Project 2

January 26, 2024

[1]:
```python
# Importing
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns

from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler

from sklearn.linear_model import LogisticRegression
from sklearn.tree import DecisionTreeClassifier
from sklearn.neighbors import KNeighborsClassifier
from xgboost import XGBClassifier

from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import precision_score
from sklearn.metrics import recall_score
from sklearn.metrics import f1_score
from sklearn.tree import export_graphviz
from sklearn.metrics import roc_auc_score

from imblearn.under_sampling import RandomUnderSampler
from imblearn.over_sampling import RandomOverSampler

from collections import Counter
from IPython.display import Image
import pydotplus

# Configuring the notebook
sns.set()
%matplotlib inline

# Reading the data
data = pd.read_csv('creditcard.csv')
```

[ ]:
```python

```

[ ]:

```

```

[ ]:

```

```

[2]:

```
data.head()
```

[2]:

```
   Time        V1        V2        V3        V4        V5        V6        V7  \
0   0.0 -1.359807 -0.072781  2.536347  1.378155 -0.338321  0.462388  0.239599
1   0.0  1.191857  0.266151  0.166480  0.448154  0.060018 -0.082361 -0.078803
2   1.0 -1.358354 -1.340163  1.773209  0.379780 -0.503198  1.800499  0.791461
3   1.0 -0.966272 -0.185226  1.792993 -0.863291 -0.010309  1.247203  0.237609
4   2.0 -1.158233  0.877737  1.548718  0.403034 -0.407193  0.095921  0.592941

         V8        V9  …       V21       V22       V23       V24       V25  \
0  0.098698  0.363787  … -0.018307  0.277838 -0.110474  0.066928  0.128539
1  0.085102 -0.255425  … -0.225775 -0.638672  0.101288 -0.339846  0.167170
2  0.247676 -1.514654  …  0.247998  0.771679  0.909412 -0.689281 -0.327642
3  0.377436 -1.387024  … -0.108300  0.005274 -0.190321 -1.175575  0.647376
4 -0.270533  0.817739  … -0.009431  0.798278 -0.137458  0.141267 -0.206010

        V26       V27       V28  Amount  Class
0 -0.189115  0.133558 -0.021053  149.62      0
1  0.125895 -0.008983  0.014724    2.69      0
2 -0.139097 -0.055353 -0.059752  378.66      0
3 -0.221929  0.062723  0.061458  123.50      0
4  0.502292  0.219422  0.215153   69.99      0

[5 rows x 31 columns]
```

[3]:

```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 284807 entries, 0 to 284806
Data columns (total 31 columns):
 #   Column  Non-Null Count   Dtype
---  ------  --------------   -----
 0   Time    284807 non-null  float64
 1   V1      284807 non-null  float64
 2   V2      284807 non-null  float64
 3   V3      284807 non-null  float64
 4   V4      284807 non-null  float64
 5   V5      284807 non-null  float64
 6   V6      284807 non-null  float64
 7   V7      284807 non-null  float64
 8   V8      284807 non-null  float64
 9   V9      284807 non-null  float64
 10  V10     284807 non-null  float64
 11  V11     284807 non-null  float64
```

```
 12  V12     284807 non-null  float64
 13  V13     284807 non-null  float64
 14  V14     284807 non-null  float64
 15  V15     284807 non-null  float64
 16  V16     284807 non-null  float64
 17  V17     284807 non-null  float64
 18  V18     284807 non-null  float64
 19  V19     284807 non-null  float64
 20  V20     284807 non-null  float64
 21  V21     284807 non-null  float64
 22  V22     284807 non-null  float64
 23  V23     284807 non-null  float64
 24  V24     284807 non-null  float64
 25  V25     284807 non-null  float64
 26  V26     284807 non-null  float64
 27  V27     284807 non-null  float64
 28  V28     284807 non-null  float64
 29  Amount  284807 non-null  float64
 30  Class   284807 non-null  int64
dtypes: float64(30), int64(1)
memory usage: 67.4 MB
```

[4]:
```
data[['Time','Amount']].describe()
```

[4]:

	Time	Amount
count	284807.000000	284807.000000
mean	94813.859575	88.349619
std	47488.145955	250.120109
min	0.000000	0.000000
25%	54201.500000	5.600000
50%	84692.000000	22.000000
75%	139320.500000	77.165000
max	172792.000000	25691.160000

[5]:
```
data.isnull().sum()
```

[5]:
```
Time      0
V1        0
V2        0
V3        0
V4        0
V5        0
V6        0
V7        0
V8        0
V9        0
V10       0
V11       0
```

```
V12       0
V13       0
V14       0
V15       0
V16       0
V17       0
V18       0
V19       0
V20       0
V21       0
V22       0
V23       0
V24       0
V25       0
V26       0
V27       0
V28       0
Amount    0
Class     0
dtype: int64
```

[6]:
```
data.fillna(data.mean(), inplace=True)
```

[7]:
```
z_scores = (data - data.mean()) / data.std()
outliers = (np.abs(z_scores) > 3).any(axis=1)
print("Number of outliers:", outliers.sum())
```

```
Number of outliers: 37864
```

[8]:
```
fig, ((ax1, ax2), (ax3, ax4)) = plt.subplots(2, 2, figsize=(15,8))
sns.distplot(data['Time'][data['Class'] == 1], bins=15, ax=ax1)
sns.distplot(data['Time'][data['Class'] == 0], bins=15, ax=ax2)

sns.distplot(data['Amount'][data['Class'] == 1], bins=5, ax=ax3)
sns.distplot(data['Amount'][data['Class'] == 0], bins=5, ax=ax4)

ax1.set_title('Fraud')
ax2.set_title('Non Fraud')
ax3.set_title('Fraud')
ax4.set_title('Non Fraud')
plt.tight_layout()
plt.show()
```

```
C:\Users\leend\anaconda3\lib\site-packages\seaborn\distributions.py:2619:
FutureWarning: `distplot` is a deprecated function and will be removed in a
future version. Please adapt your code to use either `displot` (a figure-level
function with similar flexibility) or `histplot` (an axes-level function for
```

```
histograms).
  warnings.warn(msg, FutureWarning)
C:\Users\leend\anaconda3\lib\site-packages\seaborn\distributions.py:2619:
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FutureWarning: `distplot` is a deprecated function and will be removed in a
future version. Please adapt your code to use either `displot` (a figure-level
function with similar flexibility) or `histplot` (an axes-level function for
histograms).
  warnings.warn(msg, FutureWarning)
```
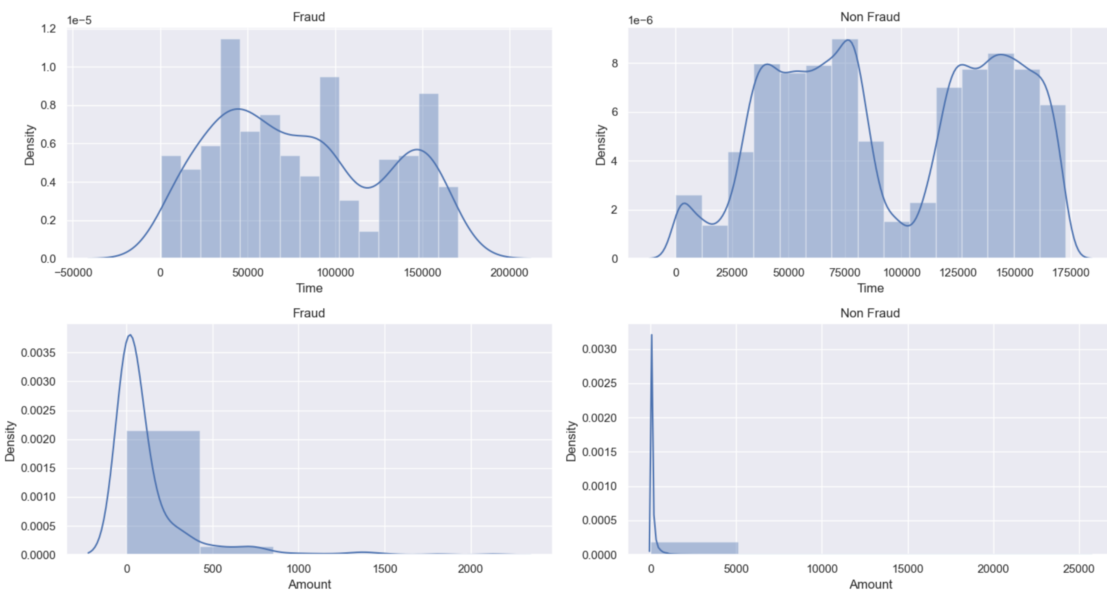
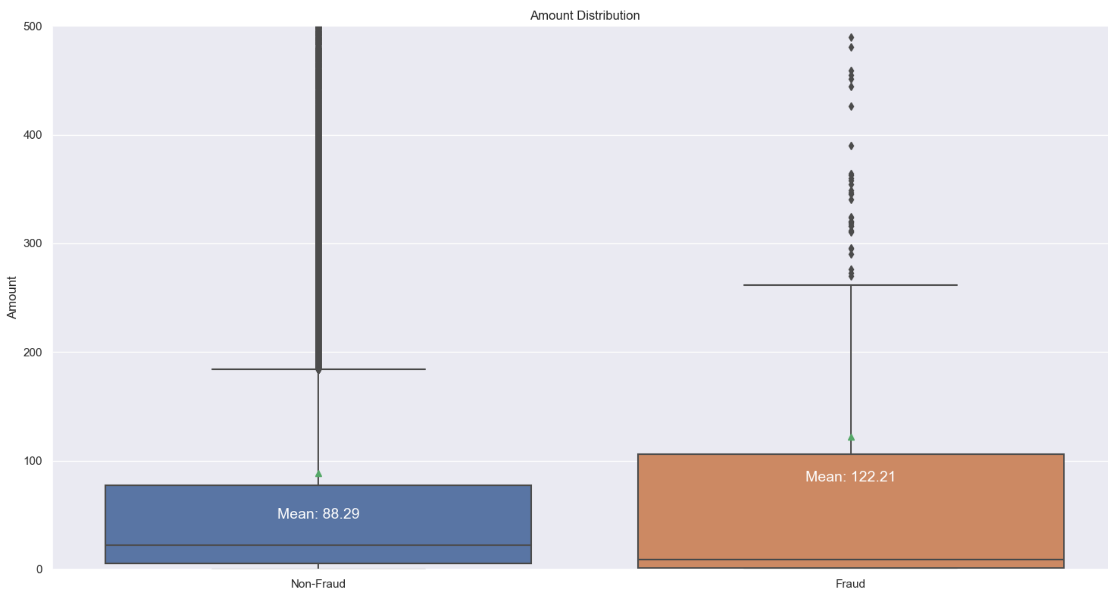



