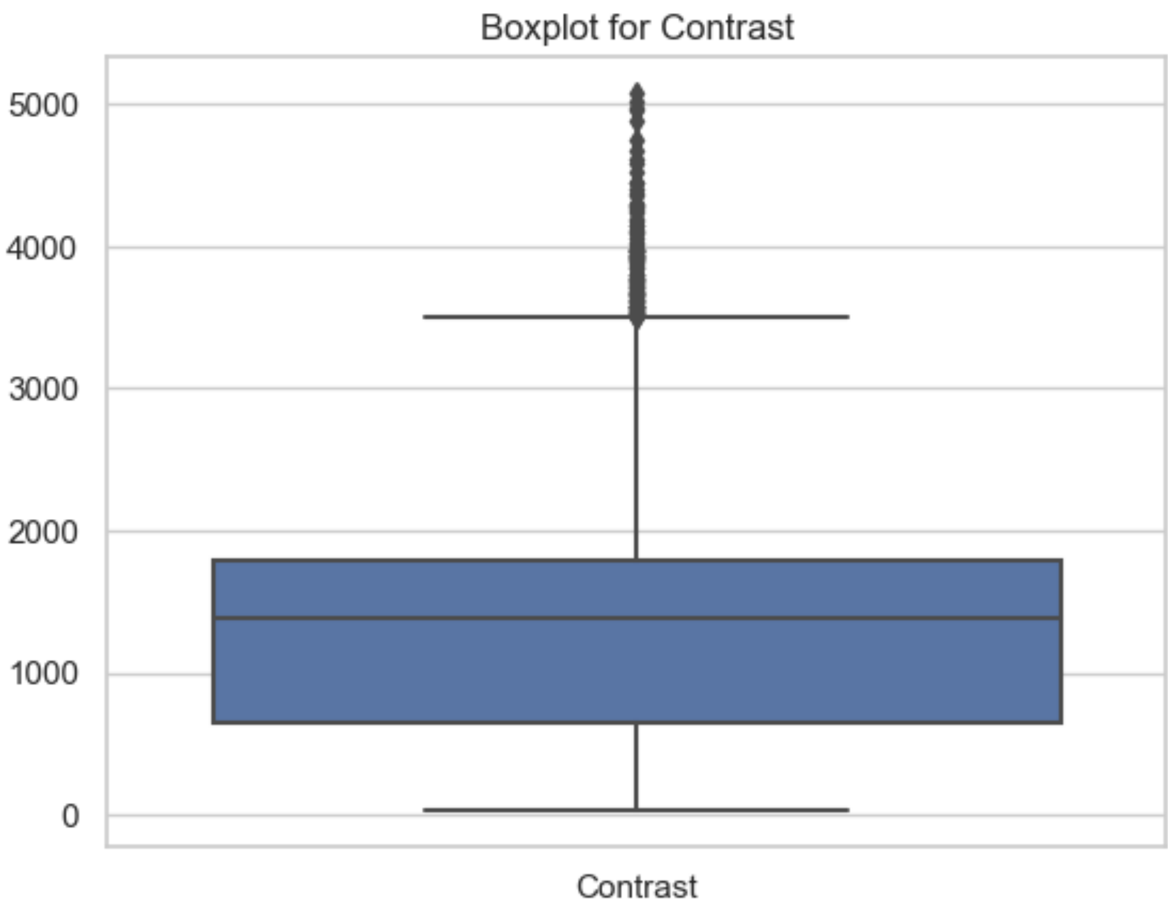
In [ ]:
```
df = df.drop(columns=['Image'])
```

In [ ]:
```
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)]
```

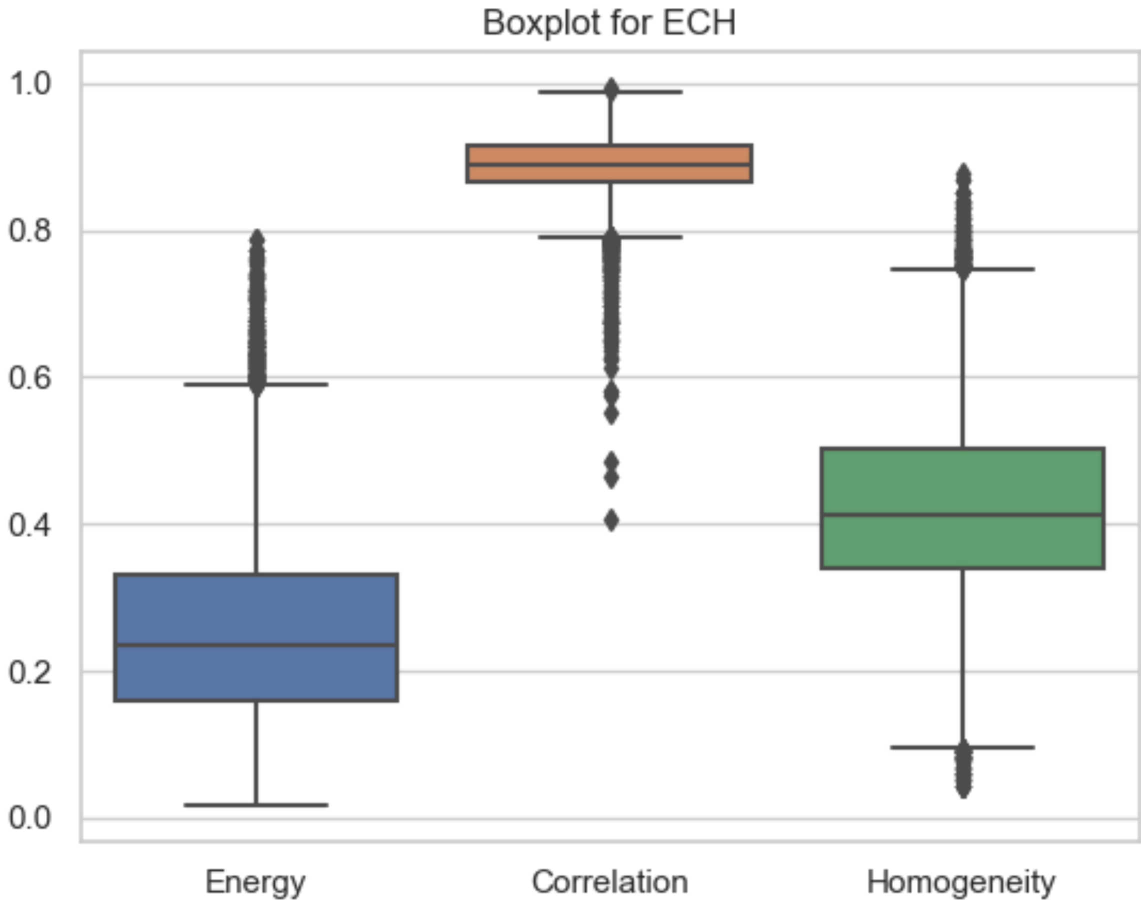
In [ ]:
```
columns = ['Red', 'Green', 'Blue']
df_rgb = df[columns]

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



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

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

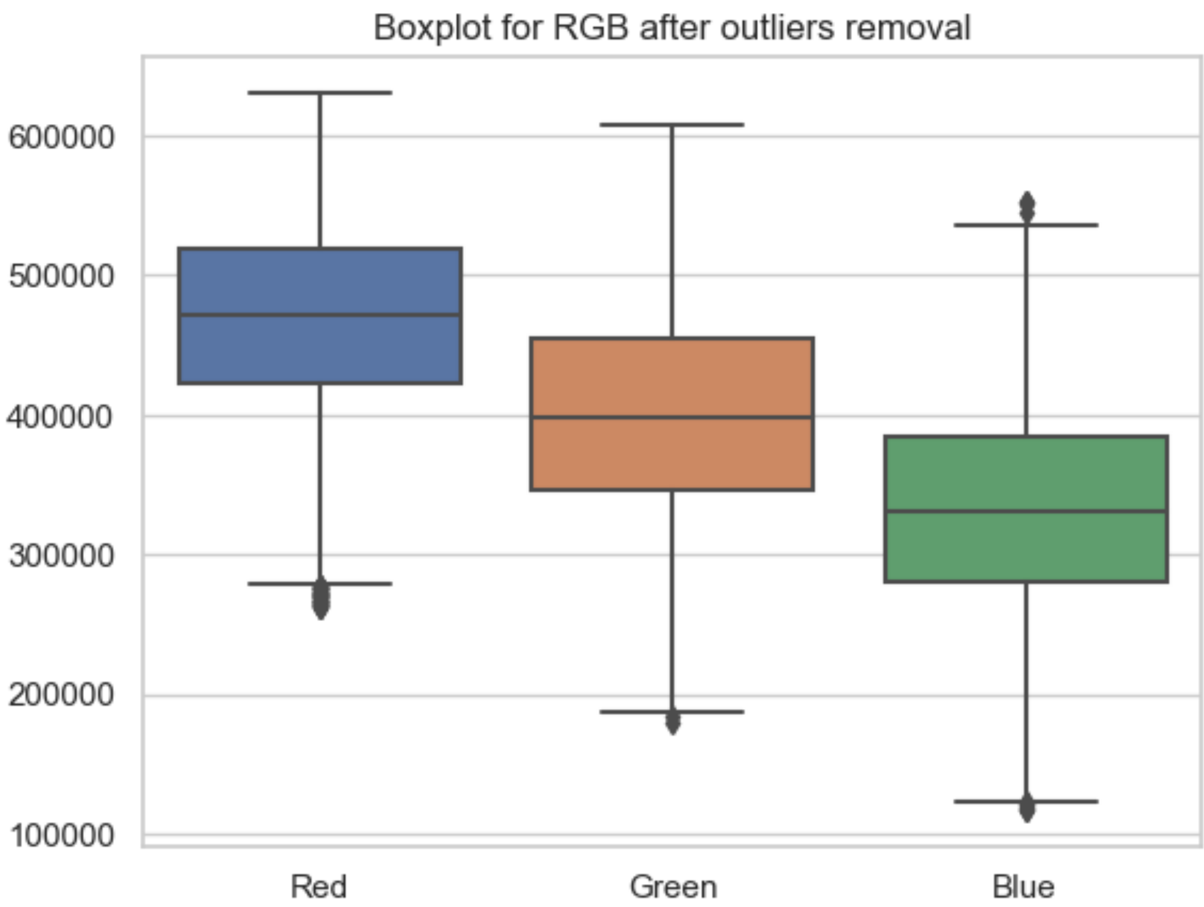



```
In [ ]: columns = ['Energy', 'Correlation', 'Homogeneity']
        df_ech = df[columns]