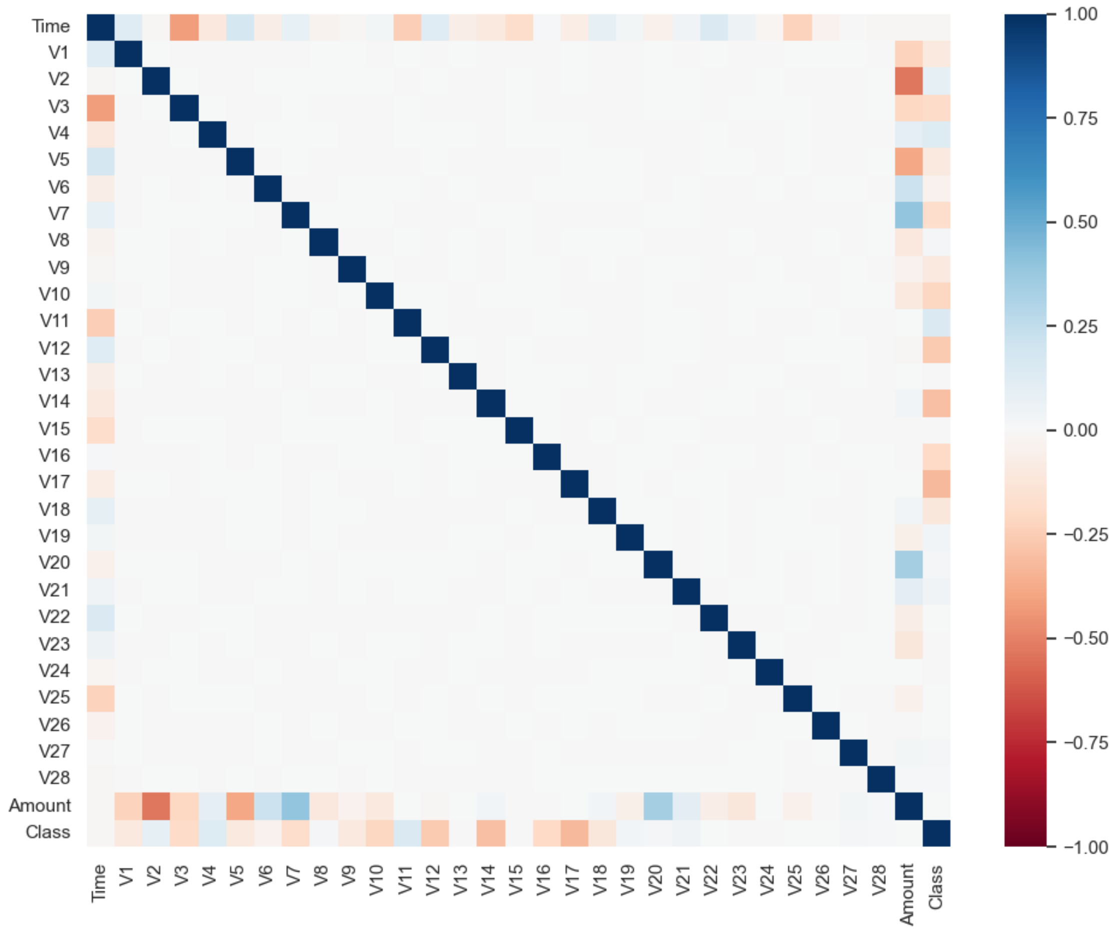
[9]:
```
fig, ax = plt.subplots(figsize=(15,8))

box_plot = sns.boxplot(data['Class'], data['Amount'], showmeans=True, ax=ax)
plt.xticks([0, 1], ['Non-Fraud', 'Fraud'])
ax.set_ylim(0, 500)
ax.set_title('Amount Distribution')
ax.set_xlabel('')
```

```
means = data.groupby(['Class'])['Amount'].mean()
vertical_offset = data['Amount'].mean() - 130 # offset from median for display

for xtick in box_plot.get_xticks():
    box_plot.text(xtick, means[xtick] + vertical_offset, f'Mean:␣
 ↪{round(means[xtick], 2)}',
            horizontalalignment='center', fontsize=14, color='w')

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

```
C:\Users\leend\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variables as keyword args: x, y. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```



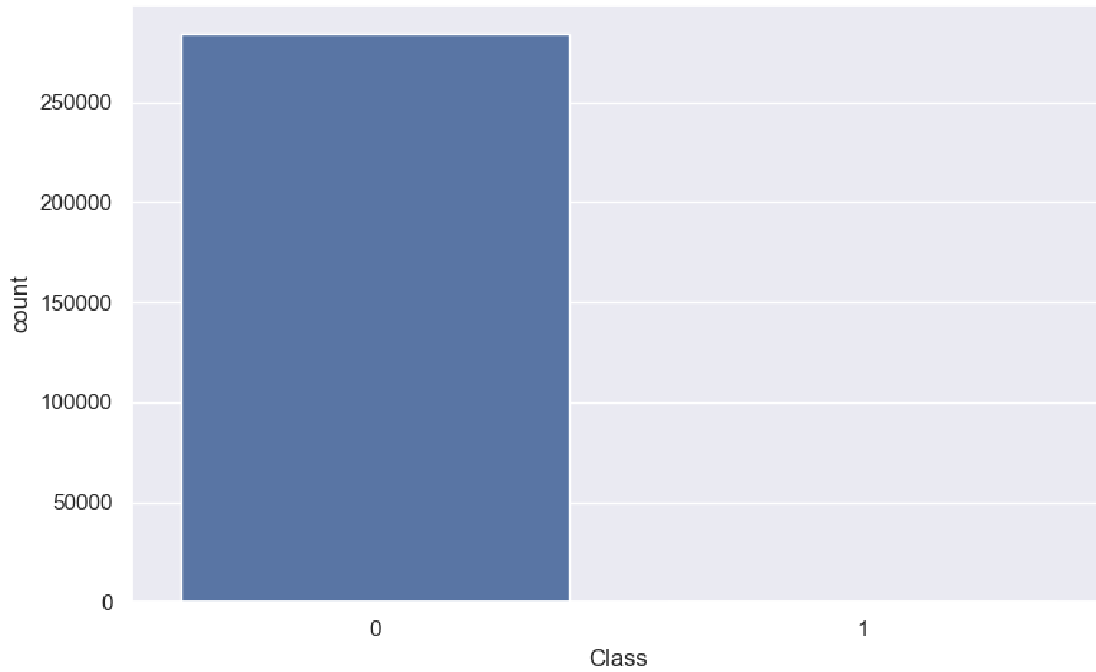
[10]:
```
corr = data.corr()
fig, ax = plt.subplots(figsize=(10, 8))
sns.heatmap(corr, cmap='RdBu', vmin=-1)

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



[11]:
```
print(data['Class'].value_counts(normalize=True))

fig, ax = plt.subplots(figsize=(8,5))
sns.countplot(data['Class'])