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

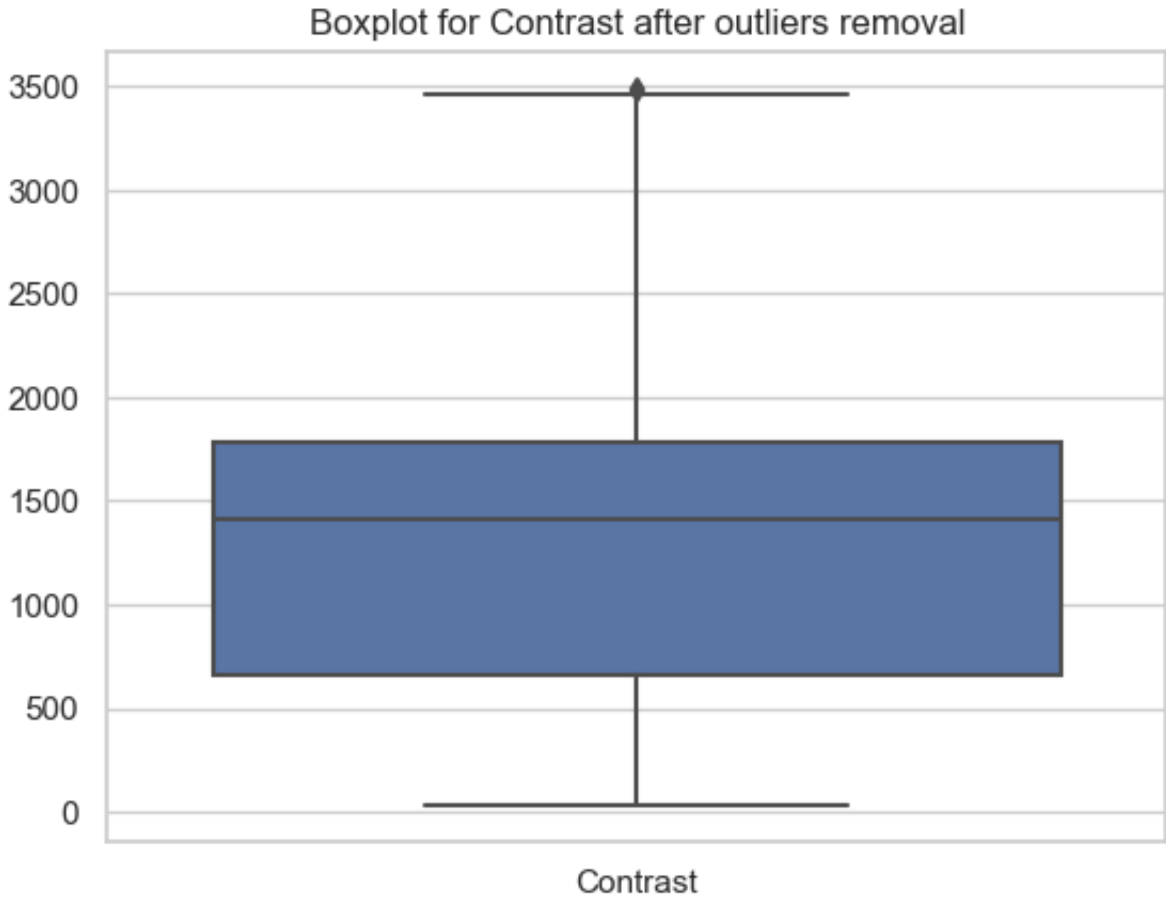


In [ ]:
```
for col in df.columns:
    df = remove_outliers(df, col)
```

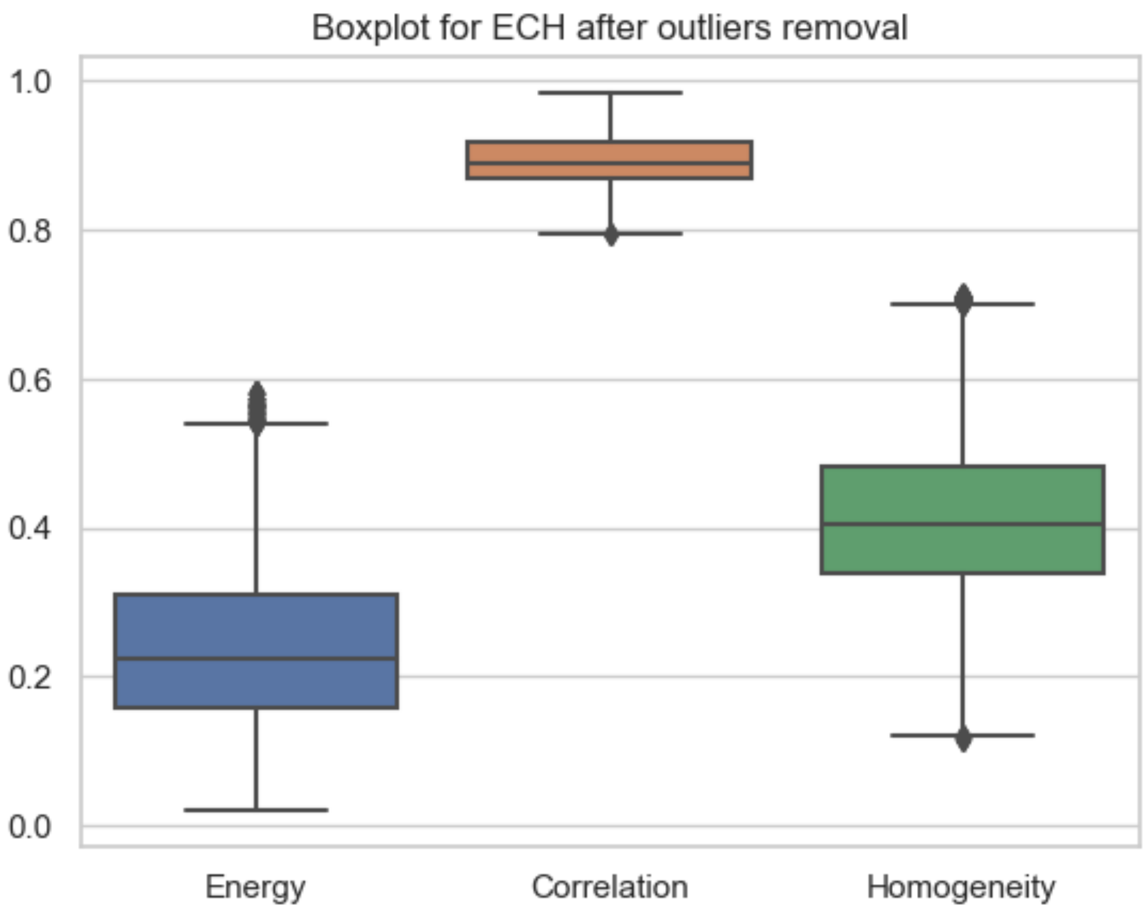
In [ ]:
```
columns = ['Red', 'Green', 'Blue']
df_rgb = df[columns]

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



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

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



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

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

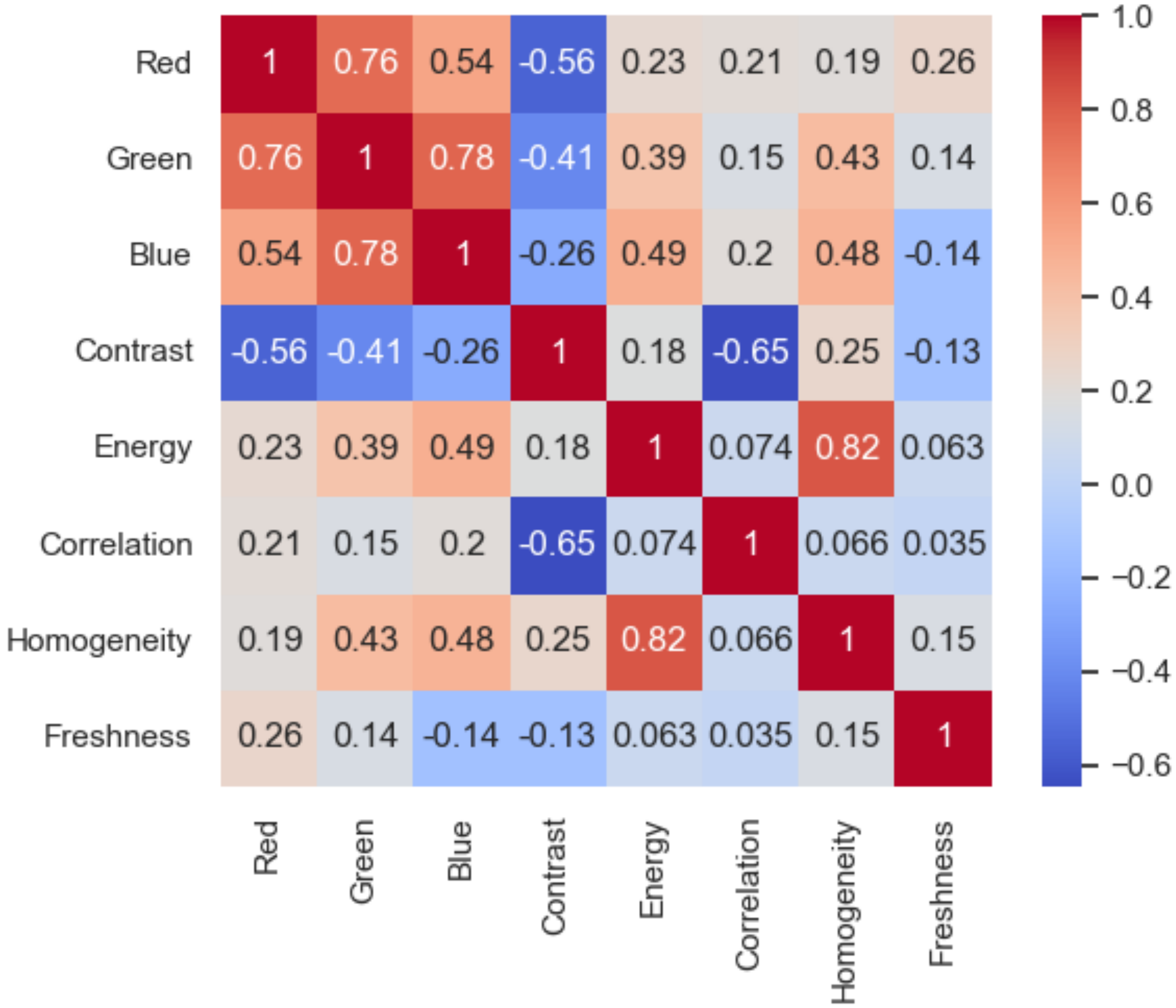


In [ ]:
```
df.info()
```

```
<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
```

Correlation Matrix

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




```
<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.

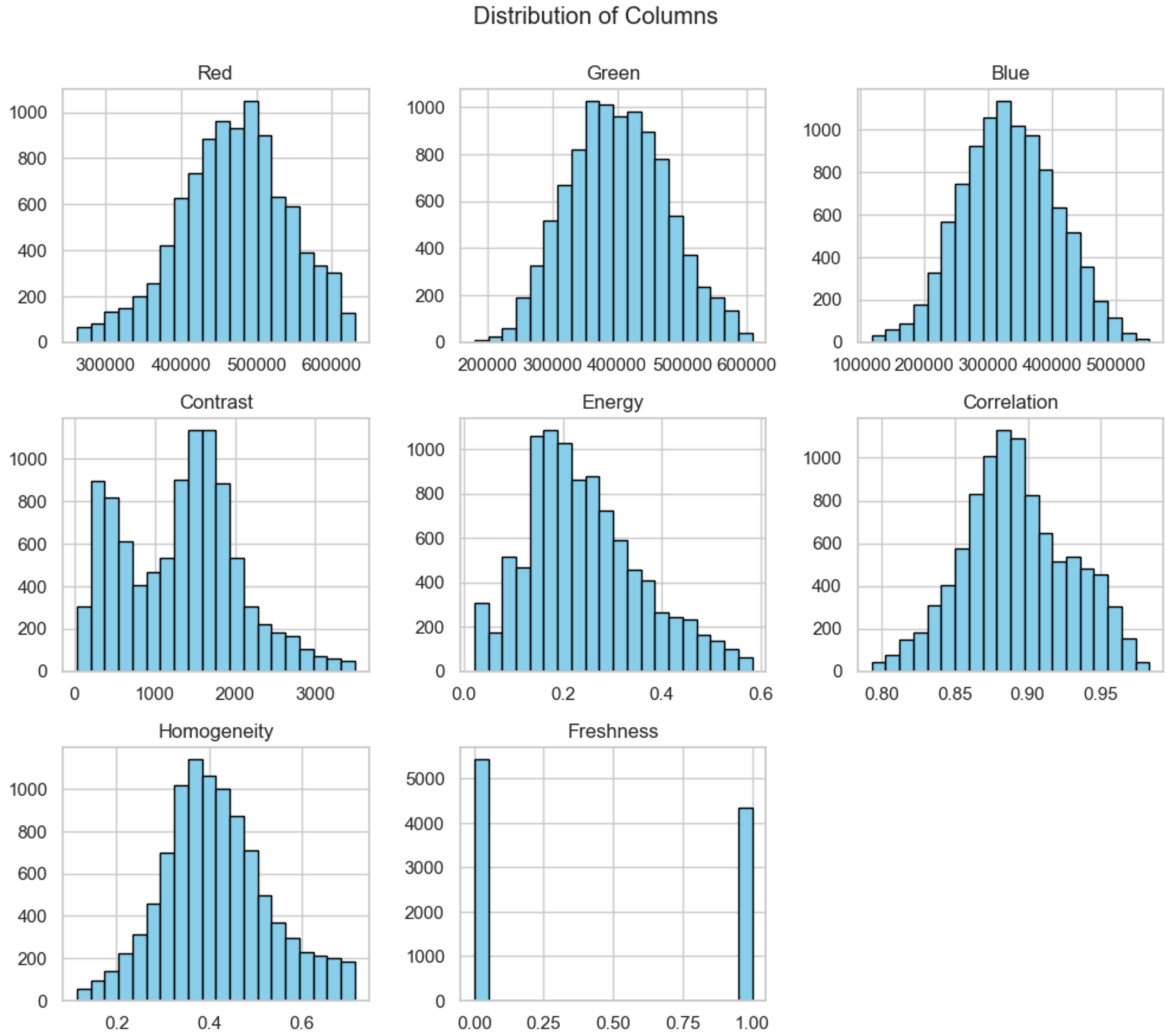
Distribution for Each Columns

In [ ]:

```
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
```

In [ ]:
```
# 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

In [ ]:
```
# Filter the DataFrame for fresh and rotten fruits
fresh_df = df[df["Freshness"] == 1]
rotten_df = df[df["Freshness"] == 0]

# List of feature names to visualize
feature_names = ["Red", "Green", "Blue", "Contrast", "Energy", "Correlati

# Set up Seaborn styles
sns.set_theme(style="whitegrid")

# Create a plot for each feature with fresh vs. rotten comparison
fig, axs = plt.subplots(len(feature_names), 1, figsize=(10, len(feature_n

for i, feature in enumerate(feature_names):
```

```
    sns.histplot(fresh_df[feature], kde=True, ax=axs[i], color="green", l
    sns.histplot(rotten_df[feature], kde=True, ax=axs[i], color="red", la
    axs[i].set_title(f"Distribution of {feature} for Fresh vs. Rotten Fru
    axs[i].set_xlabel(feature)
    axs[i].set_ylabel("Frequency")
    axs[i].legend()

# Adjust layout to prevent overlap
plt.tight_layout()
plt.show()
```

```
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/sea
born/_oldcore.py:1119: FutureWarning: use_inf_as_na option is deprecated a
nd will be removed in a future version. Convert inf values to NaN before o
perating instead.
  with pd.option_context('mode.use_inf_as_na', True):
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/sea
born/_oldcore.py:1119: FutureWarning: use_inf_as_na option is deprecated a
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nd will be removed in a future version. Convert inf values to NaN before o
```

```
perating instead.
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/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/sea
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nd will be removed in a future version. Convert inf values to NaN before o
perating instead.
  with pd.option_context('mode.use_inf_as_na', True):
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/sea
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nd will be removed in a future version. Convert inf values to NaN before o
perating instead.
  with pd.option_context('mode.use_inf_as_na', True):
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/sea
born/_oldcore.py:1119: FutureWarning: use_inf_as_na option is deprecated a
nd will be removed in a future version. Convert inf values to NaN before o
perating instead.
  with pd.option_context('mode.use_inf_as_na', True):
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/sea
born/_oldcore.py:1119: FutureWarning: use_inf_as_na option is deprecated a
nd will be removed in a future version. Convert inf values to NaN before o
perating instead.
  with pd.option_context('mode.use_inf_as_na', True):
```
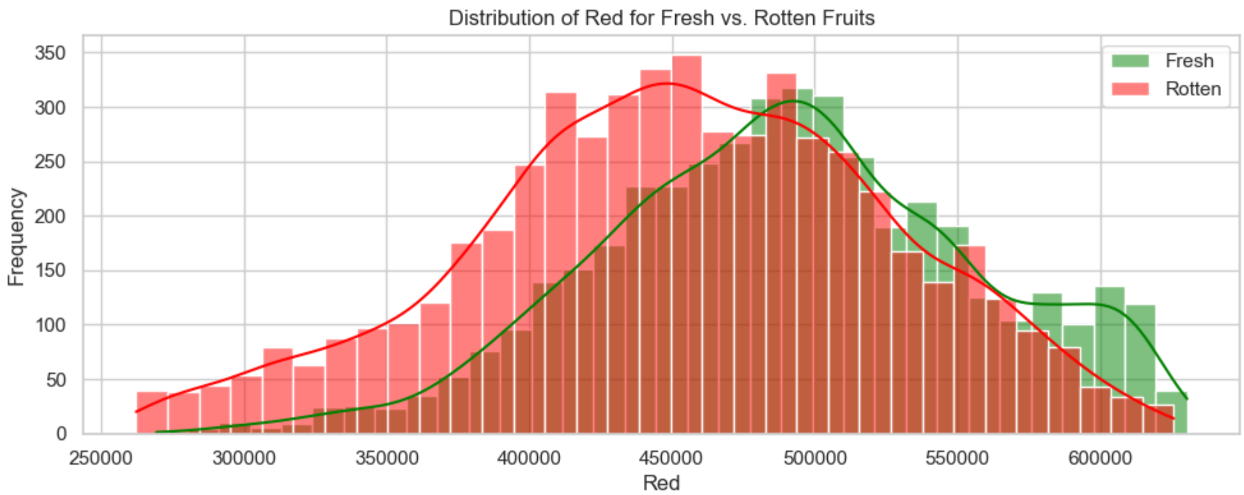
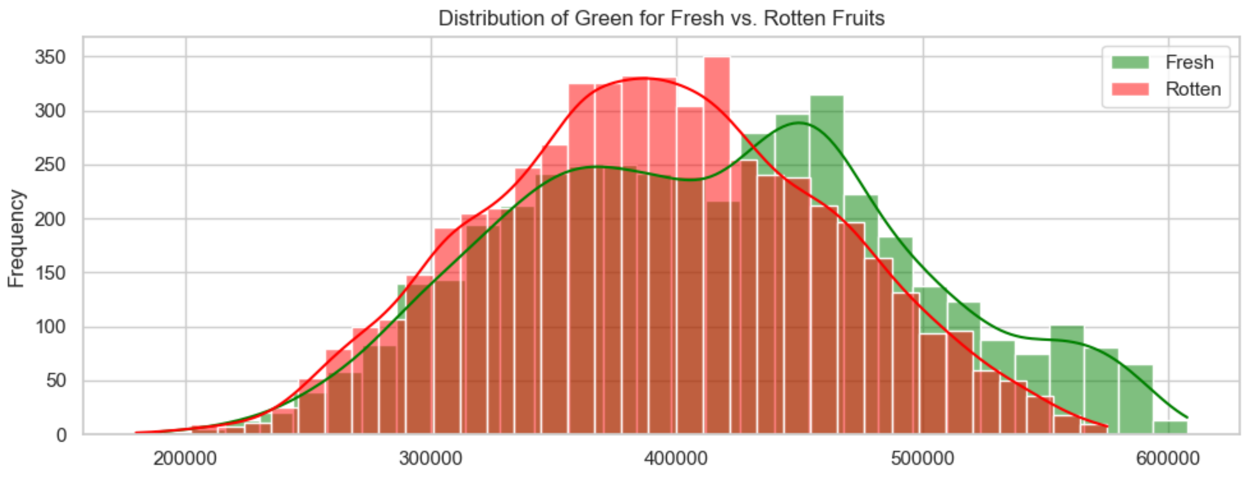
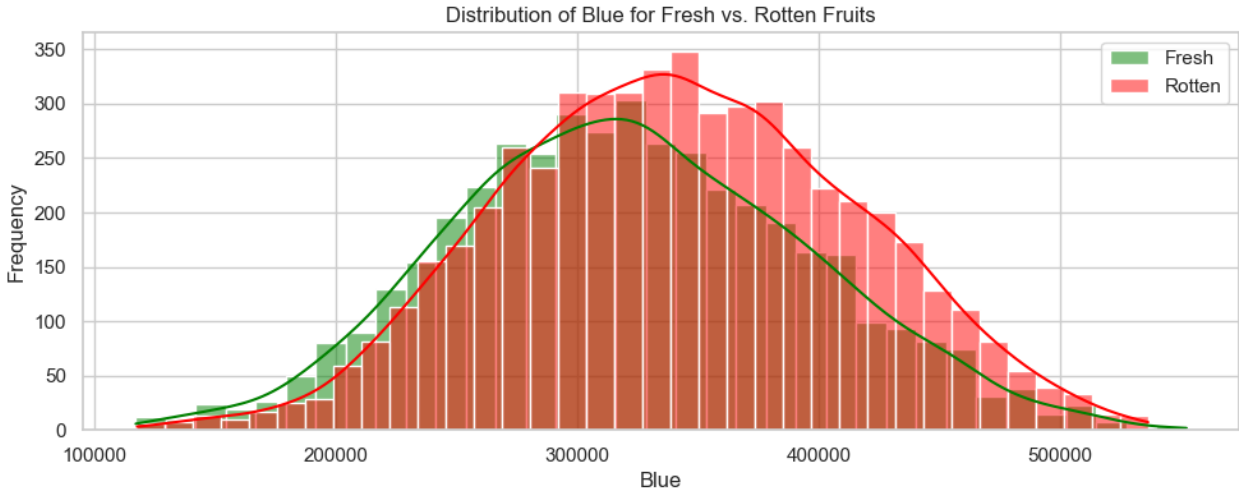
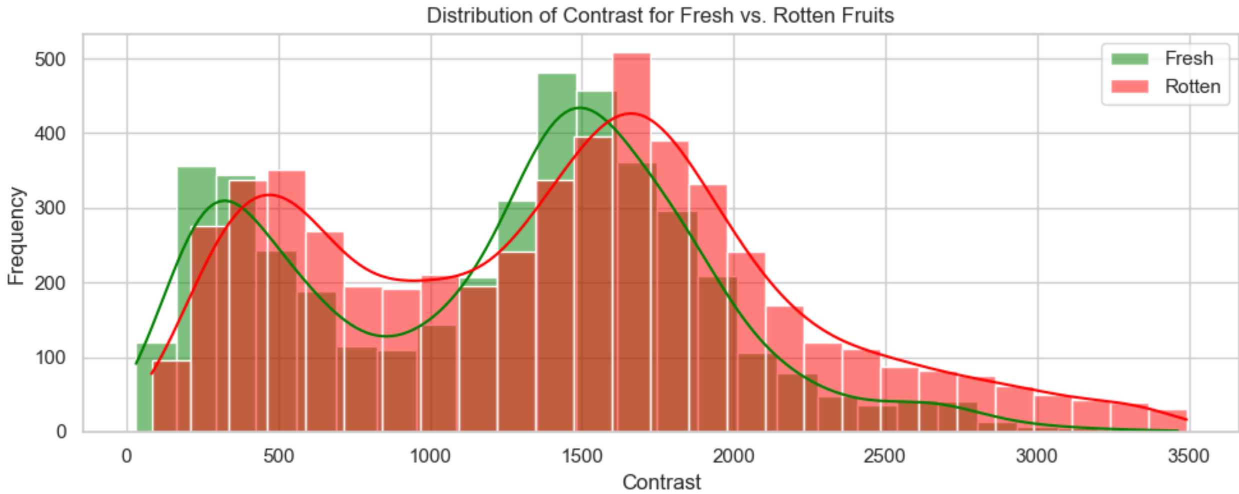
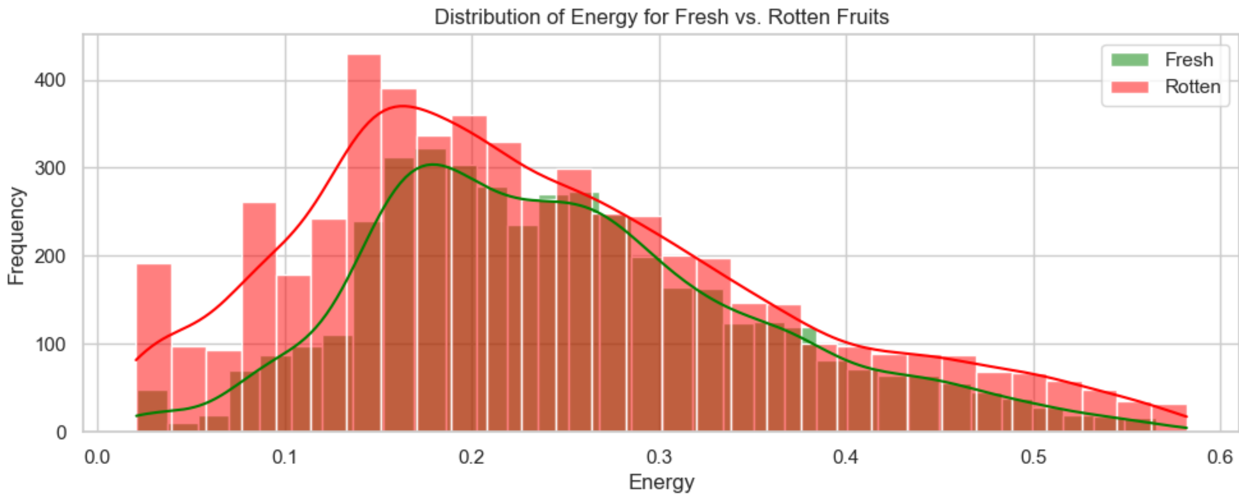



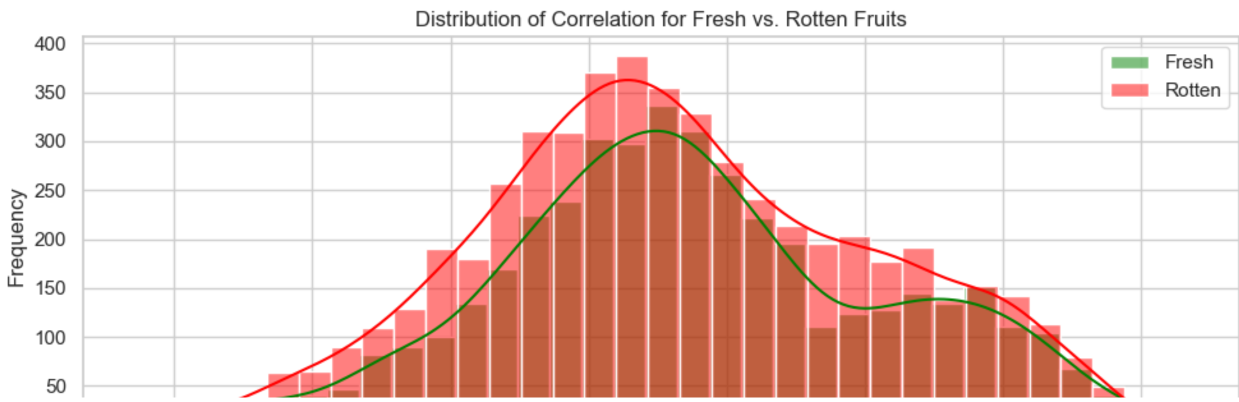


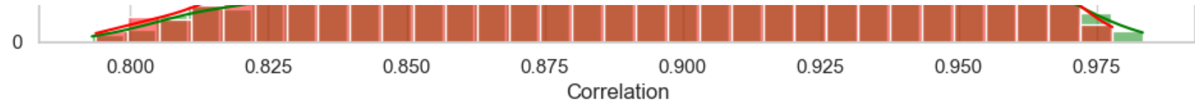
Green

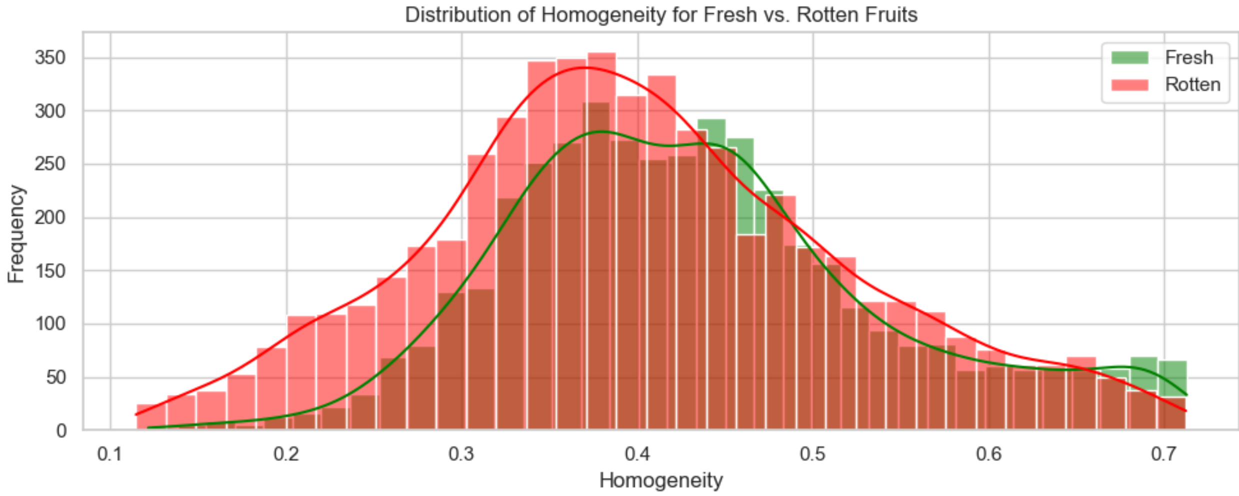

Distribution of Blue for Fresh vs. Rotten Fruits
Fresh
Rotten
Frequency
Blue
0
50
100
150
200
250
300
350
100000
200000
300000
400000
500000


Distribution of Contrast for Fresh vs. Rotten Fruits
Fresh
Rotten
Frequency
Contrast
0
100
200
300
400
500
0
500
1000
1500
2000
2500
3000
3500


Distribution of Energy for Fresh vs. Rotten Fruits
Fresh
Rotten
Frequency
Energy
0
100
200
300
400
0.0
0.1
0.2
0.3
0.4
0.5
0.6


Distribution of Correlation for Fresh vs. Rotten Fruits
Fresh
Rotten
Frequency
50
100
150
200
250
300
350
400





In [ ]:
```
# This two features doesn't differentiate fresh or rotten
feature_names.remove("Energy")
feature_names.remove("Correlation")
```

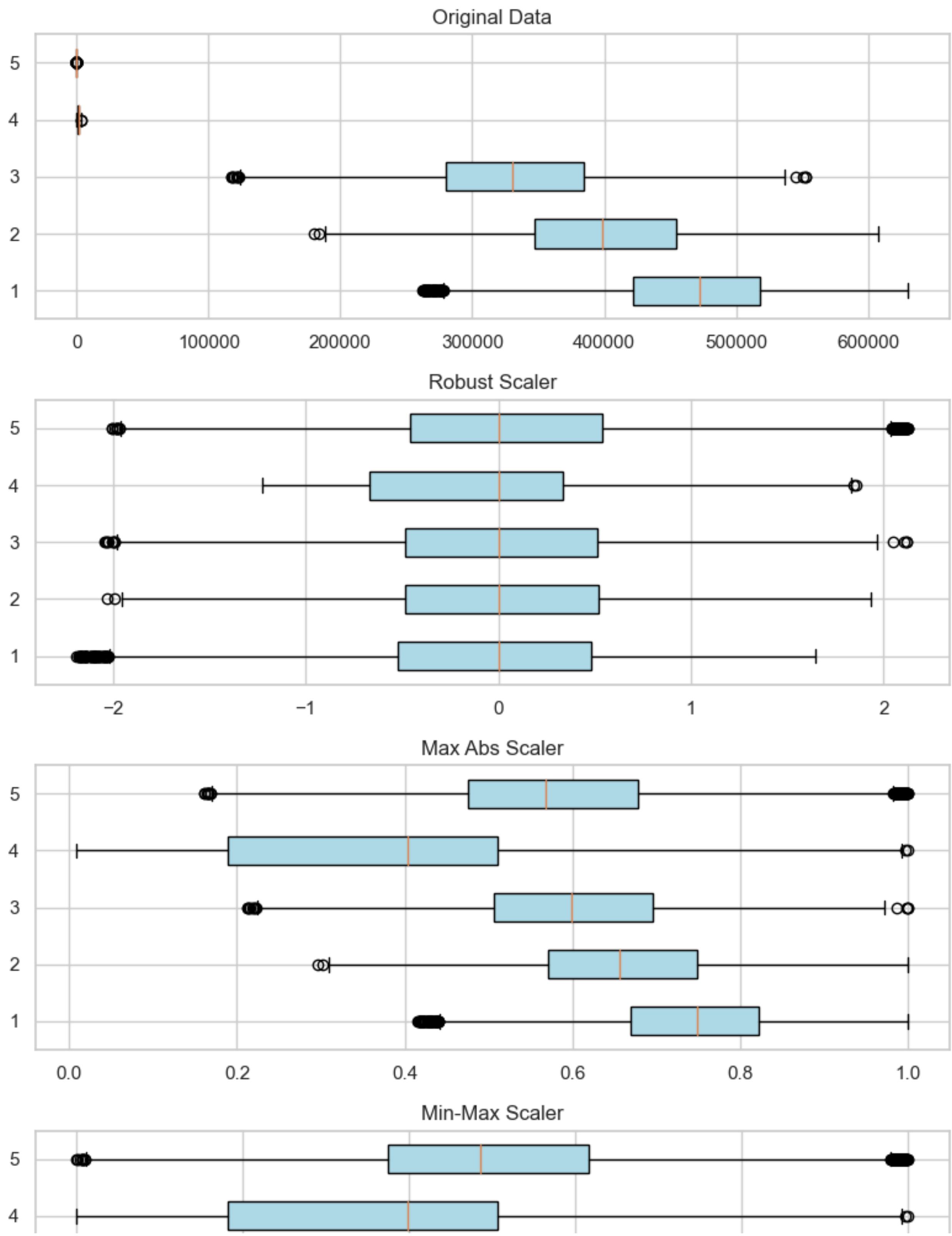
Feature Extraction

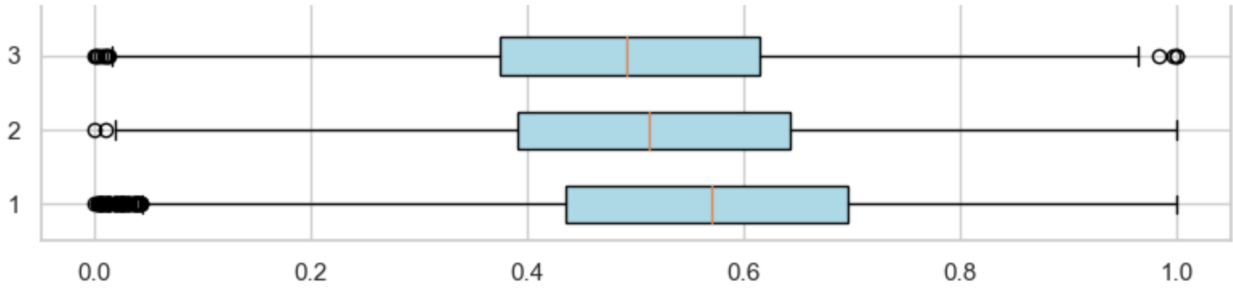
In [ ]:
```
x = df.drop(columns=['Energy','Correlation','Freshness'])
y = df['Freshness']
```

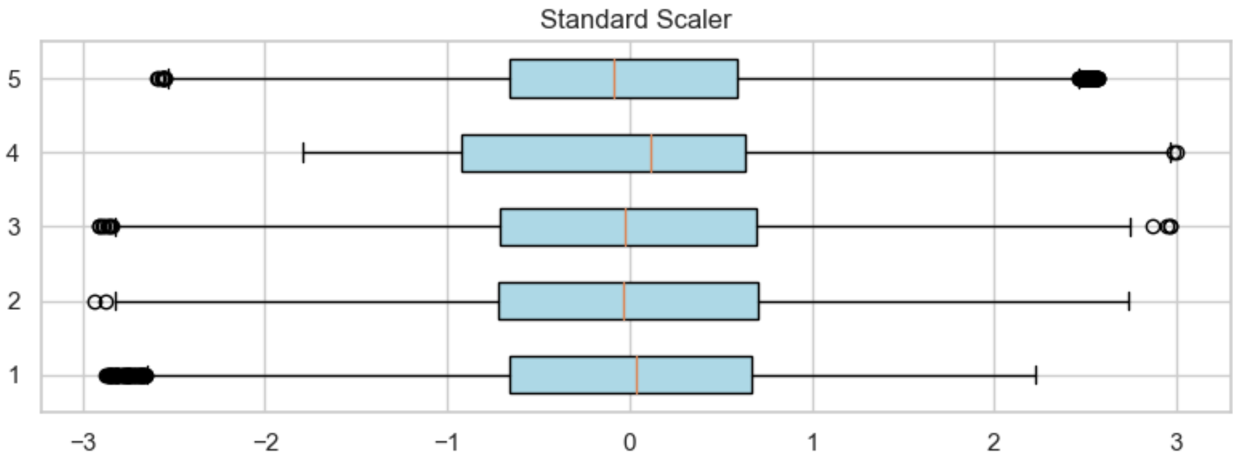
Scaling the Data

In [ ]:
```
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(fac
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(),
    axs[idx].boxplot(scaled_data, vert=False, patch_artist=True, boxprops
    axs[idx].set_title(scaler_name)