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

```
0    0.998273
1    0.001727
Name: Class, dtype: float64
```

```
C:\Users\leend\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```



[12]:
```
scaler = StandardScaler()

data['std_amount'] = scaler.fit_transform(data['Amount'].values.reshape(-1, 1))
data['std_time'] = scaler.fit_transform(data['Time'].values.reshape(-1, 1))

data.drop(['Amount', 'Time'], axis=1, inplace=True)
data.head()
```

[12]:
```
         V1        V2        V3        V4        V5        V6        V7  \
0 -1.359807 -0.072781  2.536347  1.378155 -0.338321  0.462388  0.239599
1  1.191857  0.266151  0.166480  0.448154  0.060018 -0.082361 -0.078803
2 -1.358354 -1.340163  1.773209  0.379780 -0.503198  1.800499  0.791461
3 -0.966272 -0.185226  1.792993 -0.863291 -0.010309  1.247203  0.237609
4 -1.158233  0.877737  1.548718  0.403034 -0.407193  0.095921  0.592941

         V8        V9       V10  …       V22       V23       V24       V25  \
0  0.098698  0.363787  0.090794  …  0.277838 -0.110474  0.066928  0.128539
1  0.085102 -0.255425 -0.166974  … -0.638672  0.101288 -0.339846  0.167170
2  0.247676 -1.514654  0.207643  …  0.771679  0.909412 -0.689281 -0.327642
3  0.377436 -1.387024 -0.054952  …  0.005274 -0.190321 -1.175575  0.647376
4 -0.270533  0.817739  0.753074  …  0.798278 -0.137458  0.141267 -0.206010

        V26       V27       V28  Class  std_amount  std_time
0 -0.189115  0.133558 -0.021053      0    0.244964 -1.996583
```

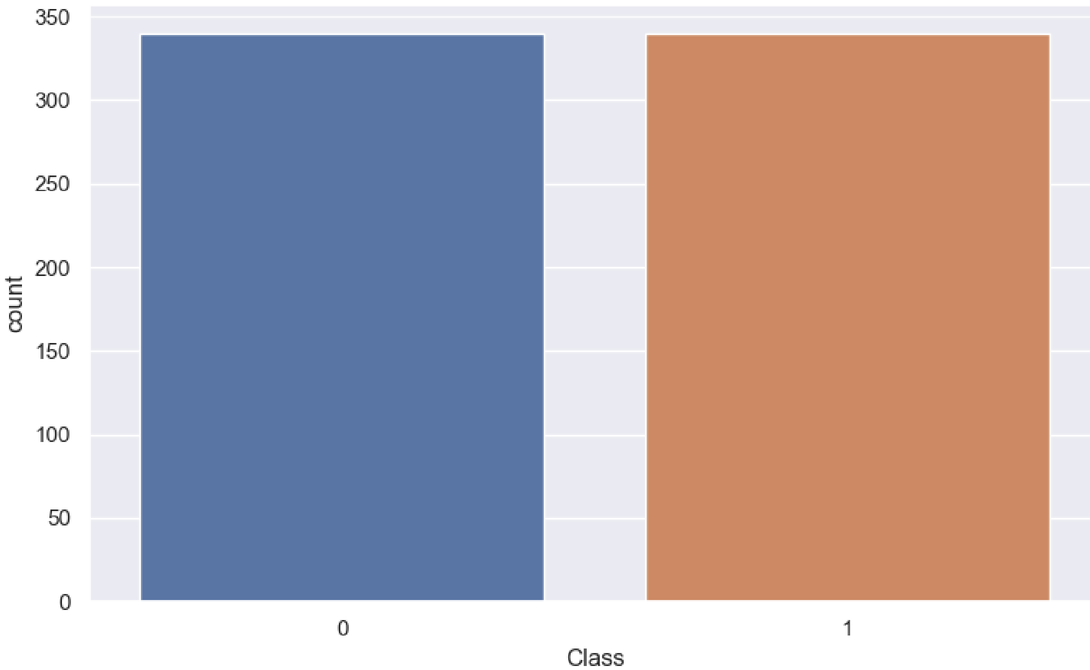
```
1  0.125895 -0.008983  0.014724      0   -0.342475 -1.996583
2 -0.139097 -0.055353 -0.059752      0    1.160686 -1.996562
3 -0.221929  0.062723  0.061458      0    0.140534 -1.996562
4  0.502292  0.219422  0.215153      0   -0.073403 -1.996541

[5 rows x 31 columns]
```

[13]:
```
X = data.drop('Class', axis=1)
y = data['Class']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)
```

[14]:
```
from imblearn.under_sampling import RandomUnderSampler

# Create a RandomUnderSampler object
rus = RandomUnderSampler()

# Use fit_resample instead of fit_sample
X_rus, y_rus = rus.fit_resample(X_train, y_train)

# Check the class distribution after undersampling
print(pd.Series(y_rus).value_counts(normalize=True))
fig, ax = plt.subplots(figsize=(8,5))
sns.countplot(y_rus)

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

```
0    0.5
1    0.5
Name: Class, dtype: float64
```

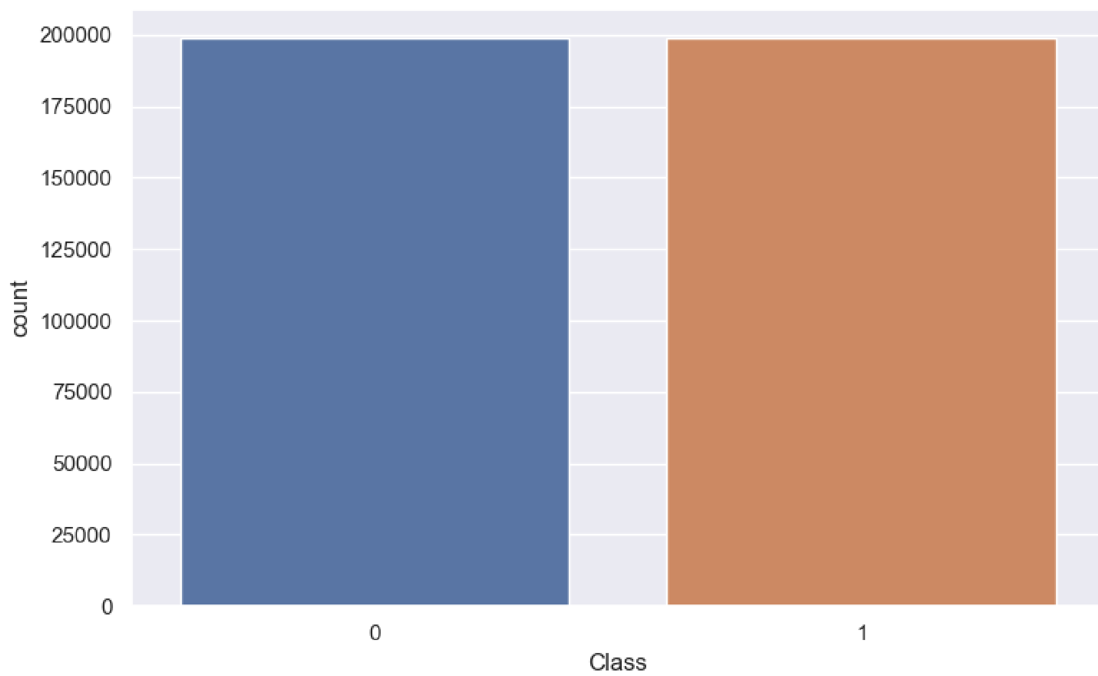
```
C:\Users\leend\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```



[15]:
```
from imblearn.over_sampling import RandomOverSampler