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







** 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

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

In [ ]:
```
x_train, x_test, y_train, y_test = train_test_split(x_standard_scale, y,
```

```
num_rotten = (y_train == 0).sum()
num_fresh = (y_train == 1).sum()

print("Number of instances labeled as 'rotten':", num_rotten)
print("Number of instances labeled as 'fresh':", num_fresh)
```

```
Number of instances labeled as 'rotten': 3812
Number of instances labeled as 'fresh': 3022
```

In [ ]:
```
smote = SMOTE(random_state=42)
x_train, y_train = smote.fit_resample(x_train, y_train)

num_rotten_resampled = (y_train == 0).sum()
num_fresh_resampled = (y_train == 1).sum()

print("Number of instances labeled as 'rotten' after resampled:", num_rot
print("Number of instances labeled as 'fresh' after resampled:", num_fres
```

```
Number of instances labeled as 'rotten' after resampled: 3812
Number of instances labeled as 'fresh' after resampled: 3812
```

Logistic Regression Classifier

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

Out[ ]:
```
LogisticRegression

LogisticRegression()
```

In [ ]:
```
logisticModelAccuracy = np.mean(cross_val_score(logisticModel, x_train, y
logisticModelPrecision = np.mean(cross_val_score(logisticModel, x_train,
logisticModelSenstivity = np.mean(cross_val_score(logisticModel, x_train,
logisticModelF1Score = np.mean(cross_val_score(logisticModel, x_train, y_
logisticModelMCCScore = np.mean(cross_val_score(logisticModel, x_train, y
logisticModelKappaCoeff = np.mean(cross_val_score(logisticModel, x_train,
```

In [ ]:
```
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 Coefficient: ", logisticModelKappaCoeff*100)
```

```
Train Accuracy:  7371.494004425915
Train Precision:  7394.028016863263
Train Senstivity:  7337.3318569553785
Train F1 Score:  7360.645739684533
Train MCC Score:  4749.160972824706
Train Kappa Coefficient:  4742.882443766669
```

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

In [ ]:
```
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: 0.2757679180887372
RMSE: 0.5251360948256529
MAE: 0.2757679180887372
```

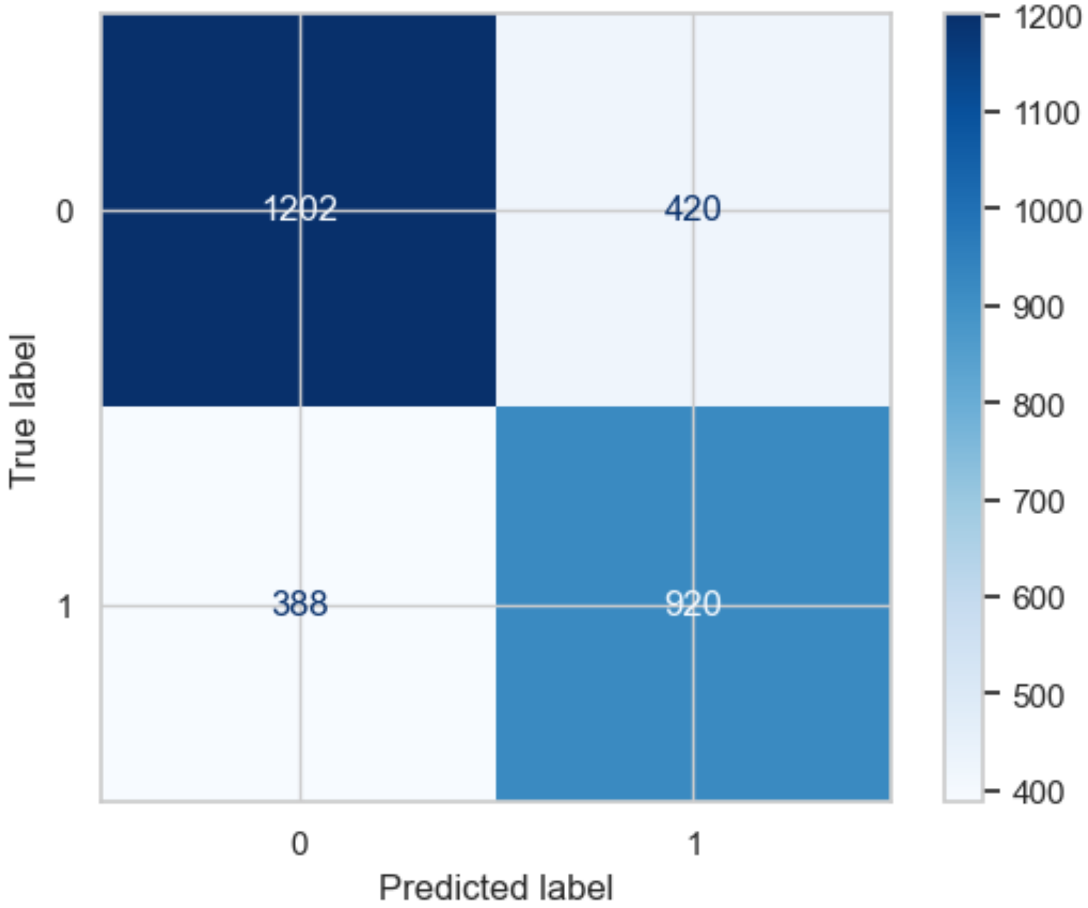
In [ ]:
```
logisticModelTestAccuracy = accuracy_score(y_test, y_pred_logistic)*100
logisticModelTestPrecision = precision_score(y_test, y_pred_logistic)*100
logisticModelTestSenstivity = recall_score(y_test, y_pred_logistic)*100
logisticModelTestF1Score = f1_score(y_test, y_pred_logistic)*100
logisticModelTestMCCScore = matthews_corrcoef(y_test, y_pred_logistic)*10
logisticModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_logistic)*

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 Coefficient: {logisticModelKappaCoeff*100}")
```

```
Test Accuracy: 7242.320819112628
Test Precision: 7394.028016863263
Test Senstivity: 7337.3318569553785
Test F1 Score: 7360.645739684533
Test MCC Score: 4749.160972824706
Test Kappa Coefficient: 4742.882443766669
```

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

```
              precision    recall  f1-score   support

           0       0.76      0.74      0.75      1622
           1       0.69      0.70      0.69      1308

    accuracy                           0.72      2930
   macro avg       0.72      0.72      0.72      2930
weighted avg       0.72      0.72      0.72      2930
```

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

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



Support Vector Machine Classifier (SVM)

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

Out[ ]:
```
▾ SVC
SVC()
```

In [ ]:
```
svmModelAccuracy = np.mean(cross_val_score(svmModel, x_train, y_train, sc
svmModelPrecision = np.mean(cross_val_score(svmModel, x_train, y_train, s
svmModelSenstivity = np.mean(cross_val_score(svmModel, x_train, y_train,
svmModelF1Score = np.mean(cross_val_score(svmModel, x_train, y_train, sco
svmModelMCCScore = np.mean(cross_val_score(svmModel, x_train, y_train, sc
svmModelKappaCoeff = np.mean(cross_val_score(svmModel, x_train, y_train,
```

In [ ]:
```
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 Coefficient: ", svmModelKappaCoeff*100)
```

```
Train Accuracy:  8549.297514281303
Train Precision:  8596.243453940791
Train Senstivity:  8494.156003937009
Train F1 Score:  8539.495363566963
Train MCC Score:  7107.630400589809
Train Kappa Coefficient:  7098.558190785962
```

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

In [ ]:
```
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: 0.15563139931740613
RMSE: 0.39450145667336406
MAE: 0.15563139931740613
```

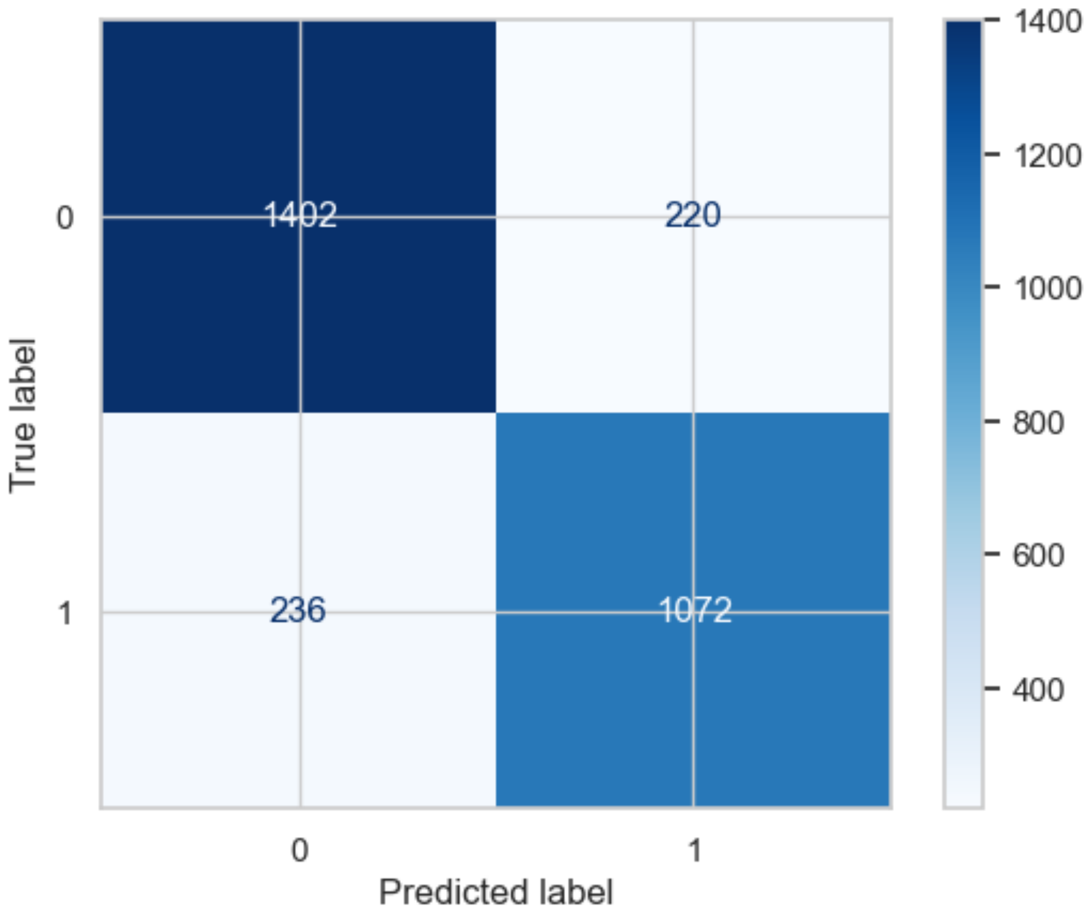
In [ ]:
```
svmModelTestAccuracy = accuracy_score(y_test, y_pred_svm)*100
svmModelTestPrecision = precision_score(y_test, y_pred_svm)*100
svmModelTestSenstivity = recall_score(y_test, y_pred_svm)*100
svmModelTestF1Score = f1_score(y_test, y_pred_svm)*100
svmModelTestMCCScore = matthews_corrcoef(y_test, 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 Coefficient: {svmModelTestKappaCoeff*100}")
```

```
Test Accuracy: 8443.68600682594
Test Precision: 8297.213622291023
Test Senstivity: 8195.718654434251
Test F1 Score: 8246.153846153848
Test MCC Score: 6847.895010536217
Test Kappa Coefficient: 6847.476055465998
```

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

```
              precision    recall  f1-score   support

           0       0.86      0.86      0.86      1622
           1       0.83      0.82      0.82      1308

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

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

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



Decision Tree Classifier

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

Out[ ]:
```
▾ DecisionTreeClassifier
DecisionTreeClassifier()
```

In [ ]:
```
decisionTreeModelAccuracy = np.mean(cross_val_score(decisionTreeModel, x_
decisionTreeModelPrecision = np.mean(cross_val_score(decisionTreeModel, x
decisionTreeModelSenstivity = np.mean(cross_val_score(decisionTreeModel,
decisionTreeModelF1Score = np.mean(cross_val_score(decisionTreeModel, x_t
decisionTreeModelMCCScore = np.mean(cross_val_score(decisionTreeModel, x_
decisionTreeModelKappaCoeff = np.mean(cross_val_score(decisionTreeModel,
```

In [ ]:
```
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 Coefficient: ", decisionTreeModelKappaCoeff*100)
```

```
Train Accuracy:  8641.145592095105
Train Precision:  8672.524078859797
Train Senstivity:  8580.790682414698
Train F1 Score:  8635.653483094515
Train MCC Score:  7281.0656401081405
Train Kappa Coefficient:  7316.385459108208
```

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

In [ ]:
```
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: 0.14948805460750852
RMSE: 0.38663685107282325
MAE: 0.14948805460750852
```

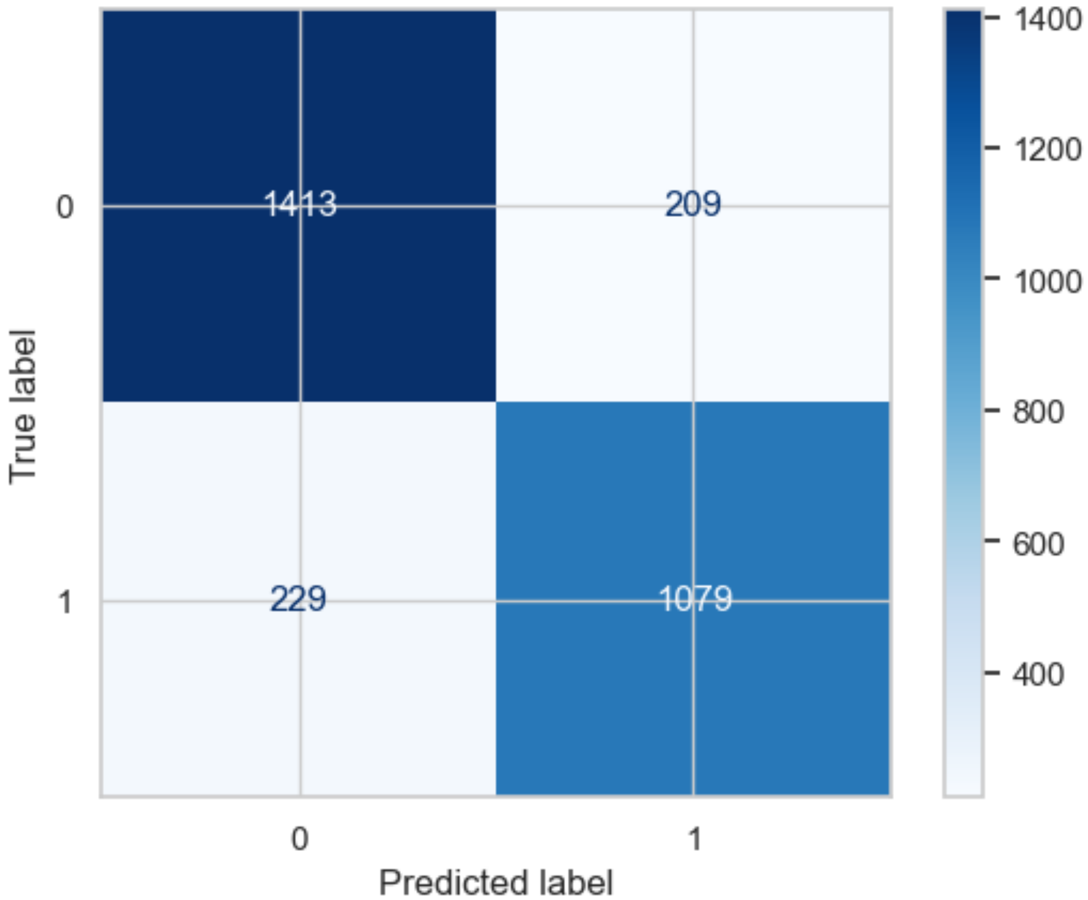
In [ ]:
```
decisionTreeModelTestAccuracy = accuracy_score(y_test, y_pred_decision_tr
decisionTreeModelTestPrecision = precision_score(y_test, y_pred_decision_
decisionTreeModelTestSenstivity = recall_score(y_test, y_pred_decision_tr
decisionTreeModelTestF1Score = f1_score(y_test, y_pred_decision_tree)*100
decisionTreeModelTestMCCScore = matthews_corrcoef(y_test, y_pred_decision
decisionTreeModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_decisi

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 Coefficient: {decisionTreeModelTestKappaCoeff*100}")
```

```
Test Accuracy: 8505.119453924914
Test Precision: 8377.329192546584
Test Senstivity: 8249.235474006116
Test F1 Score: 8312.788906009246
Test MCC Score: 6971.686987690813
Test Kappa Coefficient: 6971.020129944921
```

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

```
              precision    recall  f1-score   support

           0       0.86      0.87      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
```

In [ ]:
```
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()
```



Random Forest Classifier

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

Out[ ]:
```
▾ RandomForestClassifier
RandomForestClassifier()
```

In [ ]:
```
randomForestModelAccuracy = np.mean(cross_val_score(randomForestModel, x_
randomForestModelPrecision = np.mean(cross_val_score(randomForestModel, x
randomForestModelSenstivity = np.mean(cross_val_score(randomForestModel,
randomForestModelF1Score = np.mean(cross_val_score(randomForestModel, x_t
randomForestModelMCCScore = np.mean(cross_val_score(randomForestModel, x_
randomForestModelKappaCoeff = np.mean(cross_val_score(randomForestModel,
```

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

```
Accuracy:  9154.037362976685
Precision:  9174.92087057908
Senstivity:  9176.201607611547
F1 Score:  9152.793694569416
MCC Score:  8326.089987101403
Kappa Coefficient:  8318.549968458121
```

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

In [ ]:
```
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: 0.1
RMSE: 0.31622776601683794
MAE: 0.1
```

In [ ]:
```
randomForestModelTestAccuracy = accuracy_score(y_test, y_pred_random_fore
randomForestModelTestPrecision = precision_score(y_test, y_pred_random_fo
randomForestModelTestSenstivity = recall_score(y_test, y_pred_random_fore
randomForestTestModelF1Score = f1_score(y_test, y_pred_random_forest)*100
randomForestModelTestMCCScore = matthews_corrcoef(y_test, y_pred_random_f
randomForestModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_random

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 Coefficient: {randomForestModelTestKappaCoeff*100}")
```

```
Test Accuracy: 9000.0
Test Precision: 8980.392156862747
Test Senstivity: 8753.822629969418
Test F1 Score: 8865.66008517228
Test MCC Score: 7973.891241731465
Test Kappa Coefficient: 7971.810555212993
```

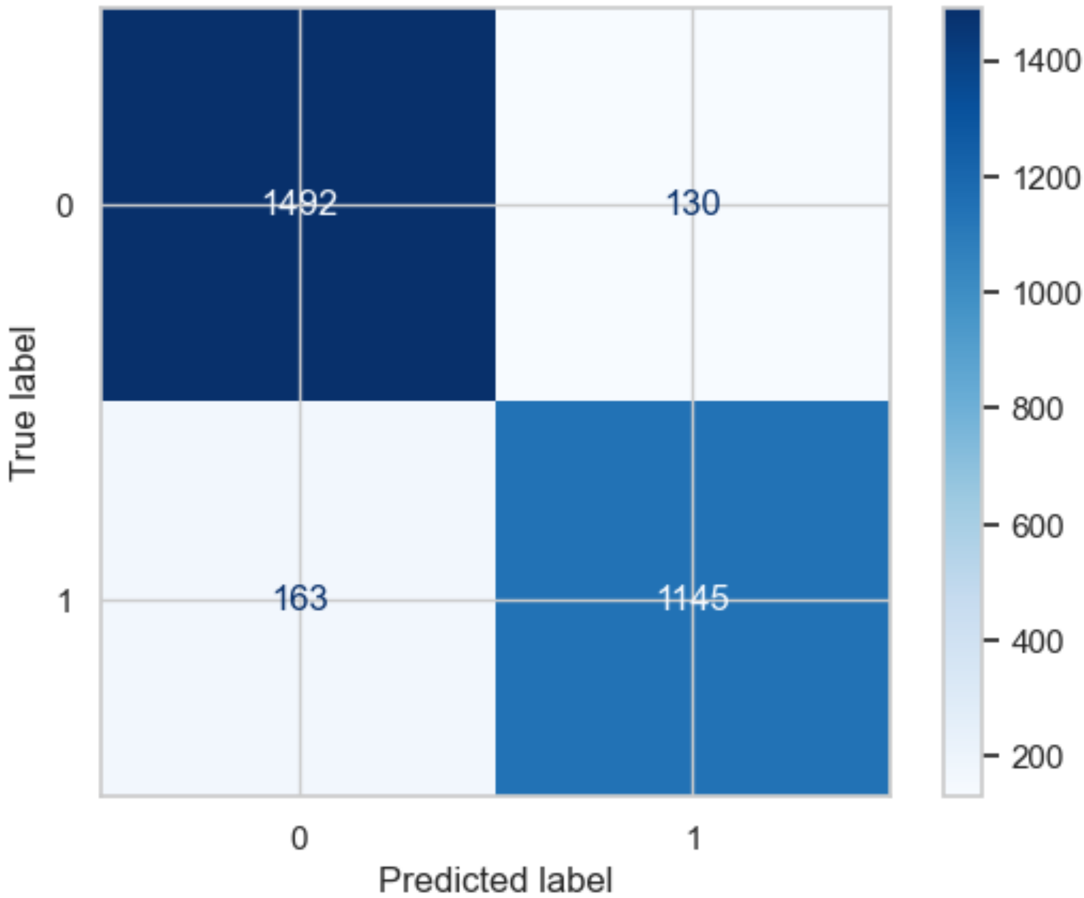
In [ ]:

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

```
              precision    recall  f1-score   support

           0       0.90      0.92      0.91      1622
           1       0.90      0.88      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
```

In [ ]:

```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()
```



K Neighbors Classifier (KNN)

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

Out[ ]:
```
▾ KNeighborsClassifier
KNeighborsClassifier()
```

In [ ]:
```
KNNModelAccuracy = np.mean(cross_val_score(KNNModel, x_train, y_train, sc
KNNModelPrecision = np.mean(cross_val_score(KNNModel, x_train, y_train, s
KNNModelSenstivity = np.mean(cross_val_score(KNNModel, x_train, y_train,
KNNModelF1Score = np.mean(cross_val_score(KNNModel, x_train, y_train, sco
KNNModelMCCScore = np.mean(cross_val_score(KNNModel, x_train, y_train, sc
KNNModelKappaCoeff = np.mean(cross_val_score(KNNModel, x_train, y_train,
```

In [ ]:
```
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 Coefficient: ", KNNModelKappaCoeff*100)
```

```
Train Accuracy:  8986.166435077967
Train Precision:  8881.664829027555
Train Senstivity:  9131.6437007874
Train F1 Score:  8998.761372177041
Train MCC Score:  7987.5253561829495
Train Kappa Coefficient:  7972.270489286548
```

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

In [ ]:
```
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: 0.12627986348122866
RMSE: 0.3553587813481308
MAE: 0.12627986348122866
```

In [ ]:
```
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 Coefficient: {KNNModelTestKappaCoeff*100}")
```

```
Test Accuracy: 8737.201365187713
Test Precision: 8510.479041916167
Test Senstivity: 8692.660550458715
Test F1 Score: 8600.605143721634
Test MCC Score: 7451.729928801278
Test Kappa Coefficient: 7450.342713826899
```

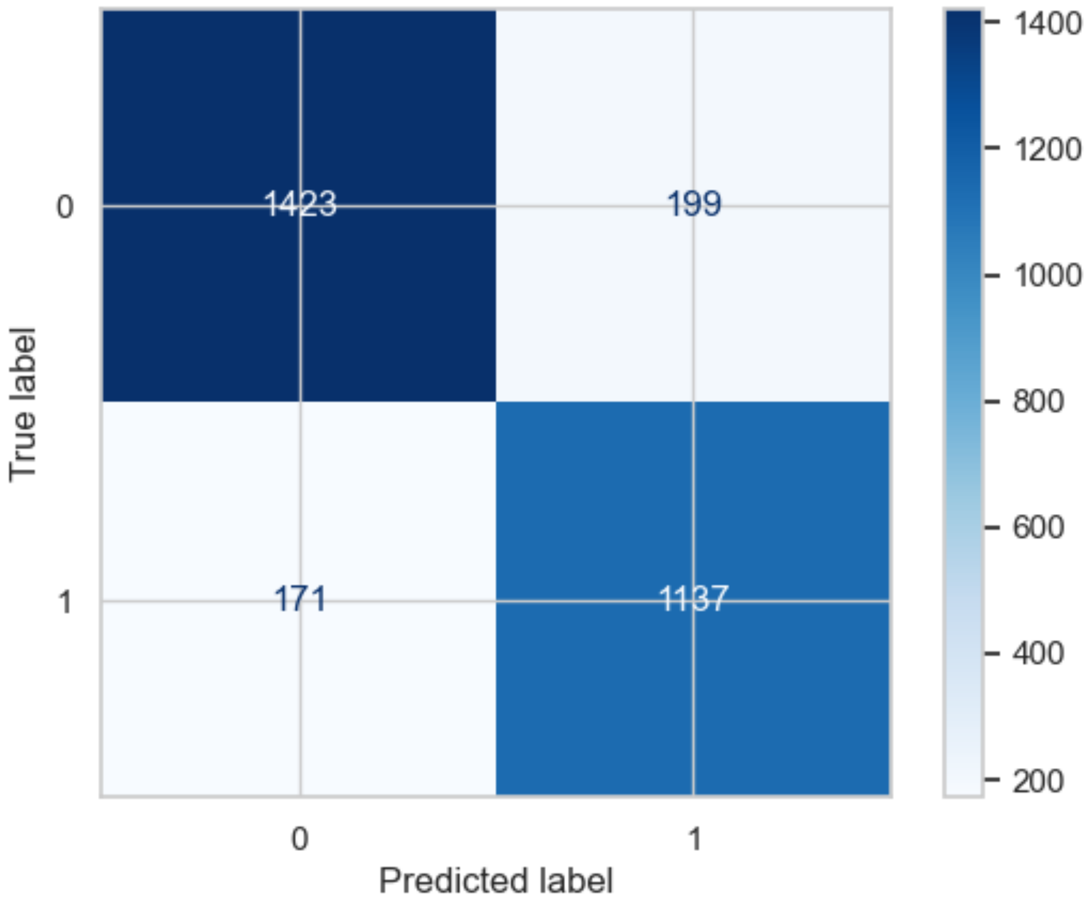
In [ ]:

```
report_knn = classification_report(y_test, y_pred_knn)
print(report_knn)
```

```
              precision    recall  f1-score   support

           0       0.89      0.88      0.88      1622
           1       0.85      0.87      0.86      1308

    accuracy                           0.87      2930
   macro avg       0.87      0.87      0.87      2930
weighted avg       0.87      0.87      0.87      2930
```

In [ ]:

```
cm_knn = confusion_matrix(y_test, y_pred_knn)

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



Naive Bayes Classifier

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

Out[ ]:
```
▾ GaussianNB
GaussianNB()
```

In [ ]:
```
naiveBayesModelAccuracy = np.mean(cross_val_score(naiveBayesModel, x_trai
naiveBayesModelPrecision = np.mean(cross_val_score(naiveBayesModel, x_tra
naiveBayesModelSenstivity = np.mean(cross_val_score(naiveBayesModel, x_tr
naiveBayesModelF1Score = np.mean(cross_val_score(naiveBayesModel, x_train
naiveBayesModelMCCScore = np.mean(cross_val_score(naiveBayesModel, x_trai
naiveBayesModelKappaCoeff = np.mean(cross_val_score(naiveBayesModel, x_tr
```

In [ ]:
```
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 Coefficient: ", naiveBayesModelKappaCoeff*100)
```

```
Train Accuracy:  6537.296073284958
Train Precision:  6479.190442912921
Train Senstivity:  6739.173228346456
Train F1 Score:  6601.154551828718
Train MCC Score:  3082.412406496794
Train Kappa Coefficient:  3074.4519545851017
```

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

In [ ]:
```
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: 0.37679180887372016
RMSE: 0.6138336980597596
MAE: 0.37679180887372016
```