# Create a RandomUnderSampler object
ros = RandomOverSampler()

# Use fit_resample instead of fit_sample
X_ros, y_ros = ros.fit_resample(X_train, y_train)

# Check the class distribution after undersampling
print(pd.Series(y_ros).value_counts(normalize=True))
fig, ax = plt.subplots(figsize=(8,5))
sns.countplot(y_ros)

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

```
0    0.5
1    0.5
Name: Class, dtype: float64
```

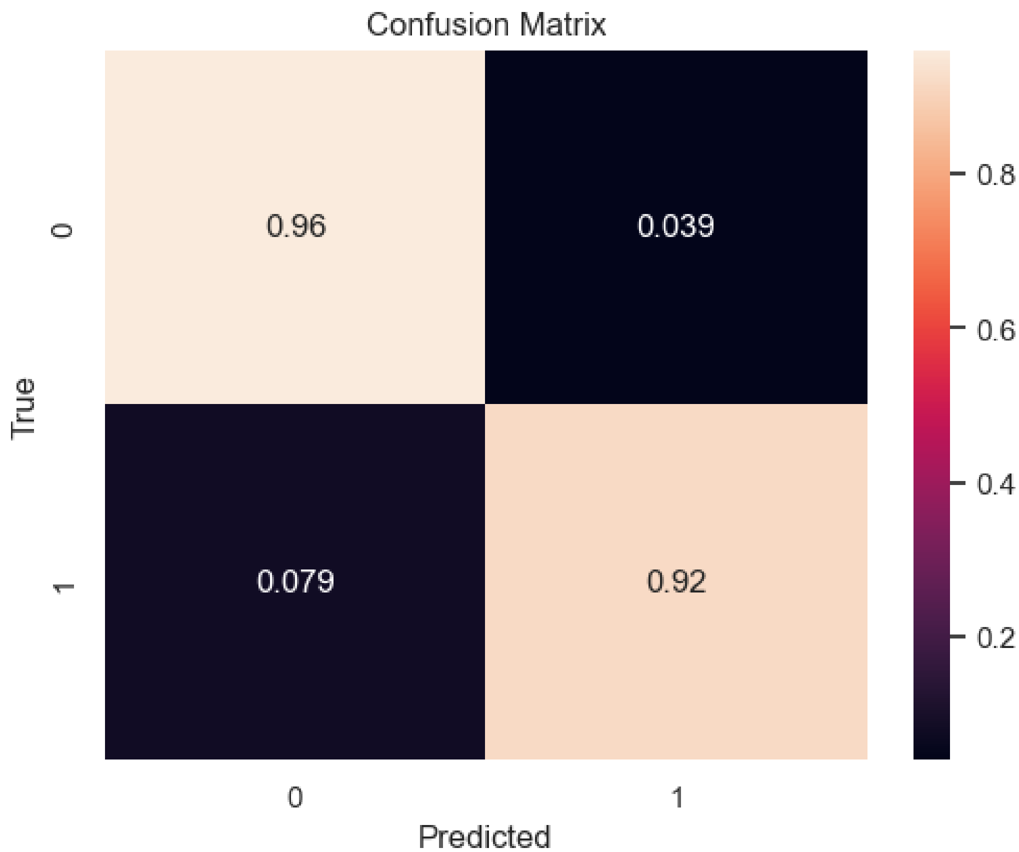
```
C:\Users\leend\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```



[16]:
```
# logistic regression
log_reg_under = LogisticRegression()

log_reg_under.fit(X_rus, y_rus)

y_pred_log_under = log_reg_under.predict(X_test)


def report(pred):
    print(classification_report(y_test, pred))
    fig, ax = plt.subplots()
    sns.heatmap(confusion_matrix(y_test, pred, normalize='true'), annot=True,␣
 ↪ax=ax)
    ax.set_title('Confusion Matrix')
    ax.set_ylabel('True')
    ax.set_xlabel('Predicted')

    plt.show()

    print(f'ROC AUC Score: {round(roc_auc_score(y_test, pred), 4)}')

report(y_pred_log_under)
```

```
              precision    recall  f1-score   support
```

```
              0       1.00      0.96      0.98     85291
              1       0.04      0.92      0.08       152

       accuracy                           0.96     85443
      macro avg       0.52      0.94      0.53     85443
   weighted avg       1.00      0.96      0.98     85443
```

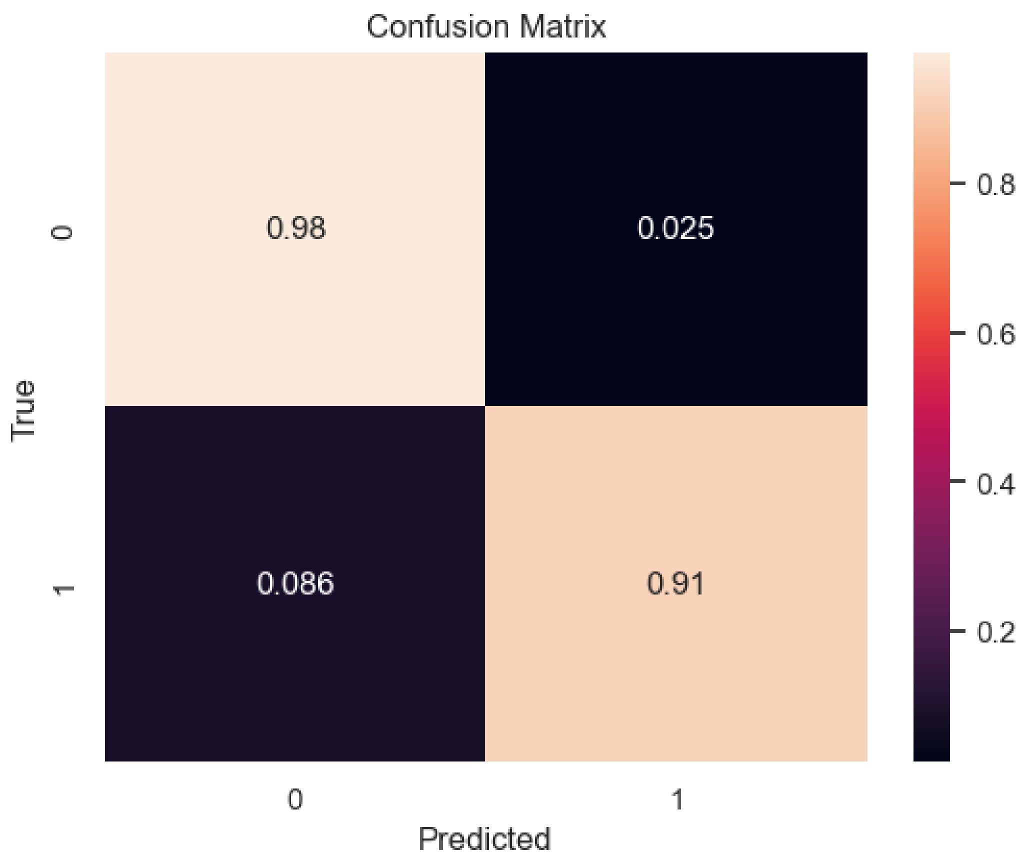



```
ROC AUC Score: 0.9411
```

[17]:
```
log_reg_over = LogisticRegression()

log_reg_over.fit(X_ros, y_ros)

y_pred_log_over = log_reg_over.predict(X_test)

report(y_pred_log_over)
```

```
              precision    recall  f1-score   support
```

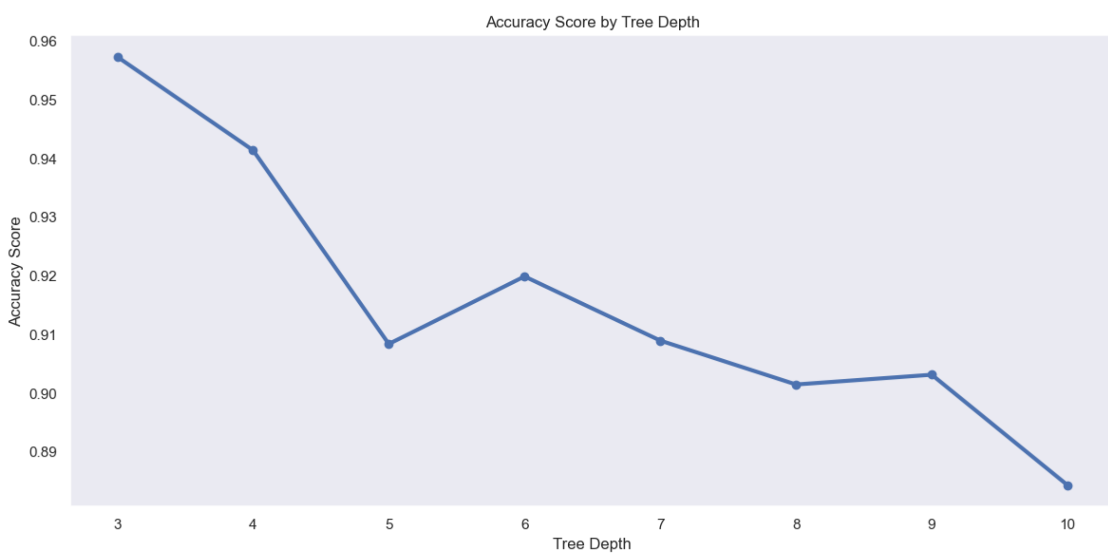
```
              0       1.00      0.98      0.99     85291
              1       0.06      0.91      0.12       152

       accuracy                           0.98     85443
      macro avg       0.53      0.94      0.55     85443
   weighted avg       1.00      0.98      0.99     85443
```




```
ROC AUC Score: 0.9448
```

[18]:
```
# decision tree
n = 11
acc_tree = np.zeros((n-3))

for i in range(3, n):

    tree = DecisionTreeClassifier(criterion='entropy', max_depth=i)

    tree.fit(X_rus, y_rus)
```

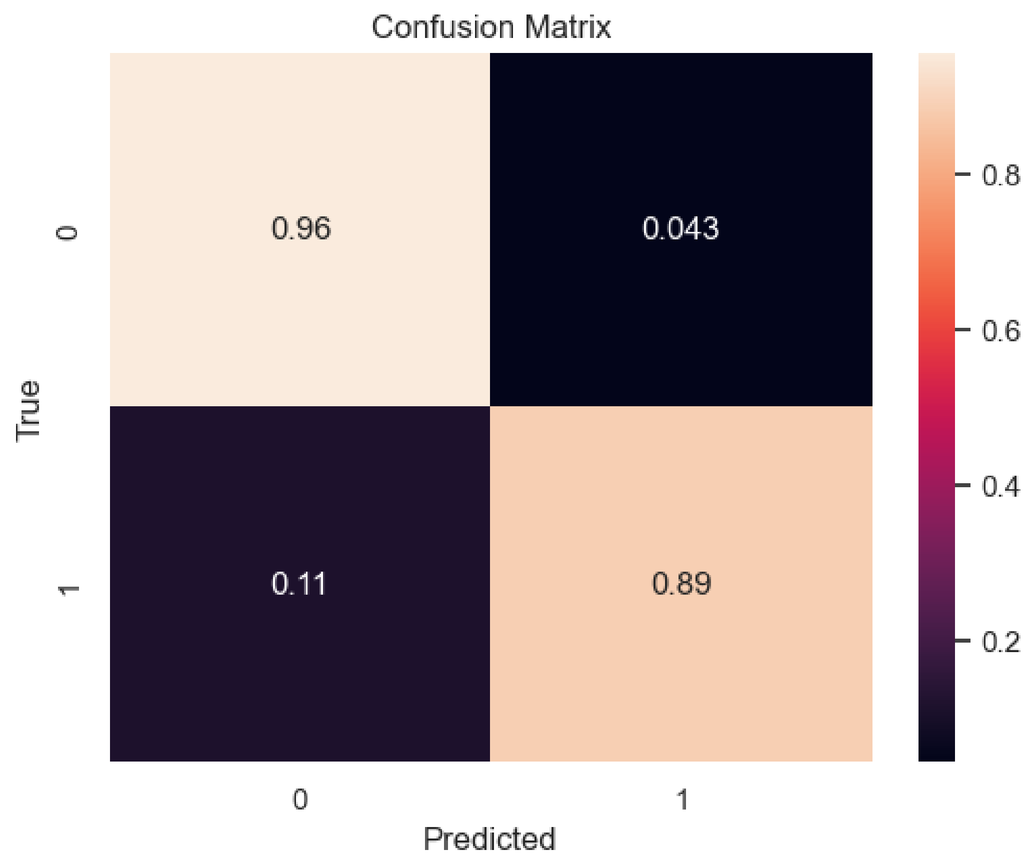
```
    y_pred_tree = tree.predict(X_test)

    acc_tree[i-3] = accuracy_score(y_test, y_pred_tree)

fig, ax = plt.subplots(figsize=(12,6))
ax.plot(range(3, n), acc_tree, linewidth=3, marker='o')
ax.set_title('Accuracy Score by Tree Depth')
ax.set_ylabel('Accuracy Score')
ax.set_xlabel('Tree Depth')
ax.grid(False)

plt.tight_layout()
plt.show()

best_depth = acc_tree.argmax()+3
print(f'The best accuracy was {round(acc_tree.max(), 4)} with␣
 ↪depth={best_depth}.')
```




```
The best accuracy was 0.9574 with depth=3.
```

[19]:
```
tree_under = DecisionTreeClassifier(criterion='entropy', max_depth=best_depth)

tree_under.fit(X_rus, y_rus)

y_pred_tree_under = tree_under.predict(X_test)

report(y_pred_tree_under)
```

```
              precision    recall  f1-score   support

           0       1.00      0.96      0.98     85291
           1       0.04      0.89      0.07       152

    accuracy                           0.96     85443
   macro avg       0.52      0.92      0.52     85443
weighted avg       1.00      0.96      0.98     85443
```



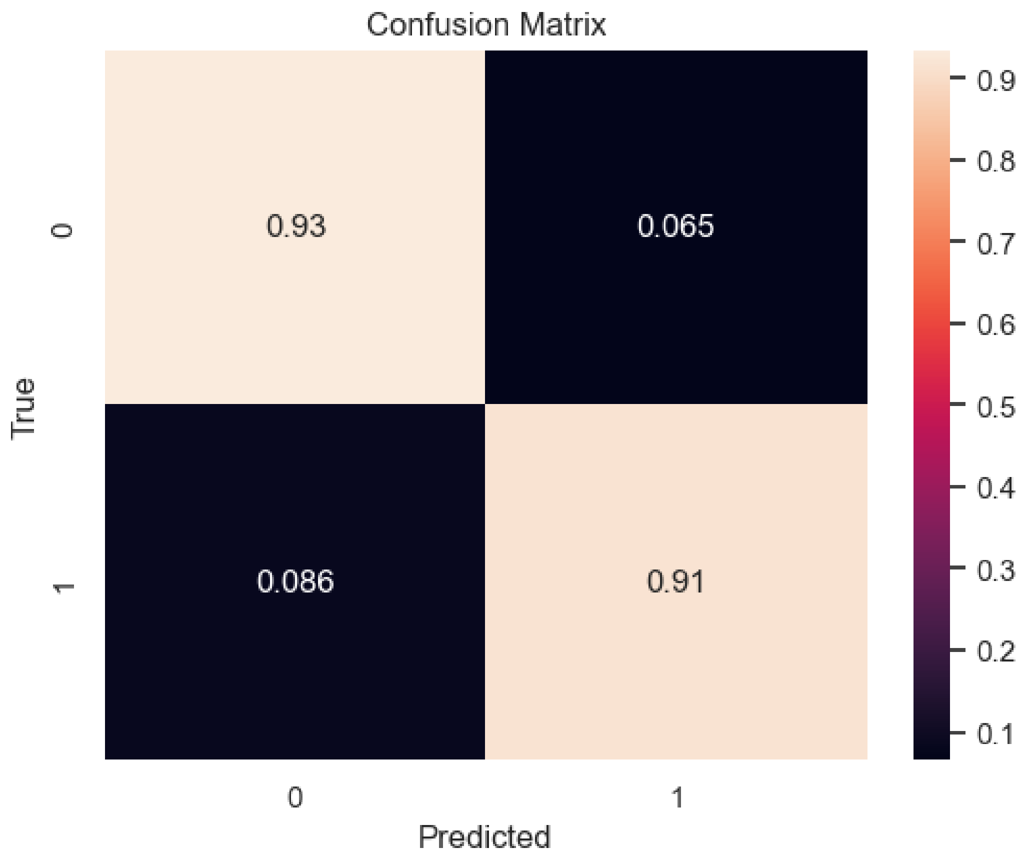