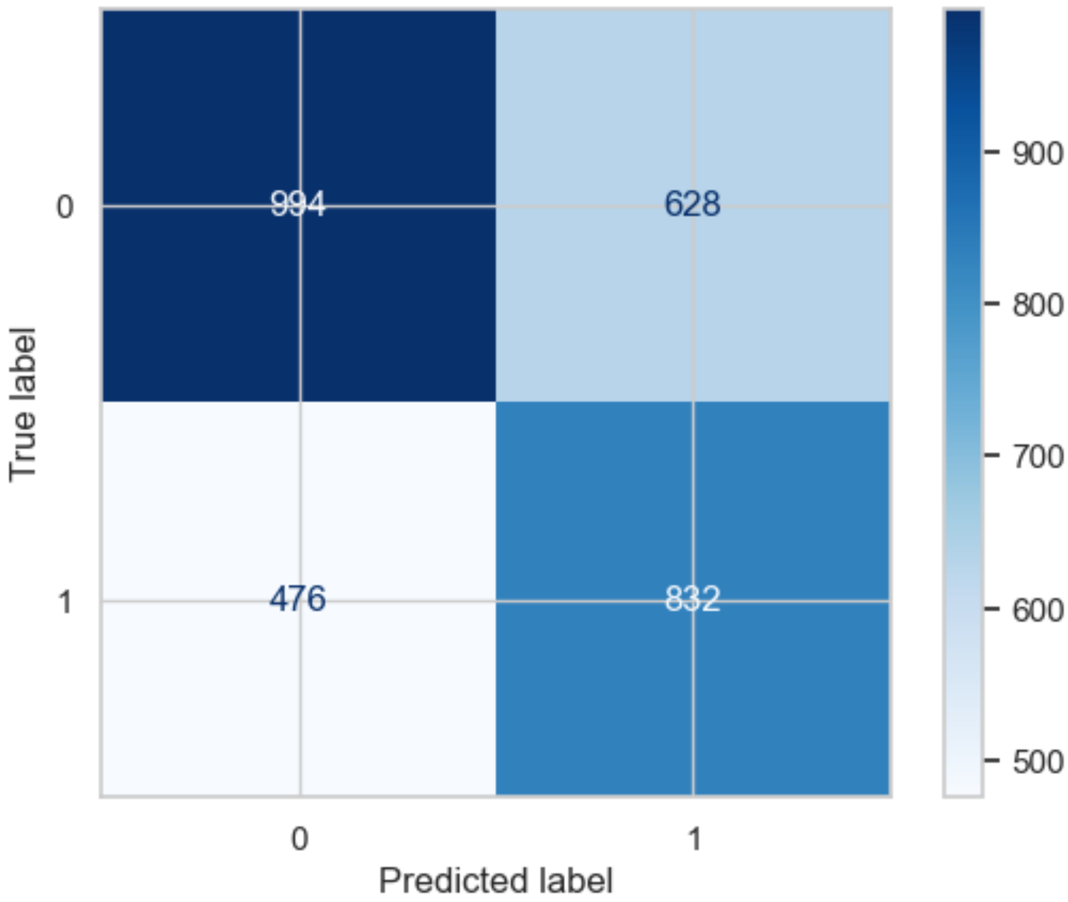
In [ ]:
```
naiveBayesModelTestAccuracy = accuracy_score(y_test, y_pred_naive_bayes)*
naiveBayesModelTestPrecision = precision_score(y_test, y_pred_naive_bayes
naiveBayesModelTestSenstivity = recall_score(y_test, y_pred_naive_bayes)*
naiveBayesModelTestF1Score = f1_score(y_test, y_pred_naive_bayes)*100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

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 Coefficient: {naiveBayesModelTestKappaCoeff*100}")
```

```
Test Accuracy: 6232.081911262799
Test Precision: 5698.630136986301
Test Senstivity: 6360.856269113149
Test F1 Score: 6011.560693641619
Test MCC Score: 2474.772762744032
Test Kappa Coefficient: 2461.4065180102907
```

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

```
              precision    recall  f1-score   support

           0       0.68      0.61      0.64      1622
           1       0.57      0.64      0.60      1308

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

In [ ]:
```
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()
```



XGBoost

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

Out[ ]:

XGBClassifier

```
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, m
ax_bin=None,
```

In [ ]:
```
xgboostModelAccuracy = np.mean(cross_val_score(xgboostModel, x_train, y_t
xgboostModelPrecision = np.mean(cross_val_score(xgboostModel, x_train, y_
xgboostModelSenstivity = np.mean(cross_val_score(xgboostModel, x_train, y
xgboostModelF1Score = np.mean(cross_val_score(xgboostModel, x_train, y_tr
xgboostModelMCCScore = np.mean(cross_val_score(xgboostModel, x_train, y_t
xgboostModelKappaCoeff = np.mean(cross_val_score(xgboostModel, x_train, y
```

In [ ]:
```
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 Coefficient: ", xgboostModelKappaCoeff*100)
```

```
Train Accuracy:  9016.314137203437
Train Precision:  8971.703535512197
Train Senstivity:  9079.191272965876
Train F1 Score:  9021.351739753547
Train MCC Score:  8040.349648550983
Train Kappa Coefficient:  8032.590553723433
```

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

In [ ]:
```
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: 0.10273037542662115
RMSE: 0.3205157959081286
MAE: 0.10273037542662115
```

In [ ]:
```
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)*10

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 Coefficient: {xgboostModelTestKappaCoeff*100}")
```

```
Test Accuracy: 8972.696245733789
Test Precision: 8906.128782001551
Test Senstivity: 8776.758409785933
Test F1 Score: 8840.970350404312
Test MCC Score: 7919.278566381003
Test Kappa Coefficient: 7918.5950298146
```

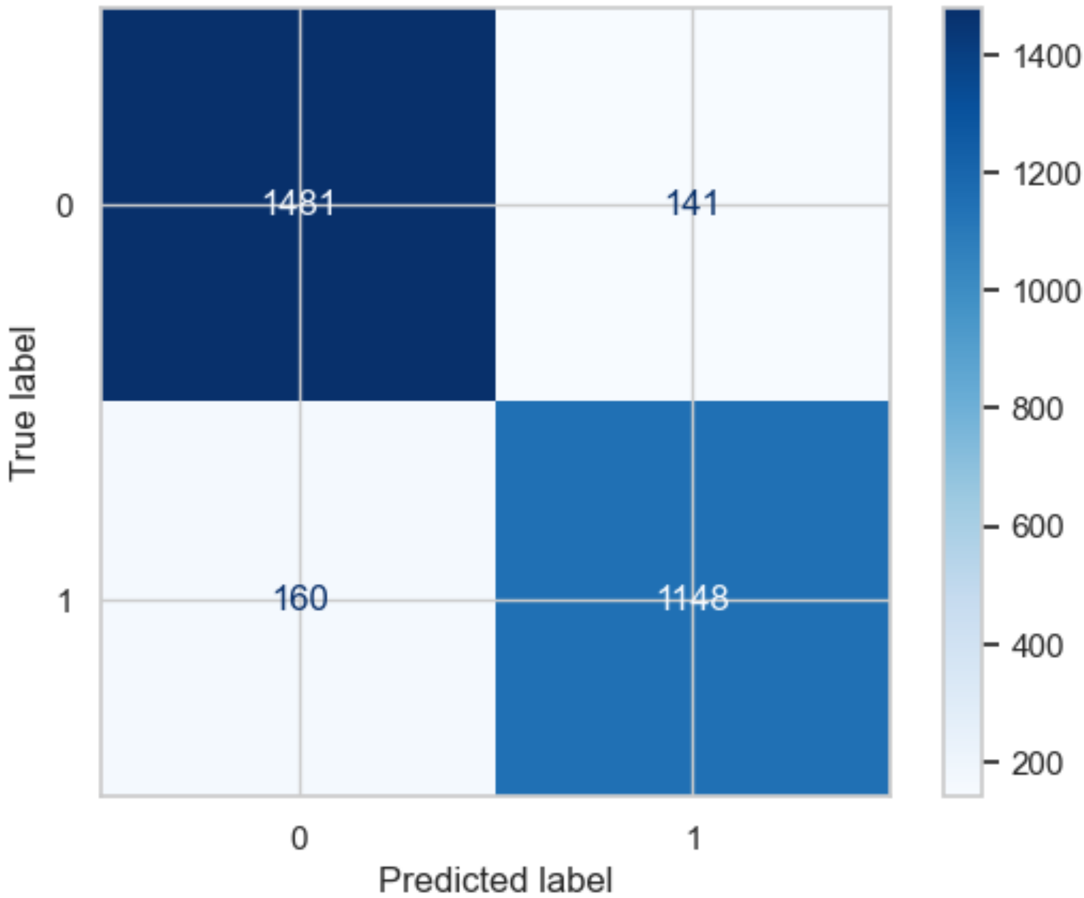
In [ ]:

```
report_xgboost = classification_report(y_test, y_pred_xgboost)
print(report_xgboost)
```

```
              precision    recall  f1-score   support

           0       0.90      0.91      0.91      1622
           1       0.89      0.88      0.88      1308

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

In [ ]:

```
cm_xgboost = confusion_matrix(y_test, y_pred_xgboost)

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



AdaBoost

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

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

Out[ ]:
```
▾ AdaBoostClassifier
AdaBoostClassifier()
```

In [ ]:
```
adaboostModelAccuracy = np.mean(cross_val_score(adaboostModel, x_train, y
adaboostModelPrecision = np.mean(cross_val_score(adaboostModel, x_train,
adaboostModelSenstivity = np.mean(cross_val_score(adaboostModel, x_train,
adaboostModelF1Score = np.mean(cross_val_score(adaboostModel, x_train, y_
adaboostModelMCCScore = np.mean(cross_val_score(adaboostModel, x_train, y
adaboostModelKappaCoeff = np.mean(cross_val_score(adaboostModel, x_train,
```

```
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/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
```

```
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  warnings.warn(
```

In [ ]:
```
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 Coefficient: ", adaboostModelKappaCoeff*100)
```

```
Train Accuracy:  7548.546137615149
Train Precision:  7512.617461709035
Train Senstivity:  7636.380413385825
Train F1 Score:  7568.58310714984
Train MCC Score:  5105.205235782601
Train Kappa Coefficient:  5096.984060993945
```

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

In [ ]:
```
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: 0.24914675767918087
RMSE: 0.49914602841170724
MAE: 0.24914675767918087
```

In [ ]:
```
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)*10
adaboostModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_adaboost)*

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 Coefficient: {adaboostModelTestKappaCoeff*100}")
```

```
Test Accuracy: 7508.53242320819
Test Precision: 7118.768328445748
Test Senstivity: 7423.547400611621
Test F1 Score: 7267.964071856288
Test MCC Score: 4983.672062170667
Test Kappa Coefficient: 4979.975290654009
```

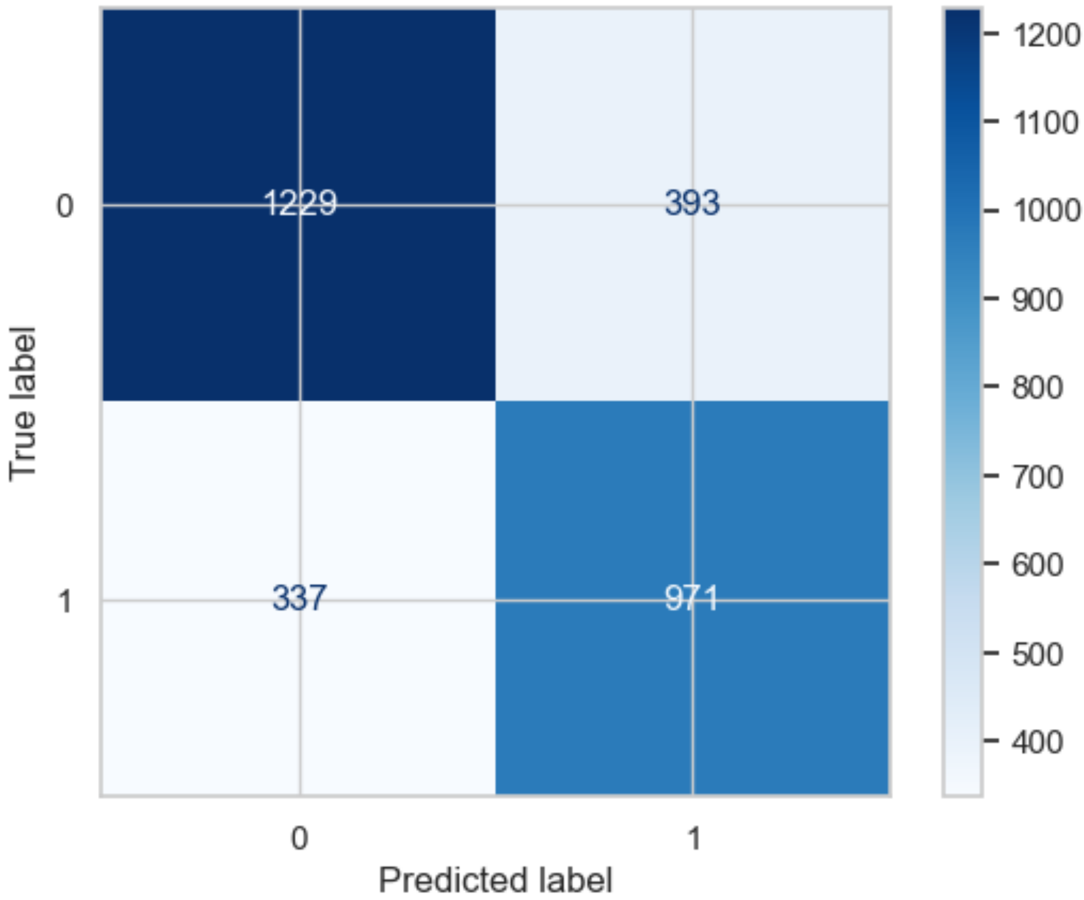
In [ ]:

```
report_adaboost = classification_report(y_test, y_pred_adaboost)
print(report_adaboost)
```

```
              precision    recall  f1-score   support

           0       0.78      0.76      0.77      1622
           1       0.71      0.74      0.73      1308

    accuracy                           0.75      2930
   macro avg       0.75      0.75      0.75      2930
weighted avg       0.75      0.75      0.75      2930
```

In [ ]:

```
cm_adaboost = confusion_matrix(y_test, y_pred_adaboost)

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



Model Comparison

Metrics Comparison on Train Data

Classification Performance Metrics

In [ ]:
```
arr_train = np.array([["Logistic Regression", logisticModelAccuracy, logi
arr_train = np.insert(arr_train, 0, ["SVM", svmModelAccuracy, svmModelPre
arr_train = np.insert(arr_train, 0, ["Decision Tree", decisionTreeModelAc
arr_train = np.insert(arr_train, 0, ["Random Forest", randomForestModelAc
arr_train = np.insert(arr_train, 0, ["KNN", KNNModelAccuracy, KNNModelPre
arr_train = np.insert(arr_train, 0, ["Naive Bayes", naiveBayesModelAccura
arr_train = np.insert(arr_train, 0, ["XGBoost", xgboostModelAccuracy, xgb
arr_train = np.insert(arr_train, 0, ["AdaBoost", adaboostModelAccuracy, a
```

In [ ]:
```
arr_train = pd.DataFrame(arr_train, columns=['Model', 'Accuracy', 'Precis
```

In [ ]:
```
arr_train
```

Out[ ]:

	Model	Accuracy	Precision	Senstivity	
0	AdaBoost	75.48546137615149	75.12617461709034	76.36380413385825	75.6
1	XGBoost	90.16314137203437	89.71703535512196	90.79191272965876	90.21
2	Naive Bayes	65.37296073284958	64.7919044291292	67.39173228346456	66.0
3	KNN	89.86166435077966	88.81664829027555	91.316437007874	89.98
4	Random Forest	91.54037362976685	91.7492087057908	91.76201607611547	91.52
5	Decision Tree	86.41145592095104	86.72524078859796	85.80790682414698	86.35
6	SVM	85.49297514281302	85.96243453940791	84.94156003937009	85.39
7	Logistic Regression	73.71494004425915	73.94028016863263	73.37331856955379	73.60