```
ROC AUC Score: 0.9228
```

[20]:

```python
tree_over = DecisionTreeClassifier(criterion='entropy', max_depth=best_depth)

tree_over.fit(X_ros, y_ros)

y_pred_tree_over = tree_over.predict(X_test)

report(y_pred_tree_over)
```

```
              precision    recall  f1-score   support
```

```
              0       1.00      0.93      0.97     85291
              1       0.02      0.91      0.05       152

       accuracy                           0.93     85443
      macro avg       0.51      0.92      0.51     85443
   weighted avg       1.00      0.93      0.96     85443
```




```
ROC AUC Score: 0.9245
```

[21]:
```
# K - nearest Neighbors
Ks = 11
acc_knn = np.zeros((Ks-1))

for k in range(1, Ks):

    knn = KNeighborsClassifier(n_neighbors=k)
    knn.fit(X_rus, y_rus)
```

```
    y_pred_knn = knn.predict(X_test)

    acc_knn[k-1] = accuracy_score(y_test, y_pred_knn)

fig, ax = plt.subplots(figsize=(12,6))
ax.plot(range(1, Ks), acc_knn, linewidth=3, marker='o')
ax.set_title('Accuracy Score by Number of Neighbors')
ax.set_ylabel('Accuracy Score')
ax.set_xlabel('Number of Neighbors')
ax.grid(False)

plt.tight_layout()
plt.show()

best_k = acc_knn.argmax()+1
print(f'The best accuracy was {round(acc_knn.max(), 4)} with k={best_k}.')
```

```
C:\Users\leend\anaconda3\lib\site-
packages\sklearn\neighbors\_classification.py:228: FutureWarning: Unlike other
reduction functions (e.g. `skew`, `kurtosis`), the default behavior of `mode`
typically preserves the axis it acts along. In SciPy 1.11.0, this behavior will
change: the default value of `keepdims` will become False, the `axis` over which
the statistic is taken will be eliminated, and the value None will no longer be
accepted. Set `keepdims` to True or False to avoid this warning.
  mode, _ = stats.mode(_y[neigh_ind, k], axis=1)
C:\Users\leend\anaconda3\lib\site-
packages\sklearn\neighbors\_classification.py:228: FutureWarning: Unlike other
reduction functions (e.g. `skew`, `kurtosis`), the default behavior of `mode`
typically preserves the axis it acts along. In SciPy 1.11.0, this behavior will
change: the default value of `keepdims` will become False, the `axis` over which
the statistic is taken will be eliminated, and the value None will no longer be
accepted. Set `keepdims` to True or False to avoid this warning.
  mode, _ = stats.mode(_y[neigh_ind, k], axis=1)
C:\Users\leend\anaconda3\lib\site-
packages\sklearn\neighbors\_classification.py:228: FutureWarning: Unlike other
reduction functions (e.g. `skew`, `kurtosis`), the default behavior of `mode`
typically preserves the axis it acts along. In SciPy 1.11.0, this behavior will
change: the default value of `keepdims` will become False, the `axis` over which
the statistic is taken will be eliminated, and the value None will no longer be
accepted. Set `keepdims` to True or False to avoid this warning.
  mode, _ = stats.mode(_y[neigh_ind, k], axis=1)
C:\Users\leend\anaconda3\lib\site-
packages\sklearn\neighbors\_classification.py:228: FutureWarning: Unlike other
reduction functions (e.g. `skew`, `kurtosis`), the default behavior of `mode`
typically preserves the axis it acts along. In SciPy 1.11.0, this behavior will
change: the default value of `keepdims` will become False, the `axis` over which
the statistic is taken will be eliminated, and the value None will no longer be
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```

```
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change: the default value of `keepdims` will become False, the `axis` over which
the statistic is taken will be eliminated, and the value None will no longer be
accepted. Set `keepdims` to True or False to avoid this warning.
```
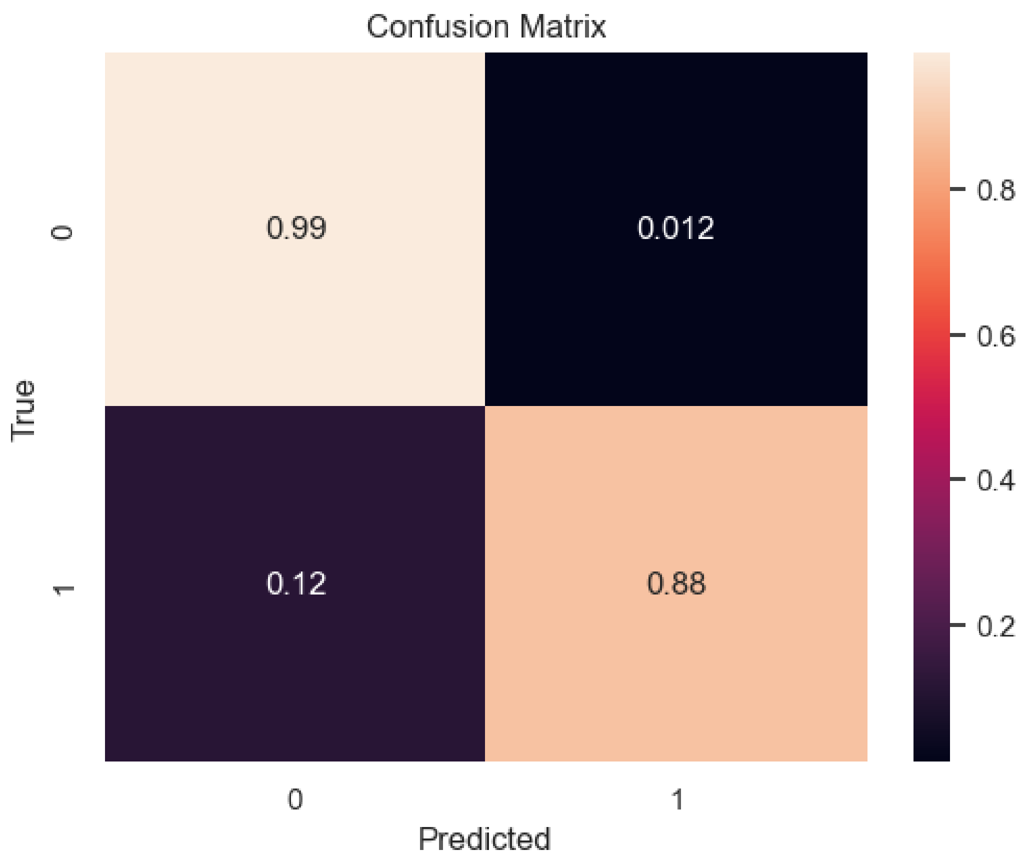

```
  mode, _ = stats.mode(_y[neigh_ind, k], axis=1)
```


```
The best accuracy was 0.9882 with k=10.
```

[22]:

```
knn_under = KNeighborsClassifier(n_neighbors=best_k)

knn_under.fit(X_rus, y_rus)

y_pred_knn_under = knn_under.predict(X_test)

report(y_pred_knn_under)
```

```
C:\Users\leend\anaconda3\lib\site-
packages\sklearn\neighbors\_classification.py:228: FutureWarning: Unlike other
reduction functions (e.g. `skew`, `kurtosis`), the default behavior of `mode`
typically preserves the axis it acts along. In SciPy 1.11.0, this behavior will
change: the default value of `keepdims` will become False, the `axis` over which
the statistic is taken will be eliminated, and the value None will no longer be
accepted. Set `keepdims` to True or False to avoid this warning.
  mode, _ = stats.mode(_y[neigh_ind, k], axis=1)

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     85291
           1       0.12      0.88      0.21       152

    accuracy                           0.99     85443
   macro avg       0.56      0.93      0.60     85443
weighted avg       1.00      0.99      0.99     85443
```



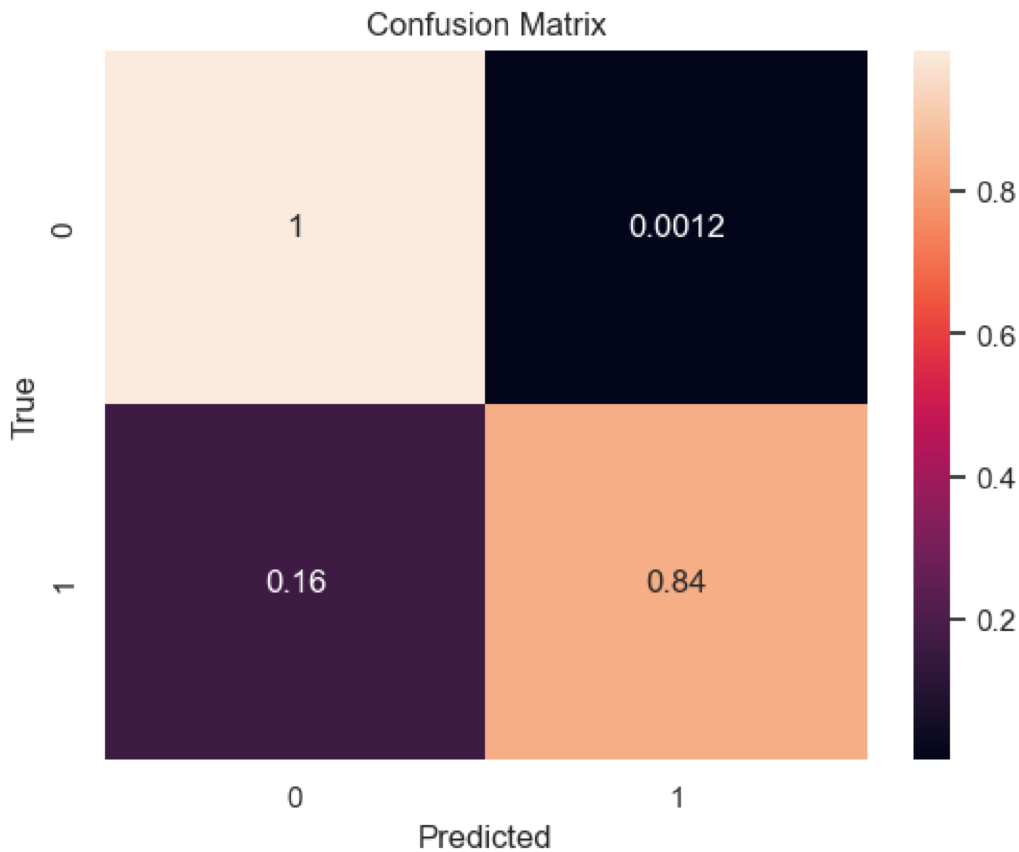

```
ROC AUC Score: 0.935
```

[24]:
```python
knn_over = KNeighborsClassifier(n_neighbors=best_k)

knn_over.fit(X_ros, y_ros)

y_pred_knn_over = knn_over.predict(X_test)

report(y_pred_knn_over)
```

```
C:\Users\leend\anaconda3\lib\site-
packages\sklearn\neighbors\_classification.py:228: FutureWarning: Unlike other
reduction functions (e.g. `skew`, `kurtosis`), the default behavior of `mode`
typically preserves the axis it acts along. In SciPy 1.11.0, this behavior will
change: the default value of `keepdims` will become False, the `axis` over which
the statistic is taken will be eliminated, and the value None will no longer be
accepted. Set `keepdims` to True or False to avoid this warning.
  mode, _ = stats.mode(_y[neigh_ind, k], axis=1)
```

```
              precision    recall  f1-score   support
```

```
              0       1.00      1.00      1.00     85291
              1       0.55      0.84      0.66       152

       accuracy                           1.00     85443
      macro avg       0.77      0.92      0.83     85443
   weighted avg       1.00      1.00      1.00     85443
```

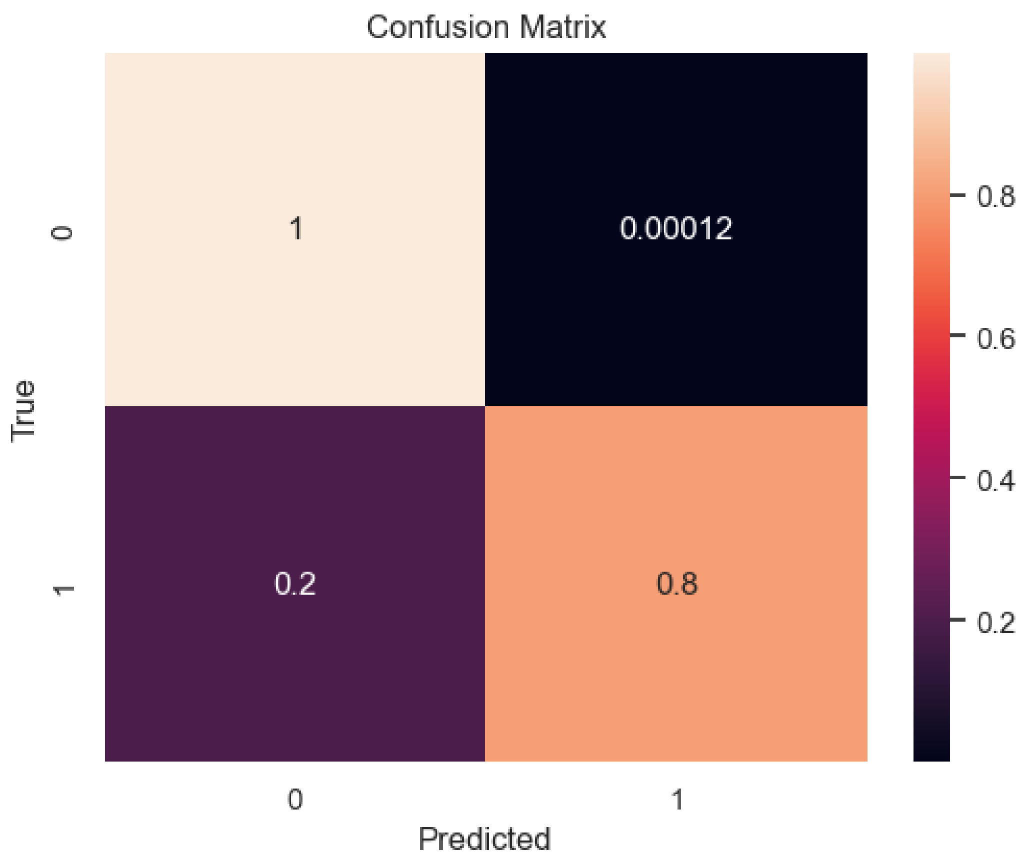



```
ROC AUC Score: 0.9204
```

[25]:

```
#XGBoost

xgb = XGBClassifier()

xgb.fit(X_train, y_train)

y_pred_xgb = xgb.predict(X_test)

report(y_pred_xgb)
```

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     85291
           1       0.92      0.80      0.86       152