** 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.

Metrics Comparison on Test Data

Classification Performance Metrics

In [ ]:
```
arr_test = np.array([["Logistic Regression", logisticModelTestAccuracy, l
arr_test = np.insert(arr_test, 0, ["SVM", svmModelTestAccuracy, svmModelT
arr_test = np.insert(arr_test, 0, ["Decision Tree", decisionTreeModelTest
arr_test = np.insert(arr_test, 0, ["Random Forest", randomForestModelTest
arr_test = np.insert(arr_test, 0, ["KNN", KNNModelTestAccuracy, KNNModelT
arr_test = np.insert(arr_test, 0, ["Naive Bayes", naiveBayesModelTestAccu
arr_test = np.insert(arr_test, 0, ["XGBoost", xgboostModelTestAccuracy, x
arr_test = np.insert(arr_test, 0, ["AdaBoost", adaboostModelTestAccuracy,
```

In [ ]:
```
arr_test = pd.DataFrame(arr_test, columns=['Model', 'Accuracy', 'Precisio
```

In [ ]:
```
arr_test
```

Out[ ]:

	Model	Accuracy	Precision	Senstivity	
0	AdaBoost	75.0853242320819	71.18768328445748	74.2354740061162	72.
1	XGBoost	89.72696245733789	89.06128782001551	87.76758409785933	88.
2	Naive Bayes	62.32081911262799	56.986301369863014	63.608562691131496	60.1
3	KNN	87.37201365187714	85.10479041916167	86.92660550458714	86.
4	Random Forest	90.0	89.80392156862746	87.53822629969419	88
5	Decision Tree	85.05119453924914	83.77329192546584	82.49235474006116	83.
6	SVM	84.43686006825939	82.97213622291022	81.9571865443425	82.
7	Logistic Regression	72.42320819112628	68.65671641791045	70.33639143730886	69.4

Regression Performance Metrics

In [ ]:
```
arr_regression = np.array([["Logistic Regression", mse_logistic, rmse_log
arr_regression = np.insert(arr_regression, 0, ["SVM", mse_svm, rmse_svm,
arr_regression = np.insert(arr_regression, 0, ["Decision Tree", mse_decis
arr_regression = np.insert(arr_regression, 0, ["Random Forest", mse_rando
arr_regression = np.insert(arr_regression, 0, ["KNN", mse_knn, rmse_knn,
arr_regression = np.insert(arr_regression, 0, ["Naive Bayes", mse_naive_b
arr_regression = np.insert(arr_regression, 0, ["XGBoost", mse_xgboost, rm
arr_regression = np.insert(arr_regression, 0, ["AdaBoost", mse_adaboost,
```

In [ ]:
```
arr_regression = pd.DataFrame(arr_regression, columns=['Model', 'MSE', 'R
```

In [ ]:
```
arr_regression
```

Out[ ]:

	Model	MSE	RMSE	MAE
0	AdaBoost	0.24914675767918087	0.49914602841170724	0.24914675767918087
1	XGBoost	0.10273037542662115	0.3205157959081286	0.10273037542662115
2	Naive Bayes	0.37679180887372016	0.6138336980597596	0.37679180887372016
3	KNN	0.12627986348122866	0.3553587813481308	0.12627986348122866
4	Random Forest	0.1	0.31622776601683794	0.1
5	Decision Tree	0.14948805460750852	0.38663685107282325	0.14948805460750852
6	SVM	0.15563139931740613	0.39450145667336406	0.15563139931740613
7	Logistic Regression	0.2757679180887372	0.5251360948256529	0.2757679180887372

** The lower the value, the better the performance of hte model

Final Comparison: Random Forest vs XG Boost using GridSearch

In [ ]:

```
# Random Forest Hyperparameter Grid
random_forest_param_grid = {
    'n_estimators': [100, 200, 300, 400, 500],        # Number of tre
    'max_depth': [None, 10, 20, 30, 40],              # Maximum depth
    'min_samples_split': [2, 5, 10, 15, 20],          # Minimum numbe
    'min_samples_leaf': [1, 2, 4, 6, 8],              # Minimum numbe
    'max_features': ['auto', 'sqrt', 'log2', 0.2, 0.4]    # Number of fea
}

# Define Scoring Metrics
scorers = {
    'accuracy': make_scorer(accuracy_score),
    'precision': make_scorer(precision_score),
    'sensitivity': make_scorer(recall_score),
    'f1': make_scorer(f1_score),
    'mcc': make_scorer(matthews_corrcoef),
    'kappa': make_scorer(cohen_kappa_score)
}

# Random Forest Grid Search
random_forest_model = RandomForestClassifier(random_state=42)
grid_search_rf = GridSearchCV(
    estimator=random_forest_model,
    param_grid=random_forest_param_grid,
    scoring=scorers,
```

```
    refit='f1',
    cv=5,
    return_train_score=True
)
grid_search_rf.fit(x_train, y_train)
```

```
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_validation.py:547: FitFailedWarning:
3125 fits failed out of a total of 15625.
The score on these train-test partitions for these parameters will be set
to nan.
If these failures are not expected, you can try to debug them by setting e
rror_score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------
------
3125 fits failed with the following error:
Traceback (most recent call last):
  File "/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-pack
ages/sklearn/model_selection/_validation.py", line 895, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-pack
ages/sklearn/base.py", line 1467, in wrapper
    estimator._validate_params()
  File "/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-pack
ages/sklearn/base.py", line 666, in _validate_params
    validate_parameter_constraints(
  File "/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-pack
ages/sklearn/utils/_param_validation.py", line 95, in validate_parameter_c
onstraints
    raise InvalidParameterError(
sklearn.utils._param_validation.InvalidParameterError: The 'max_features'
parameter of RandomForestClassifier must be an int in the range [1, inf),
a float in the range (0.0, 1.0], a str among {'log2', 'sqrt'} or None. Got
'auto' instead.

  warnings.warn(some_fits_failed_message, FitFailedWarning)
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the test
scores are non-finite: [       nan        nan        nan ... 0.87618304 0.
8743468  0.87605232]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the trai
n scores are non-finite: [       nan        nan        nan ... 0.93510634
0.93441769 0.9349424 ]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the test
scores are non-finite: [       nan        nan        nan ... 0.87336709 0.
87019617 0.87268716]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
```

```
earn/model_selection/_search.py:1051: UserWarning: One or more of the trai
n scores are non-finite: [       nan        nan        nan ... 0.93382883
0.93317052 0.93369425]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the test
scores are non-finite: [       nan        nan        nan ... 0.88012164 0.
88012198 0.88064623]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the trai
n scores are non-finite: [       nan        nan        nan ... 0.93658208
0.93586064 0.93638531]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the test
scores are non-finite: [       nan        nan        nan ... 0.8764682  0.
87486064 0.87638758]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the trai
n scores are non-finite: [       nan        nan        nan ... 0.93520001
0.93450964 0.9350333 ]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the test
scores are non-finite: [       nan        nan        nan ... 0.75288649 0.
74926091 0.75263509]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the trai
n scores are non-finite: [       nan        nan        nan ... 0.87022292
0.86884652 0.86989694]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the test
scores are non-finite: [       nan        nan        nan ... 0.75236645 0.
74869418 0.75210511]
  warnings.warn(
/Users/brahderlau/anaconda3/envs/capstone/lib/python3.10/site-packages/skl
earn/model_selection/_search.py:1051: UserWarning: One or more of the trai
n scores are non-finite: [       nan        nan        nan ... 0.87021269
0.86883538 0.86988479]
  warnings.warn(
```

Out[ ]:

▸ **GridSearchCV**

▸ **estimator: RandomForestClassifier**

▸ RandomForestClassifier

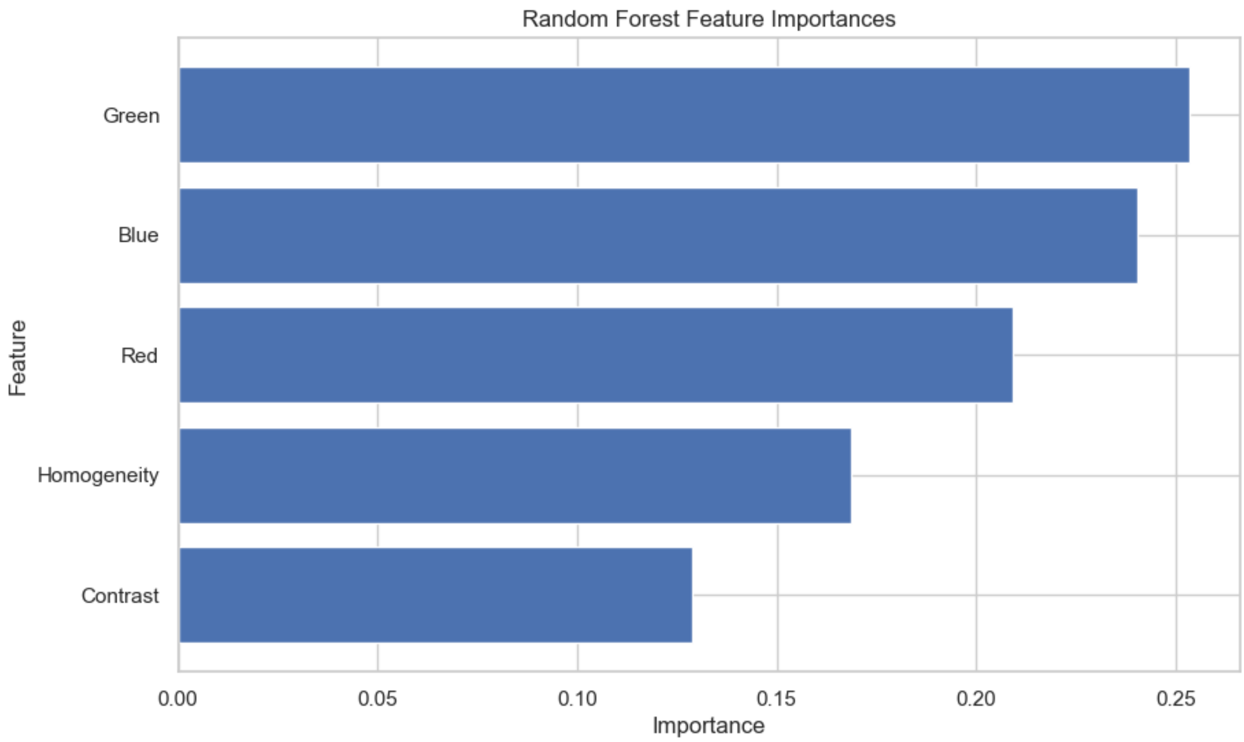
In [ ]:

```
---------------------------------------------------------------------------
-
AttributeError                            Traceback (most recent call las
t)
Cell In[505], line 3
      1 # Feature importance
----> 3 importance_values_rf = grid_search_rf.feature_importances_
      5 sorted_indices_rf = importance_values_rf.argsort()[::-1]
      6 sorted_importances_rf = importance_values_rf[sorted_indices_rf]

AttributeError: 'GridSearchCV' object has no attribute 'feature_importance
s_'
```

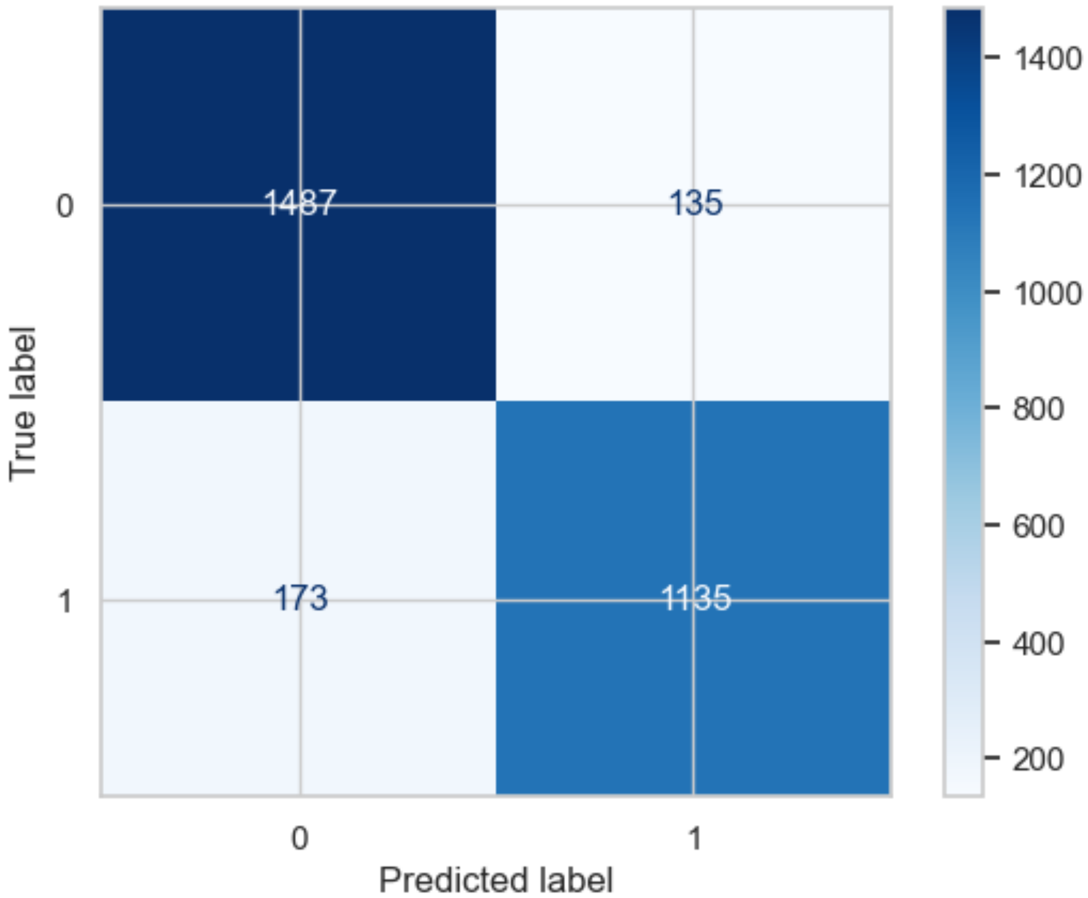
In [ ]:

```
# Evaluate Random Forest Best Model
rf_best = grid_search_rf.best_estimator_

# Feature importance
importance_values_rf = rf_best.feature_importances_

sorted_indices_rf = importance_values_rf.argsort()[::-1]
sorted_importances_rf = importance_values_rf[sorted_indices_rf]
sorted_feature_names_rf = [feature_names[i] for i in sorted_indices_rf]

plt.figure(figsize=(10, 6))
plt.barh(range(len(sorted_importances_rf)), sorted_importances_rf, tick_l
plt.xlabel('Importance')
plt.ylabel('Feature')
plt.title('Random Forest Feature Importances')
plt.gca().invert_yaxis()
plt.show()


rf_saved_name = "best_rf_model_" + str(grid_search_rf.best_params_) + ".p
with open(rf_saved_name, 'wb') as model_file:
    pickle.dump(grid_search_rf, model_file)

print("Best Random Forest Model saved successfully.")

y_pred_rf = rf_best.predict(x_test)
print("\nRandom Forest Best Parameters:", grid_search_rf.best_params_)

finalRfModelTestAccuracy = accuracy_score(y_test, y_pred_rf)*100
finalRfModelTestPrecision = precision_score(y_test, y_pred_rf)*100
finalRfModelTestSenstivity = recall_score(y_test, y_pred_rf)*100
finalRfModelTestF1Score = f1_score(y_test, y_pred_rf)*100
finalRfModelTestMCCScore = matthews_corrcoef(y_test, y_pred_rf)*100
finalRfModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_rf)*100

print(f"\nTest Accuracy: {finalRfModelTestAccuracy*100}")
print(f"Test Precision: {finalRfModelTestPrecision*100}")
print(f"Test Senstivity: {finalRfModelTestSenstivity*100}")
print(f"Test F1 Score: {finalRfModelTestF1Score*100}")
print(f"Test MCC Score: {finalRfModelTestMCCScore*100}")
```

```
print(f"Test Kappa Coefficient: {finalRfModelTestKappaCoeff*100}")

print("\nRandom Forest Classification Report:")
print(classification_report(y_test, y_pred_rf))
cm_rf = confusion_matrix(y_test, y_pred_rf)
disp_rf = ConfusionMatrixDisplay(confusion_matrix=cm_rf)
disp_rf.plot(cmap=plt.cm.Blues)
plt.show()

final_mse_rf = mean_squared_error(y_test, y_pred_rf)
final_rmse_rf = np.sqrt(final_mse_rf)
final_mae_rf = mean_absolute_error(y_test, y_pred_rf)

print(f"Final MSE: {final_mse_rf}")
print(f"Final RMSE: {final_rmse_rf}")
print(f"Final MAE: {final_mae_rf}")
```



```
Best Random Forest Model saved successfully.

Random Forest Best Parameters: {'max_depth': None, 'max_features': 'sqrt',
'min_samples_leaf': 1, 'min_samples_split': 2, 'n_estimators': 200}

Test Accuracy: 8948.805460750853
Test Precision: 8937.007874015748
Test Senstivity: 8677.37003058104
Test F1 Score: 8805.275407292474
Test MCC Score: 7869.912365823544
Test Kappa Coefficient: 7867.187241504815

Random Forest Classification Report:
              precision    recall  f1-score   support

           0       0.90      0.92      0.91      1622
           1       0.89      0.87      0.88      1308

    accuracy                           0.89      2930
   macro avg       0.89      0.89      0.89      2930
weighted avg       0.89      0.89      0.89      2930
```




```
Final MSE: 0.10511945392491467
Final RMSE: 0.3242213039343878
Final MAE: 0.10511945392491467
```

In [ ]:
```
# XGBoost Hyperparameter Grid
xgboost_param_grid = {
```

```
    'n_estimators': [100, 200, 300, 400, 500],
    'max_depth': [3, 5, 7, 10, 15],
    'learning_rate': [0.01, 0.05, 0.1, 0.2, 0.3],
    'subsample': [0.7, 0.8, 0.85, 0.9, 1.0],
    'gamma': [0, 0.1, 0.2, 0.3, 0.5]
}

# XGBoost Grid Search
xgboost_model = XGBClassifier(random_state=42)
grid_search_xgb = GridSearchCV(
    estimator=xgboost_model,
    param_grid=xgboost_param_grid,
    scoring=scorers,
    refit='f1',
    cv=5,
    return_train_score=True
)
grid_search_xgb.fit(x_train, y_train)
```

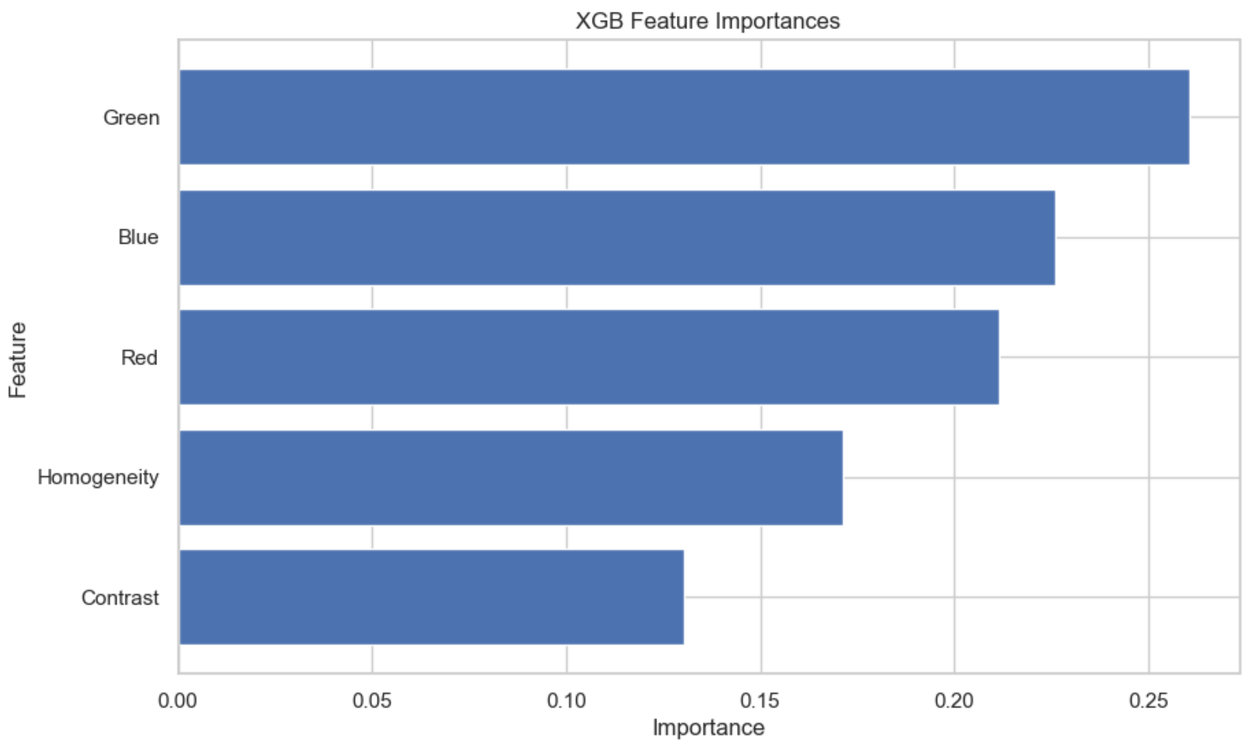
Out[ ]:

```
▸ GridSearchCV
▸ estimator: XGBClassifier
    ▸ XGBClassifier
```

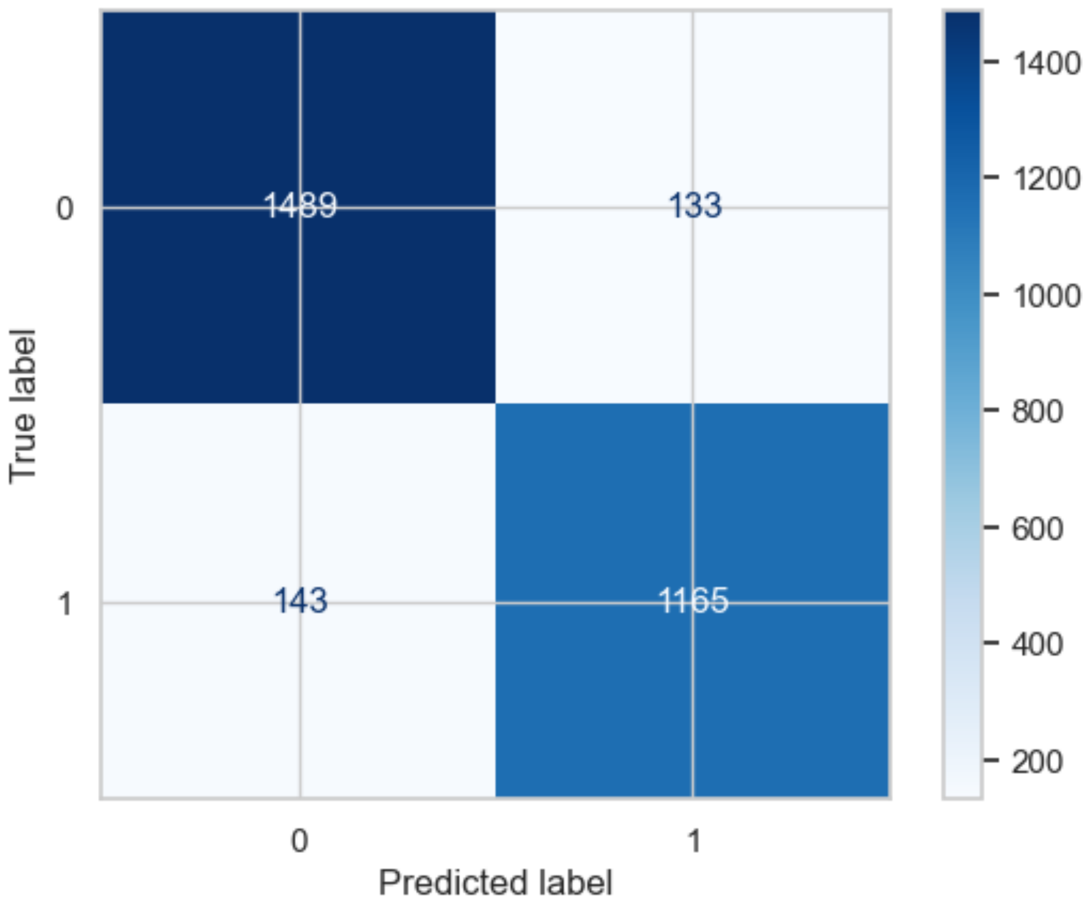
In [ ]:

```
# Evaluate XGBoost Best Model
xgb_best = grid_search_xgb.best_estimator_

importance_values_xgb = xgb_best.feature_importances_

sorted_indices_xgb = importance_values_xgb.argsort()[::-1]
sorted_importances_xgb = importance_values_xgb[sorted_indices_xgb]
sorted_feature_names_xgb = [feature_names[i] for i in sorted_indices_xgb]

plt.figure(figsize=(10, 6))
plt.barh(range(len(sorted_importances_xgb)), sorted_importances_xgb, tick
plt.xlabel('Importance')
plt.ylabel('Feature')
plt.title('XGB Feature Importances')
plt.gca().invert_yaxis()
plt.show()

xgb_saved_name = "best_xgb_model_" + str(grid_search_xgb.best_params_) +
with open(xgb_saved_name, 'wb') as model_file:
    pickle.dump(xgb_best, model_file)

print("Best XG Boost Model saved successfully.")

y_pred_xgb = xgb_best.predict(x_test)
print("XGBoost Best Parameters:", grid_search_xgb.best_params_)
```

```
finalXgbModelTestAccuracy = accuracy_score(y_test, y_pred_xgb)*100
finalXgbModelTestPrecision = precision_score(y_test, y_pred_xgb)*100
finalXgbModelTestSenstivity = recall_score(y_test, y_pred_xgb)*100
finalXgbModelTestF1Score = f1_score(y_test, y_pred_xgb)*100
finalXgbModelTestMCCScore = matthews_corrcoef(y_test, y_pred_xgb)*100
finalXgbModelTestKappaCoeff = cohen_kappa_score(y_test, y_pred_xgb)*100

print(f"\nTest Accuracy: {finalXgbModelTestAccuracy*100}")
print(f"Test Precision: {finalXgbModelTestPrecision*100}")
print(f"Test Senstivity: {finalXgbModelTestSenstivity*100}")
print(f"Test F1 Score: {finalXgbModelTestF1Score*100}")
print(f"Test MCC Score: {finalXgbModelTestMCCScore*100}")
print(f"Test Kappa Coefficient: {finalXgbModelTestKappaCoeff*100}")

print("\nXGBoost Classification Report:")
print(classification_report(y_test, y_pred_xgb))
cm_xgb = confusion_matrix(y_test, y_pred_xgb)
disp_xgb = ConfusionMatrixDisplay(confusion_matrix=cm_xgb)
disp_xgb.plot(cmap=plt.cm.Blues)
plt.show()

final_mse_xgb = mean_squared_error(y_test, y_pred_xgb)
final_rmse_xgb= np.sqrt(final_mse_xgb)
final_mae_xgb= mean_absolute_error(y_test, y_pred_xgb)

print(f"Final MSE: {final_mse_xgb}")
print(f"Final RMSE: {final_rmse_xgb}")
print(f"Final MAE: {final_mae_xgb}")
```



```
Best XG Boost Model saved successfully.
XGBoost Best Parameters: {'gamma': 0.1, 'learning_rate': 0.1, 'max_depth':
15, 'n_estimators': 300, 'subsample': 0.8}

Test Accuracy: 9058.0204778157
Test Precision: 8975.346687211095
Test Senstivity: 8906.727828746178
Test F1 Score: 8940.90560245587
Test MCC Score: 8092.934480397588
Test Kappa Coefficient: 8092.741246958735

XGBoost Classification Report:
              precision    recall  f1-score   support

           0       0.91      0.92      0.92      1622
           1       0.90      0.89      0.89      1308

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




```
Final MSE: 0.09419795221843004
Final RMSE: 0.3069168490298798
Final MAE: 0.09419795221843004
```

Conclusion

After applying the GridSearch method, it can be seen that XG Boost performs slightly better than the previous default parameters as well as hypertuned Random Forest. The classification and regression performance of the model has increased by 0.01 - 0.02 in each metrics

Neural Network Attempt (IGNORE)

In [ ]:
```
'''
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 activat
    mu = cost function
    eta = a standard learning rate initialization. It can be modified by
    '''
    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 ba
        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]

        '''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] )

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

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

        '''GRADIENT DESCENT'''
        # We start from the first layer that is special, since it is conn
        self.W.append( w[0] - self.eta * np.kron(self.delta[0], x).reshap
        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
            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
        '''
        print('Model recap: \n')
        print('You are fitting an ANN with the following amount of layers

        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 ArX
                self.w.append( np.random.randn(self.HiddenLayer[i][0] , s
                self.b.append( np.random.randn(self.HiddenLayer[i][0])/np
                # Old initialization
```

```
            #self.w.append(2 * np.random.rand(self.HiddenLayer[i][0]
            #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 ArX
            self.w.append( np.random.randn(self.HiddenLayer[i][0] , s
            self.b.append( np.random.randn(self.HiddenLayer[i][0])/np
            # Old initialization
            #self.w.append(2*np.random.rand(self.HiddenLayer[i][0] ,
            #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.ph

        for i in range(1, len(self.HiddenLayer)): #Looping over layer
            self.z.append( self.FeedForward(self.w[i] , self.b[i], se


        '''
        Here we backpropagate
        '''
        self.w, self.b  = self.BackPropagation(self.X[I], self.z, sel

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

    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.ph

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

            # Append the prediction;
            # We now need a binary classifier; we this apply an Heaviside
            # if y < 0.5 the output is zero, otherwise is zero
            self.pred.append( np.heaviside(  self.z[-1] - 0.5, 1)[0] ) #

        print('Predictions done. \n')

        return np.array(self.pred)

    '''
    We need a method to retrieve the accuracy for each training data to f
    '''
    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 metho
            # 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)
                #self.loss_avg += self.mu[60*i+m]/60
                self.loss_avg += self.mu[(int(math.ceil((self.X.shape[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 Convolutiona
    '''
    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 de
    '''
    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 T
            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
```

In [ ]:
```
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.ph
i[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(s
elf.z)-1] - self.Y[I])
    146 )

File ~/anaconda3/envs/capstone/lib/python3.10/site-packages/pandas/core/se
ries.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 slice
s)
   1116 if is_iterator(key):

File ~/anaconda3/envs/capstone/lib/python3.10/site-packages/pandas/core/se
ries.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 positiona
l
-> 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/in
dexes/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
```