    accuracy                           1.00     85443
   macro avg       0.96      0.90      0.93     85443
weighted avg       1.00      1.00      1.00     85443
```



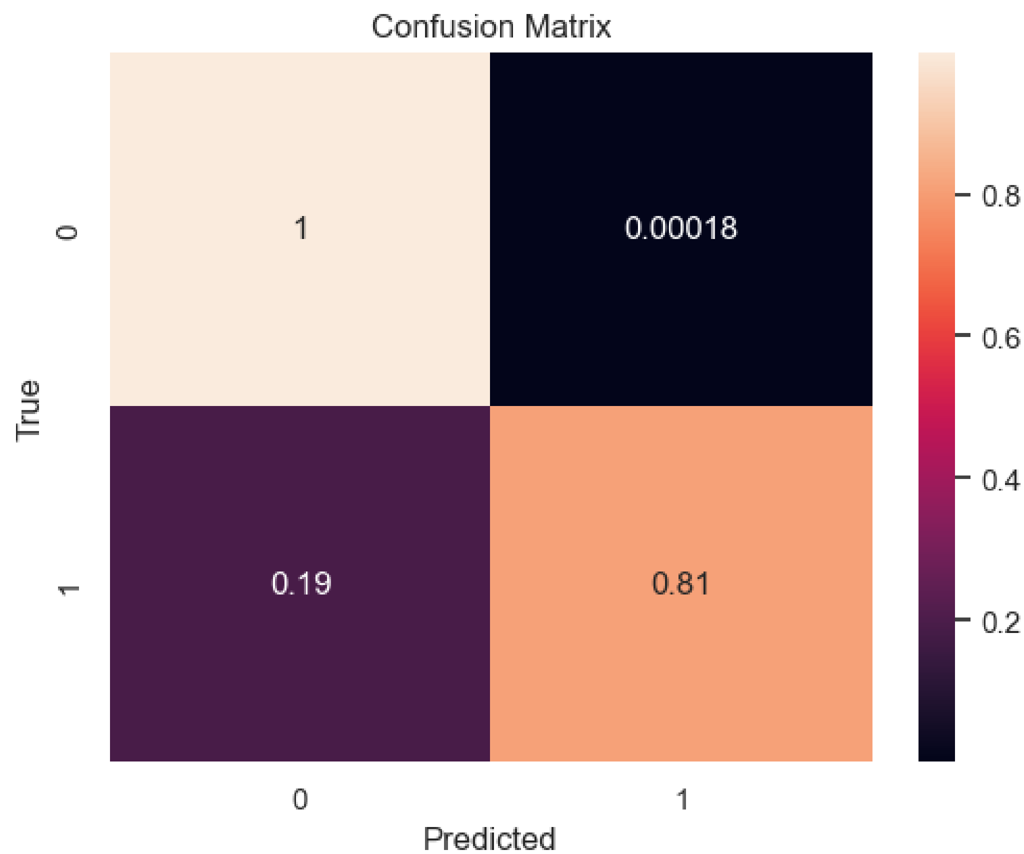

```
ROC AUC Score: 0.9013
```

[26]:

```
# Caculating the ratio
counter = Counter(y_train)
estimate = counter[0] / counter[1]

# Implementing the model
xgb = XGBClassifier(scale_pos_weight=estimate)

xgb.fit(X_train, y_train)
```

```
y_pred_xgb_scaled = xgb.predict(X_test)

report(y_pred_xgb_scaled)
```

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     85291
           1       0.89      0.81      0.85       152

    accuracy                           1.00     85443
   macro avg       0.95      0.90      0.92     85443
weighted avg       1.00      1.00      1.00     85443
```




```
ROC AUC Score: 0.9045
```

[27]:
```
#Comparing the models
summary = pd.DataFrame(data={
'labels': ['Accuracy', 'Precision', 'Recall', 'F1_score', 'roc_auc'],
```

```
'log_reg_under': [accuracy_score(y_test, y_pred_log_under),␣
 ↪precision_score(y_test, y_pred_log_under), recall_score(y_test,␣
 ↪y_pred_log_under), f1_score(y_test, y_pred_log_under), roc_auc_score(y_test,␣
 ↪y_pred_log_under)],
'log_reg_over': [accuracy_score(y_test, y_pred_log_over),␣
 ↪precision_score(y_test, y_pred_log_over), recall_score(y_test,␣
 ↪y_pred_log_over), f1_score(y_test, y_pred_log_over), roc_auc_score(y_test,␣
 ↪y_pred_log_over)],
'decision_trees_under': [accuracy_score(y_test, y_pred_tree_under),␣
 ↪precision_score(y_test, y_pred_tree_under), recall_score(y_test,␣
 ↪y_pred_tree_under), f1_score(y_test, y_pred_tree_under),␣
 ↪roc_auc_score(y_test, y_pred_tree_under)],
'decision_trees_over': [accuracy_score(y_test, y_pred_tree_over),␣
 ↪precision_score(y_test, y_pred_tree_over), recall_score(y_test,␣
 ↪y_pred_tree_over), f1_score(y_test, y_pred_tree_over), roc_auc_score(y_test,␣
 ↪y_pred_tree_over)],
'knn_under': [accuracy_score(y_test, y_pred_knn_under), precision_score(y_test,␣
 ↪y_pred_knn_under), recall_score(y_test, y_pred_knn_under), f1_score(y_test,␣
 ↪y_pred_knn_under), roc_auc_score(y_test, y_pred_knn_under)],
'knn_over': [accuracy_score(y_test, y_pred_knn_over), precision_score(y_test,␣
 ↪y_pred_knn_over), recall_score(y_test, y_pred_knn_over), f1_score(y_test,␣
 ↪y_pred_knn_over), roc_auc_score(y_test, y_pred_knn_over)],
'XGBoost': [accuracy_score(y_test, y_pred_xgb), precision_score(y_test,␣
 ↪y_pred_xgb), recall_score(y_test, y_pred_xgb), f1_score(y_test, y_pred_xgb),␣
 ↪roc_auc_score(y_test, y_pred_xgb)],
'XGBoost_scaled': [accuracy_score(y_test, y_pred_xgb_scaled),␣
 ↪precision_score(y_test, y_pred_xgb_scaled), recall_score(y_test,␣
 ↪y_pred_xgb_scaled), f1_score(y_test, y_pred_xgb_scaled),␣
 ↪roc_auc_score(y_test, y_pred_xgb_scaled)]
}).set_index('labels')
summary.index.name = None

summary
```

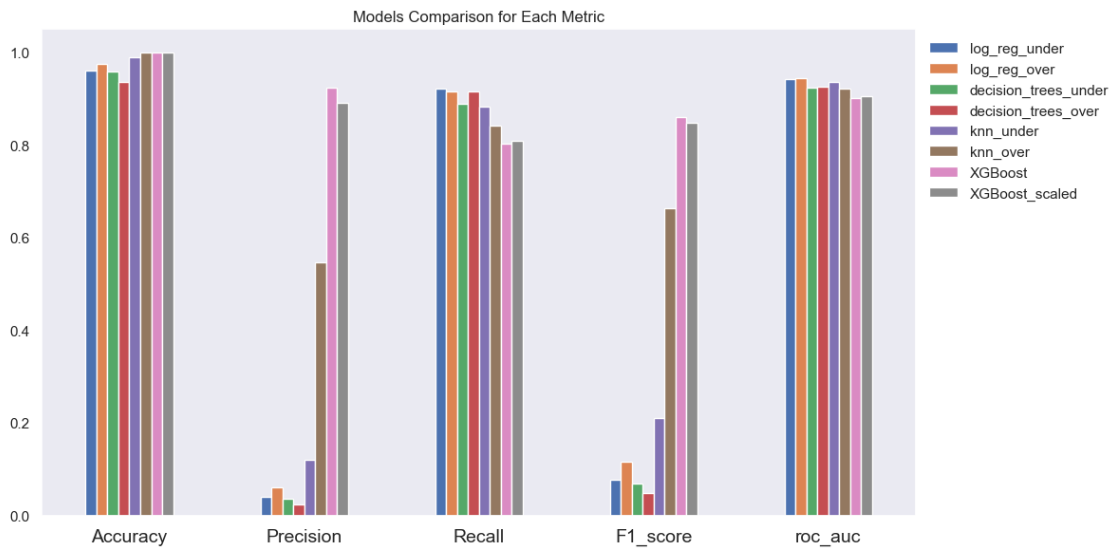
[27]:

	log_reg_under	log_reg_over	decision_trees_under	\
Accuracy	0.961167	0.975013	0.957352	
Precision	0.040627	0.061477	0.035885	
Recall	0.921053	0.914474	0.888158	
F1_score	0.077821	0.115209	0.068983	
roc_auc	0.941146	0.944797	0.922816	

	decision_trees_over	knn_under	knn_over	XGBoost	XGBoost_scaled
Accuracy	0.934588	0.988179	0.998479	0.999532	0.999485
Precision	0.024322	0.119005	0.547009	0.924242	0.891304
Recall	0.914474	0.881579	0.842105	0.802632	0.809211
F1_score	0.047384	0.209703	0.663212	0.859155	0.848276

```
roc_auc                0.924549   0.934974  0.920431  0.901257         0.904517
```

[28]:
```
fig, ax = plt.subplots(figsize=(12, 6))
summary.plot.bar(ax=ax)
ax.legend(bbox_to_anchor=(1, 1), frameon=False)
ax.grid(False)
ax.set_title('Models Comparison for Each Metric')

plt.xticks(rotation=0, fontsize=14)
plt.tight_layout()
plt.show()
```



[ ]: