AML_Homework_2_CS4090

March 2, 2022

1 Homework 2: Trees and Calibration

1.1 Instructions

Please push the .ipynb, .py, and .pdf to Github Classroom prior to the deadline. Please include your UNI as well.

Make sure to use the dataset that we provide in CourseWorks/Classroom. DO NOT download it from the link provided (It may be different).

Due Date : 03/02 (2nd March), 11:59 PM EST

1.2 Name: Chandan Suri

1.3 UNI: CS4090

1.4 The Dataset

Credit (Link | License)

The goal is to predict wins based on in match performace of multiple players. Please use this dataset and this task for all parts of the assignment.

1.4.1 Features

idLobbyGame - Categorical (The Lobby ID for the game)

idPlayer - Categorical (The ID of the player)

idRooom - Categorical (The ID of the room)

qtKill - Numerical (Number of kills)

qtAssist - Numerical (Number of Assists)

qtDeath - Numerical (Number of Deaths)

qtHs - Numerical (Number of kills by head shot)

qtBombeDefuse - Numerical (Number of Bombs Defuses)

qtBombePlant - Numerical (Number of Bomb plants)

qtTk - Numerical (Number of Team kills)

qtTkAssist - Numerical Number of team kills assists) qt1Kill - Numerical (Number of rounds with one kill)

qt2Kill - Numerical (Number of rounds with two kill)

qt3Kill - Numerical (Number of rounds with three kill)

qt4Kill - Numerical (Number of rounds with four kill)

qt5Kill - Numerical (Number of rounds with five kill)

qtPlusKill - Numerical (Number of rounds with more than one kill)

qtFirstKill - Numerical (Number of rounds with first kill)

vlDamage - Numerical (Total match Damage)

qtHits - Numerical (Total match hits)

qtShots - Numerical (Total match shots)

qtLastAlive - Numerical (Number of rounds being last alive)

qtClutchWon - Numerical (Number of total clutchs wons)

qtRoundsPlayed - Numerical (Number of total Rounds Played)

descMapName - Categorical (Map Name - de_mirage, de_inferno, de_dust2, de_vertigo, de_overpass, de_nuke, de_train, de_ancient)

vlLevel - Numerical (GC Level)

qtSurvived - Numerical (Number of rounds survived)

qtTrade - Numerical (Number of trade kills)

qtFlashAssist - Numerical (Number of flashbang assists)

qtHitHeadshot - Numerical (Number of times the player hit headshot

qtHitChest - Numerical (Number of times the player hit chest)

qtHitStomach - Numerical (Number of times the player hit stomach)

qtHitLeftAtm - Numerical (Number of times the player hit left arm)

qtHitRightArm - Numerical (Number of times the player hit right arm)

qtHitLeftLeg - Numerical (Number of times the player hit left leg)

qtHitRightLeg - Numerical (Number of times the player hit right leg)

flWinner - Winner Flag (**Target Variable**).

dtCreatedAt - Date at which this current row was added. (Date)

[1]:

```python
# Imports
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from collections import defaultdict
```

```python
import numpy as np
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.compose import make_column_transformer
from sklearn.pipeline import make_pipeline
from sklearn.tree import DecisionTreeClassifier
from sklearn import tree
from sklearn.metrics import accuracy_score
```

1.5 Question 1: Decision Trees

1.1: Load the provided dataset

[2]:
```python
game_data = pd.read_csv("tb_lobby_stats_player.csv")
game_data.head()
```

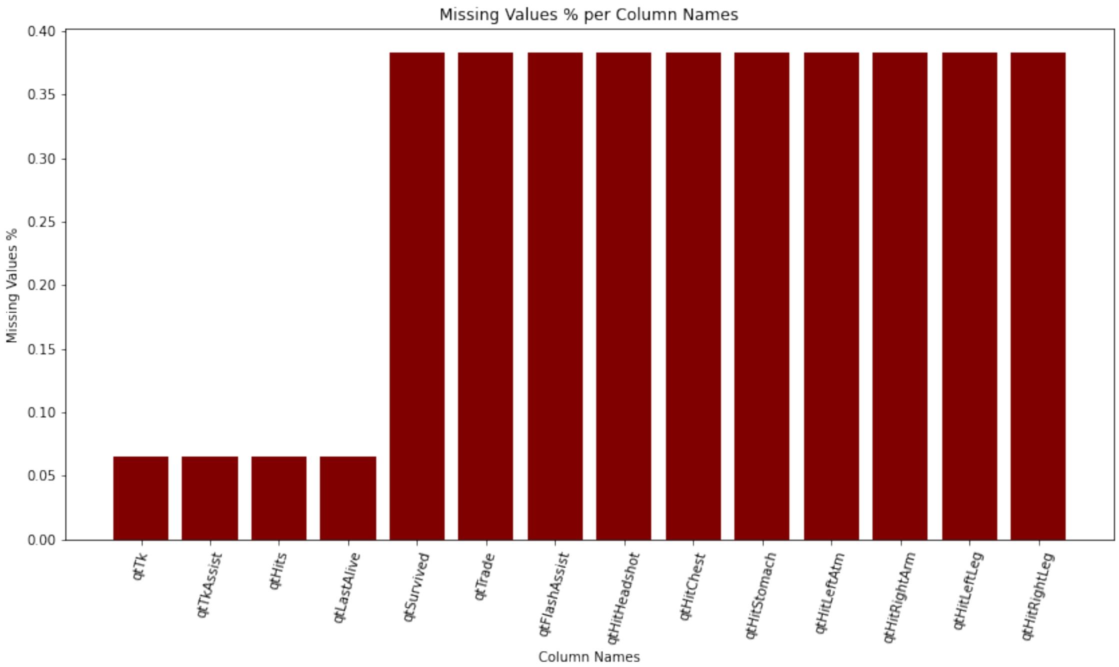
[2]:
```
   idLobbyGame  idPlayer  idRoom  …  qtHitRightLeg  flWinner
dtCreatedAt
0            1         1       1  …            0.0         0  2022-01-21
19:45:44
1            2         1       2  …            3.0         1  2022-02-04
02:09:47
2            3         2       3  …            2.0         0  2021-09-18
18:07:43
3            3       391   27508  …            6.0         1  2021-09-18
18:07:43
4            4         2       4  …            5.0         0  2021-09-27
00:17:45

[5 rows x 38 columns]
```

[3]:
```python
original_num_rows_in_game_data = len(game_data)
print(f"Number of rows in the dataset: {original_num_rows_in_game_data}")
```

```
Number of rows in the dataset: 184152
```

1.2: Plot % of missing values in each column. Would you consider dropping any columns? Assuming we want to train a decision tree, would you consider imputing the missing values? If not, why? (Remove the columns that you consider dropping - you must remove the dtCreatedAt column)

[4]:
```python
# Analyzing missing values data

'''
Returns the percentages of missing values in each of the columns in the dataset.
'''
def get_missing_value_percentages(data_df):
    col_missing_vals_percent_map = dict()
    num_rows = len(data_df)
    for col in data_df.columns:
        num_missing_vals_in_col = data_df[col].isnull().sum()
        if num_missing_vals_in_col > 0:
            col_missing_vals_percent_map[col] = (num_missing_vals_in_col/
 ↪num_rows)*100.0

    return col_missing_vals_percent_map

'''
Plots a bar chart for the missing values percentage present in the dataset.
'''
def plot_percent_missing_vals(col_missing_vals_percent_map):
    fig = plt.figure(figsize = (14, 7))
    column_names = list(col_missing_vals_percent_map.keys())
    percent_missing_vals = list(col_missing_vals_percent_map.values())
    plt.bar(column_names, percent_missing_vals, color ='maroon')

    plt.xlabel("Column Names")
    plt.ylabel("Missing Values %")
    plt.title("Missing Values % per Column Names")
    plt.xticks(rotation = 75)
    plt.show()

col_missing_vals_percent_map = get_missing_value_percentages(game_data)
plot_percent_missing_vals(col_missing_vals_percent_map)
```



Dropping Columns: 1. I will only be discarding the ID columns like “idLobbyGame”, “idPlayer”, “idRoom” and “dtCreatedAt” column as the ID columns have a lot of unique values and thus, wouldn’t contribute much to the ML algorithm being trained. Also, these are ID columns for the data and shouldn’t be trained on ideally for our use case here. Also, we drop the “dtCreatedAt” column as that’s the date of the game and wouldn’t contribute much to ML training. 2. Other than the columns above, I haven’t dropped any other columns with missing values. The main reason for this being that the percentage of missing values in any of those columns is at most (approximately 0.38%) which is really less data considering the number of rows (184152) and discarding the columns with missing values would mean a much bigger data loss than imputing/discarding the rows with missing values. Thus, I have chosen to rather keep the columns with missing values.

[5]:

```
# Remove Columns

# Remove dtCreated Column by default (most probably because it won't affect the␣
 ↪target much,
# because of no/significant corelation)
game_data.drop(["dtCreatedAt"], inplace = True, axis = 1)
```

[6]:

```
categorical_features = ["idLobbyGame", "idPlayer", "idRoom", "descMapName"]
categories_count_map = dict()
for categorical_feature in categorical_features:
    categories_count = game_data[categorical_feature].nunique()
    categories_count_map[categorical_feature] = categories_count

for feature_name, categories_num in categories_count_map.items():
    print(f"{feature_name} : {categories_num}")
```

```
idLobbyGame : 172911
idPlayer : 2469
idRoom : 178500
descMapName : 8
```

[7]:

```
categorical_features_to_drop = ["idLobbyGame", "idPlayer", "idRoom"]
game_data.drop(categorical_features_to_drop, inplace = True, axis = 1)
```

[8]:

```
game_data.dropna(subset = list(col_missing_vals_percent_map.keys()), how="any",␣
 ↪inplace=True)
```

[9]:

```
# Looking at the data after removing the columns
game_data
```

[9]:

```
      qtKill  qtAssist  qtDeath  …  qtHitLeftLeg  qtHitRightLeg  flWinner
0          5         1       16  …           1.0            0.0         0
1         24         3       18  …           1.0            3.0         1
2          6         4       23  …           0.0            2.0         0
3         10         5       20  …           6.0            6.0         1
4          8         4       26  …           2.0            5.0         0
```

```
…         …        …       …  …        …          …         …
184147    21       3      13  …      6.0        2.0         1
184148    15       1      22  …      2.0        4.0         1
184149     9       6      23  …      6.0        7.0         0
184150    15       5      20  …      3.0        6.0         0
184151    12       6      11  …      6.0        1.0         1

[183447 rows x 34 columns]
```

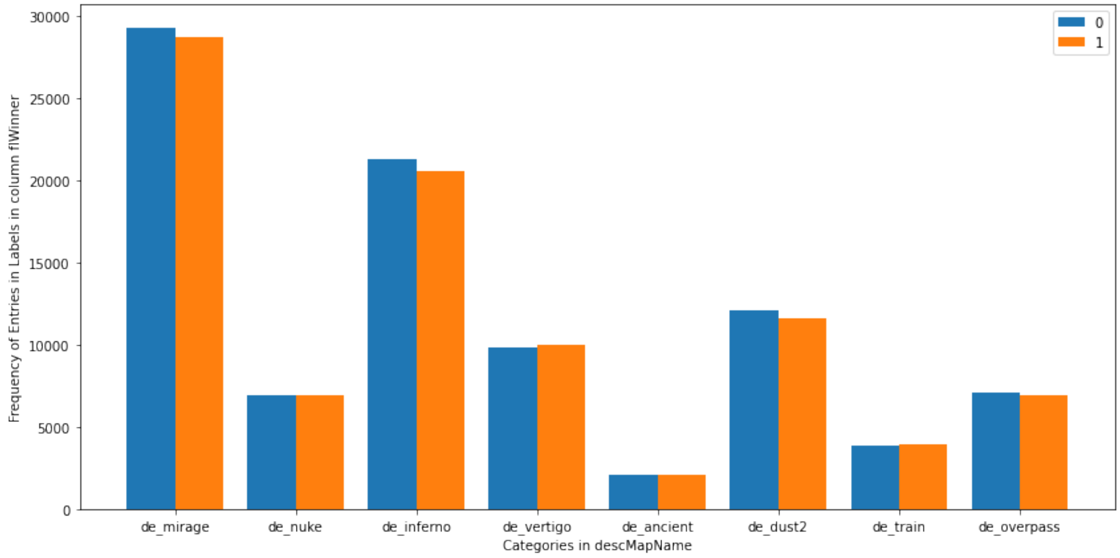
[10]:
```
num_rows_removed = original_num_rows_in_game_data - len(game_data)
print(f"Number of rows that had to be removed because of any missing values:␣
 ↪{num_rows_removed}")
print(f"Percentage of rows removed that had missing values:␣
 ↪{num_rows_removed*100/original_num_rows_in_game_data}")
```

```
Number of rows that had to be removed because of any missing values: 705
Percentage of rows removed that had missing values: 0.38283591815456797
```

As we can see above, I have decided to remove the rows with any missing values rather than imputing those values in the data that are missing. This decision is based on the fact that the percentage of rows removed (0.38%) is really less in comparison to the number of rows that we have in our dataset. Imputing our dataset just because of these small number of rows could rather introduce some imbalances in our dataset rather than help much. If the number of rows with missing values were quite high such that removing those rows would be a huge/moderate data loss, then, I would have just imputed those values. However, that's not the case here, so, I have decided to remove those rows with missing values rather than impute the values for the missing data in the original game data provided.

1.3: Plot side-by-siide bars of class distribtuion for each category for the categorical feature and the target categories.

[11]:
```
# Getting columns in different buckets
categorical_feature = "descMapName"
target_feature_name = "flWinner"
numerical_features = list(set(game_data.columns) - set([categorical_feature,␣
 ↪target_feature_name]))

# As first 3 categorical features above are IDs, we only consider the␣
 ↪"descMapName" here to visualize
data_per_category_label = game_data[[categorical_feature, target_feature_name]].
 ↪value_counts()
categories_in_feature = list(game_data[categorical_feature].unique())
categories_in_label = list(game_data[target_feature_name].unique())

def plot_chart_distribution(data_per_category_label, categories_in_feature,␣
 ↪categories_in_label):
    x_axis_data = np.arange(len(categories_in_feature))
    labels_data = defaultdict(list)
    for category in categories_in_feature:
        for label in categories_in_label:
            if label not in labels_data:
                labels_data[label] = list()
            labels_data[label].append(data_per_category_label[category][label])

    fig = plt.figure(figsize = (14, 7))
    sign = -1
    for label, label_data in labels_data.items():
        plt.bar(x_axis_data + sign * 0.2, labels_data[label], width = 0.4,␣
 ↪label = label)
        sign *= -1

    plt.xticks(x_axis_data, categories_in_feature)
    plt.xlabel(f"Categories in {categorical_feature}")
    plt.ylabel(f"Frequency of Entries in Labels in column␣
 ↪{target_feature_name}")
    plt.legend()
    plt.show()

plot_chart_distribution(data_per_category_label, categories_in_feature,␣
 ↪categories_in_label)
```



1.4: Split the data into development and test datasets. Which splitting methodology did you choose and why?

```
[12]: # Firstly I separate the labels from the feature wise data
      labels_data = game_data[target_feature_name]
      X_data = game_data.drop([target_feature_name], axis = 1)
```

```
[13]: # Analyzing the labels frequency
      game_data[target_feature_name].value_counts()
```

```
[13]: 0    92586
      1    90861
      Name: flWinner, dtype: int64
```

```
[14]: # Now I split the data using random splitting
      X_dev, X_test, y_dev, y_test = train_test_split(X_data, labels_data, test_size␣
       ↪= 0.2, random_state = 2102)
```

As we can see above, I have employed "Random splitting" methodology here. This is due to the fact that the number of rows for each of the labels (flWinner) is quite well balanced in our dataset (As shown above). Also, the data is quite well balanced w.r.t the categorical variables in our dataset. In case it wasn't balanced well w.r.t the labels, we could have employed "Stratified Splitting" but as that's not the case here, I have rather used "Random Splitting" which works like a charm. Additionally, I have used the test size to be 20% as I want to maximize the data used for training and as have quite huge dataset here, we will have decent number of rows each for the training and testing procedures.

1.5: Preprocess the data (Handle the Categorical Variable). Do we need to apply scaling? Briefly Justify

```
[15]: X_dev = pd.get_dummies(X_dev, columns = [categorical_feature])
      print(f"Dev DataSet Size: {X_dev.shape}")
      X_dev
```

```
Dev DataSet Size: (146757, 40)
```

```
[15]:         qtKill  qtAssist  …  descMapName_de_train  descMapName_de_vertigo
      84449       20         5  …                     0                       0
      165570      18         2  …                     0                       0
      6406        22         5  …                     0                       0
      131625      13         3  …                     0                       0
      18183       17         4  …                     0                       0
      …          …         …  …                     …                       …
      37503       12         2  …                     0                       0
      137044      18         7  …                     0                       0
      67003       12         4  …                     0                       0
      27861       24        10  …                     0                       0
      72246       22         2  …                     0                       0

      [146757 rows x 40 columns]
```

[16]:

```
X_test = pd.get_dummies(X_test, columns = [categorical_feature])
print(f"Test DataSet Size: {X_test.shape}")
X_test
```

```
Test DataSet Size: (36690, 40)
```

[16]:

```
        qtKill  qtAssist  …  descMapName_de_train  descMapName_de_vertigo
88852        9         0  …                     0                       0
156198      18         5  …                     0                       0
69349       14         4  …                     0                       0
21096       17         4  …                     0                       0
99334       13         4  …                     0                       1
…          …         …   …                    …                       …
19797       18         5  …                     0                       0
13350       20         4  …                     0                       0
59177       16         2  …                     0                       1
57928       22         5  …                     0                       0
26355       16         3  …                     0                       0

[36690 rows x 40 columns]
```

[17]:

```
categorical_features = list(set(X_dev.columns) - set(numerical_features))
std_scaler = StandardScaler()

# Dev data Rescaling
X_dev_scaled = pd.DataFrame(std_scaler.
 ↪fit_transform(X_dev[numerical_features]), columns = numerical_features)
X_dev_scaled.reset_index(drop = True, inplace = True)
X_dev_scaled = pd.concat([X_dev_scaled, X_dev[categorical_features].
 ↪reset_index(drop = True)], axis = 1)

# Test data Rescaling
X_test_scaled = pd.DataFrame(std_scaler.transform(X_test[numerical_features]),␣
 ↪columns = numerical_features)
X_test_scaled.reset_index(drop = True, inplace = True)
X_test_scaled = pd.concat([X_test_scaled, X_test[categorical_features].
 ↪reset_index(drop = True)], axis = 1)
```

Yes, we will need to apply scaling here. That's because some of the columns in our dataset have quite large values like "vlDamage", "qtHits", "qtShots", "qtKill", "qtRoundsPlayed", etc. The model could get biased because of these high valued features in our dataset. Also, in general, scaling the dataset and thus, normalizing it helps the ML models to train well and gives a similar level field for all the features so, that the data in the distribution can be learnt in an efficient manner. Thus, I have decided to use "Standard Scaler" here.

1.6: Fit a Decision Tree on the development data until all leaves are pure. What is the performance of the tree on the development set and test set? Provide metrics you believe are relevant and briefly justify.

[ ]:

```
dec_tree_clf = DecisionTreeClassifier(criterion = "entropy", random_state =␣
 ↪2102)
dec_tree_clf.fit(X_dev_scaled, y_dev)

print(f"Score on Dev Data: {dec_tree_clf.score(X_dev_scaled, y_dev)}")
print(f"Score on Test Data: {dec_tree_clf.score(X_test_scaled, y_test)}")
```

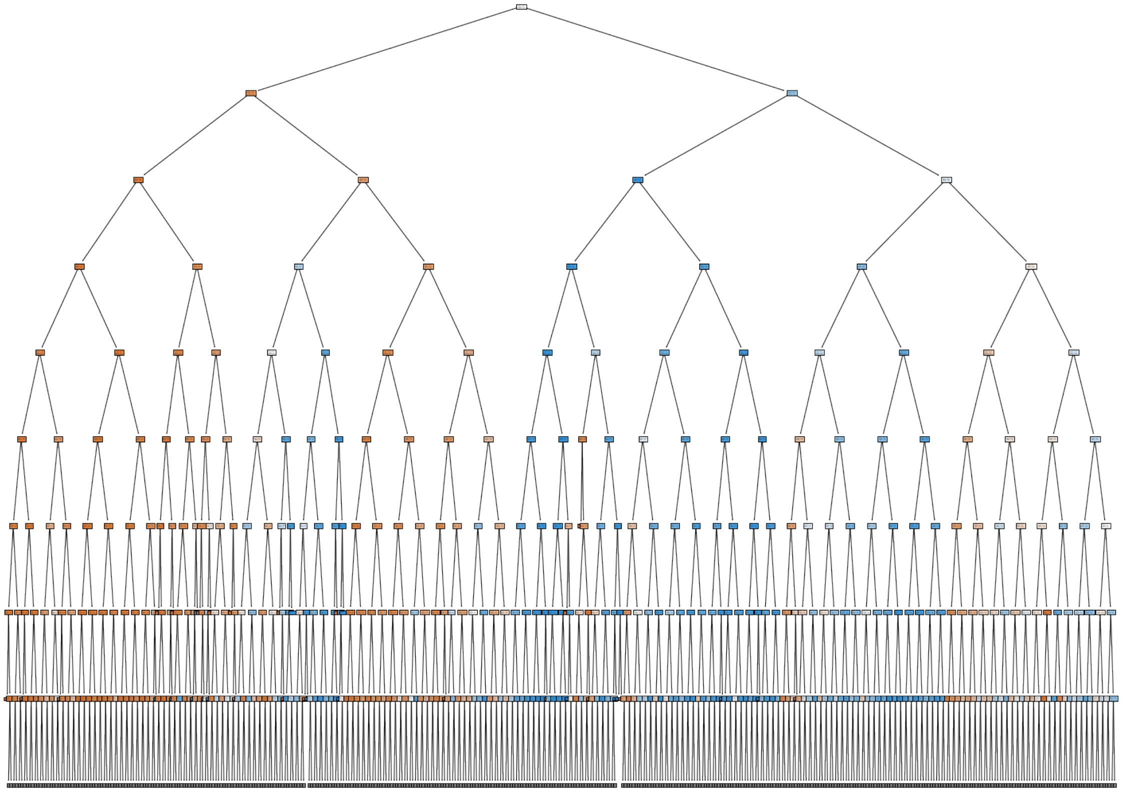
```
Score on Dev Data: 1.0
Score on Test Data: 0.730335241210139
```

As the dataset is quite well balanced here w.r.t the labels under consideration, I can easily use the “Accuracy score” metric to determine the performance of the model (Decision Tree). The “Accuracy score” will provide me with the percentage of correctly classified data which should suggest the performance of the model quite well here because of the balanced dataset and also because of the model under consideration (Decision Tree Classification).

1.7: Visualize the trained tree until the max_depth 8

[ ]:

```
fig = plt.figure(figsize=(25,20))
_ = tree.plot_tree(dec_tree_clf, max_depth = 8, filled = True)
fig.savefig("decision_tree_non_pruned_depth_8.png")
```



1.8: Prune the tree using one of the techniques discussed in class and evaluate the performance

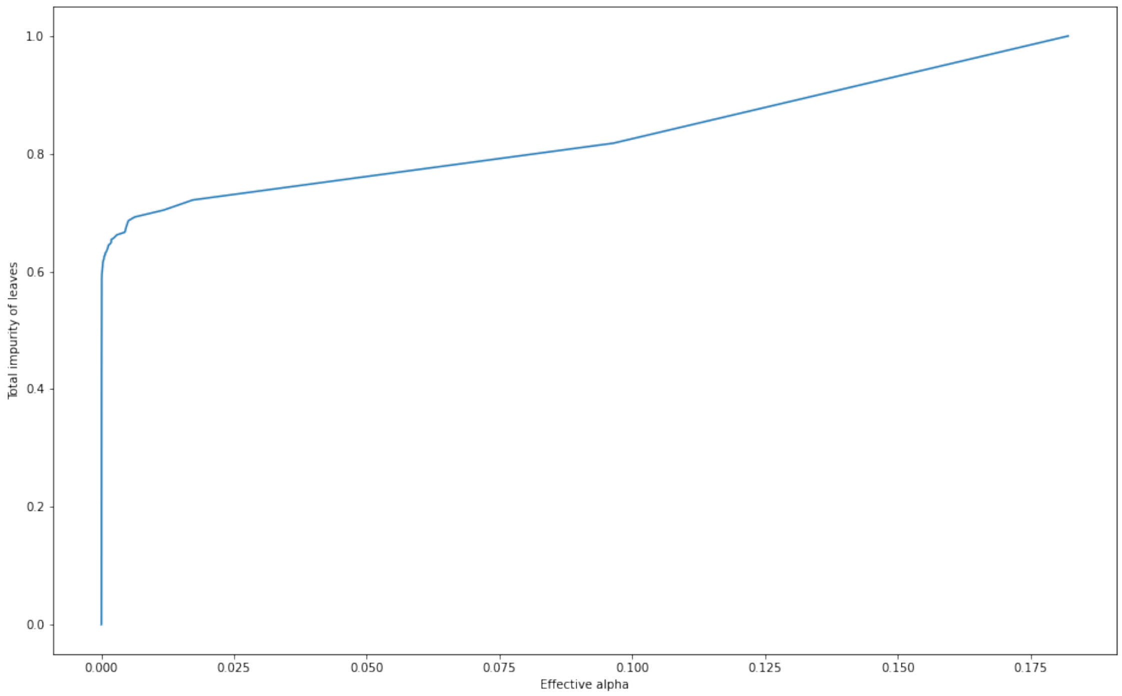
[ ]:

```
# I will try and perform a post-pruning technique - Cost Complexity Prunning␣
 ↪which is based on an alpha parameter
# Training the model and getting the range of alpha values and impurities
dec_tree_clf = DecisionTreeClassifier(criterion = "entropy", random_state =␣
 ↪2102)
dec_tree_clf.fit(X_dev_scaled, y_dev)

path = dec_tree_clf.cost_complexity_pruning_path(X_dev_scaled, y_dev)
print(f"The values of alpha and impurities are shown below:")
print(path)

print(f"The number of alpha values: {len(path['ccp_alphas'])}")
print(f"The numner of impurities' values: {len(path['impurities'])}")
```

```
The values of alpha and impurities are shown below:
{'ccp_alphas': array([0.00000000e+00, 1.22980181e-05, 1.22980181e-05, …,
       1.72398417e-02, 9.64459831e-02, 1.82112769e-01]), 'impurities':
array([0.00000000e+00, 2.45960361e-05, 4.91920723e-05, …,
       7.21378660e-01, 8.17824643e-01, 9.99937412e-01])}
The number of alpha values: 8645
The numner of impurities' values: 8645
```

[ ]:

```
# Let's visualize the relationship between alphas between impurities
fig = plt.figure(figsize=(16,10))
ccp_alphas, impurities = path.ccp_alphas, path.impurities
plt.plot(ccp_alphas, impurities)
plt.xlabel("Effective alpha")
plt.ylabel("Total impurity of leaves")
plt.show()
```



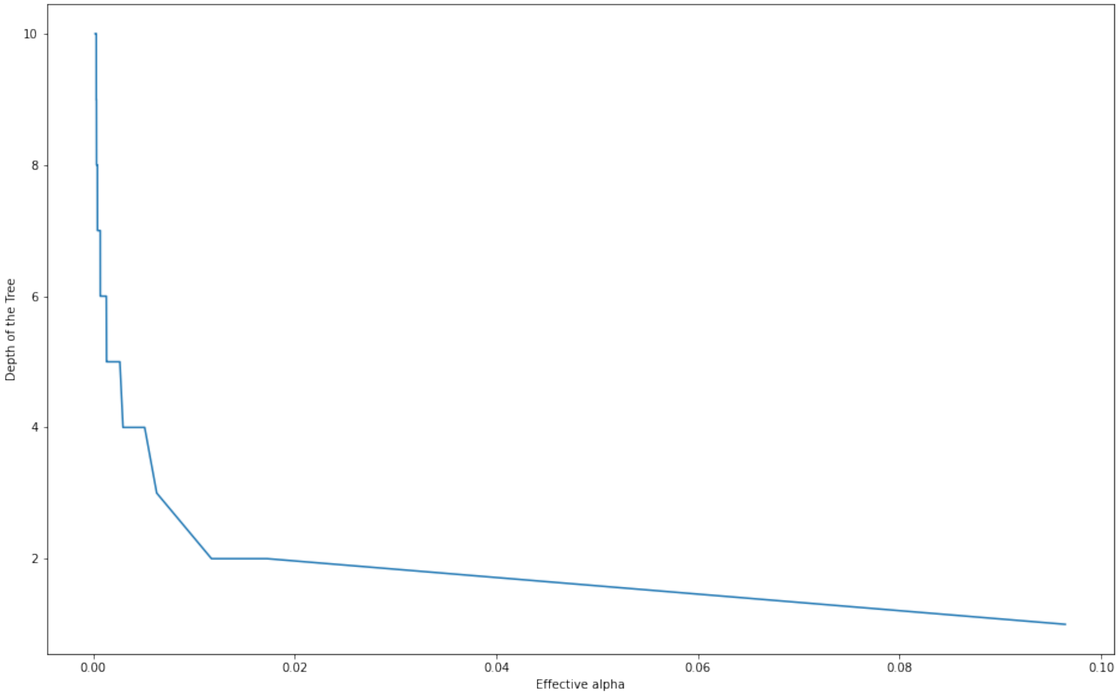
```
[ ]: # Now, we will find the optimal value of alpha (this will help us prune our tree)
     # I will only be taking the last 100 alpha values into consideration due to the computational time
     classifiers = []

     for idx, ccp_alpha in enumerate(ccp_alphas[-101:-1]):
         print(f"At the {idx} : Running for Alpha Value: {ccp_alpha}")
         dec_tree_clf = DecisionTreeClassifier(criterion = "entropy", ccp_alpha = ccp_alpha, random_state = 2102)
         dec_tree_clf.fit(X_dev_scaled, y_dev)
         classifiers.append(dec_tree_clf)

     print(f"Number of classifier trained: {len(classifiers)}")
```

```
At the 0 : Running for Alpha Value: 0.00018342773091504366
At the 1 : Running for Alpha Value: 0.00018343702898282986
At the 2 : Running for Alpha Value: 0.00018506338701328748
At the 3 : Running for Alpha Value: 0.00019095616456841005
At the 4 : Running for Alpha Value: 0.00019181838802418772
At the 5 : Running for Alpha Value: 0.00019425452384781022
At the 6 : Running for Alpha Value: 0.00019497083922229673
At the 7 : Running for Alpha Value: 0.00020136630968504293
At the 8 : Running for Alpha Value: 0.00020557010110616725
At the 9 : Running for Alpha Value: 0.0002146493782831803
At the 10 : Running for Alpha Value: 0.0002176327634655249
At the 11 : Running for Alpha Value: 0.00021925356541602214
At the 12 : Running for Alpha Value: 0.00022265058267974345
At the 13 : Running for Alpha Value: 0.00022303127246518263
At the 14 : Running for Alpha Value: 0.00022470008279738048
At the 15 : Running for Alpha Value: 0.0002272015026234149
At the 16 : Running for Alpha Value: 0.00022843458398584798
At the 17 : Running for Alpha Value: 0.0002307634615261317
At the 18 : Running for Alpha Value: 0.0002314289778917126
At the 19 : Running for Alpha Value: 0.00023218724996516837
At the 20 : Running for Alpha Value: 0.00023578720528436578
At the 21 : Running for Alpha Value: 0.0002363012430072666
At the 22 : Running for Alpha Value: 0.0002381433720930956
At the 23 : Running for Alpha Value: 0.00023937245683555014
At the 24 : Running for Alpha Value: 0.00024115758651090287
At the 25 : Running for Alpha Value: 0.0002480883611120574
At the 26 : Running for Alpha Value: 0.00024829579055573973
At the 27 : Running for Alpha Value: 0.00025012010678151717
At the 28 : Running for Alpha Value: 0.0002637229804582416
At the 29 : Running for Alpha Value: 0.00026463647020629096
At the 30 : Running for Alpha Value: 0.0002677702022937014
At the 31 : Running for Alpha Value: 0.0002720441694330708
At the 32 : Running for Alpha Value: 0.00027518781097115533
At the 33 : Running for Alpha Value: 0.0002778515790458455
At the 34 : Running for Alpha Value: 0.00028073122731391703
At the 35 : Running for Alpha Value: 0.00028468233297664243
At the 36 : Running for Alpha Value: 0.0002848915075214318
At the 37 : Running for Alpha Value: 0.0002868672795662622
At the 38 : Running for Alpha Value: 0.00029756340288856174
At the 39 : Running for Alpha Value: 0.00030110937168389973
At the 40 : Running for Alpha Value: 0.00030222940657249116
At the 41 : Running for Alpha Value: 0.00031066337385583787
At the 42 : Running for Alpha Value: 0.0003117981232336215
At the 43 : Running for Alpha Value: 0.00031745183292586354
At the 44 : Running for Alpha Value: 0.00031760771428736984
At the 45 : Running for Alpha Value: 0.00034270103828519874
At the 46 : Running for Alpha Value: 0.0003438806520745883
At the 47 : Running for Alpha Value: 0.0003440322556685499
At the 48 : Running for Alpha Value: 0.00035536019431029603
At the 49 : Running for Alpha Value: 0.00038958571393235206
At the 50 : Running for Alpha Value: 0.0003941804926304174
At the 51 : Running for Alpha Value: 0.00040091661746538554
At the 52 : Running for Alpha Value: 0.00040223131766743605
At the 53 : Running for Alpha Value: 0.00045726466000730465
At the 54 : Running for Alpha Value: 0.0004731760449580777
At the 55 : Running for Alpha Value: 0.00048542490165692787
At the 56 : Running for Alpha Value: 0.000498540901733238
At the 57 : Running for Alpha Value: 0.000500716778091749
At the 58 : Running for Alpha Value: 0.000502370708810318
At the 59 : Running for Alpha Value: 0.0005032404353842931
At the 60 : Running for Alpha Value: 0.0005125485114022207
At the 61 : Running for Alpha Value: 0.0005209609257594856
At the 62 : Running for Alpha Value: 0.0005316041793834575
At the 63 : Running for Alpha Value: 0.0005363964347806956
At the 64 : Running for Alpha Value: 0.000577728599825994
At the 65 : Running for Alpha Value: 0.0005817308875466984
At the 66 : Running for Alpha Value: 0.0006768706734439564
At the 67 : Running for Alpha Value: 0.0006817147477588062
At the 68 : Running for Alpha Value: 0.0007172472366224932
At the 69 : Running for Alpha Value: 0.000726883487826957
At the 70 : Running for Alpha Value: 0.000731285289682946
At the 71 : Running for Alpha Value: 0.000732677741213307
At the 72 : Running for Alpha Value: 0.0007690569976762547
At the 73 : Running for Alpha Value: 0.0008480840827089116
At the 74 : Running for Alpha Value: 0.0009351880263272806
At the 75 : Running for Alpha Value: 0.0009830754332438088
At the 76 : Running for Alpha Value: 0.0010204340645042238
At the 77 : Running for Alpha Value: 0.0010836307072093487
At the 78 : Running for Alpha Value: 0.0011179805969821922
At the 79 : Running for Alpha Value: 0.0011648489707082321
At the 80 : Running for Alpha Value: 0.0012277859509776806
At the 81 : Running for Alpha Value: 0.0012790565805599948
At the 82 : Running for Alpha Value: 0.0013036761052913903
At the 83 : Running for Alpha Value: 0.0013094994346635955
At the 84 : Running for Alpha Value: 0.0014143026255295649
At the 85 : Running for Alpha Value: 0.0016535065758256679
At the 86 : Running for Alpha Value: 0.001807798724658527
At the 87 : Running for Alpha Value: 0.0018688024600281503
At the 88 : Running for Alpha Value: 0.001868854457021625
At the 89 : Running for Alpha Value: 0.0018786093501987622
At the 90 : Running for Alpha Value: 0.002321433397675786
At the 91 : Running for Alpha Value: 0.0026256287866670835
At the 92 : Running for Alpha Value: 0.00293617488551582
At the 93 : Running for Alpha Value: 0.004427690346443761
At the 94 : Running for Alpha Value: 0.004701389279076901
At the 95 : Running for Alpha Value: 0.005087480218589971
At the 96 : Running for Alpha Value: 0.00628081126651453
At the 97 : Running for Alpha Value: 0.011721073416441075
At the 98 : Running for Alpha Value: 0.0172398416515058
At the 99 : Running for Alpha Value: 0.09644598308120511
Number of classifier trained: 100
```

[ ]:

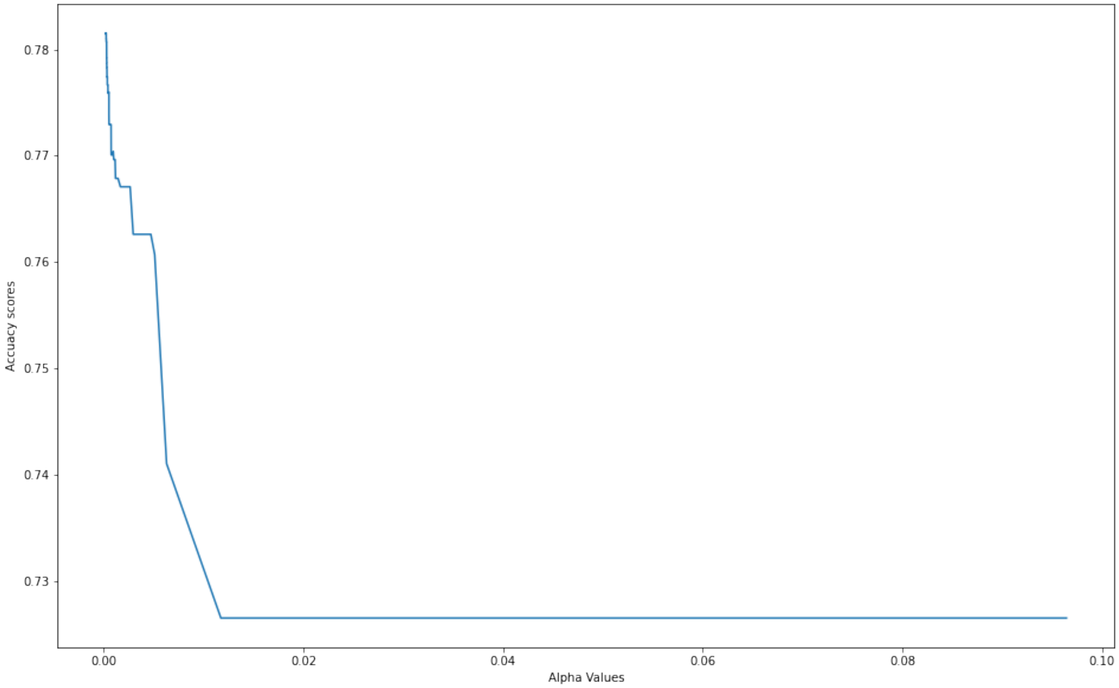
```
# Finding relationship between tree depth and alpha
tree_depths = [classifier.tree_.max_depth for classifier in classifiers]
fig = plt.figure(figsize=(16,10))
```

```
plt.plot(ccp_alphas[-101:-1], tree_depths)
plt.xlabel("Effective alpha")
plt.ylabel("Depth of the Tree")
plt.show()
```



[ ]:

```
# Finding relationship between alpha and accuracy
acc_scores = [accuracy_score(y_test, classifer.predict(X_test_scaled)) for␣
 ↪classifer in classifiers]
fig = plt.figure(figsize=(16,10))
plt.plot(ccp_alphas[-101:-1], acc_scores)
plt.xlabel("Alpha Values")
plt.ylabel("Accuacy scores")
plt.show()
```



```
[ ]: # Now let's get the exact value of alpha at which we get the best accuracy
     # I am taking last 100 alphas going forward to get better insights (not taking␣
      ↪more due to high computational time)
     best_ccp_alpha = float("-inf")
     best_max_depth = float("-inf")
     highest_score = float("-inf")
     for ccp_alpha, max_depth, score in zip(ccp_alphas[-101:-1], tree_depths,␣
      ↪acc_scores):
         if score > highest_score:
             best_ccp_alpha = ccp_alpha
             best_max_depth = max_depth
             highest_score = score

     print(f"I get the highest score {highest_score} at Max depth: {best_max_depth}␣
      ↪and Alpha value: {best_ccp_alpha}")
```

```
I get the highest score 0.7815208503679477 at Max depth: 10 and Alpha value:
0.00019425452384781022
```

```
[ ]: # Now we will apply the optimal max depth and alpha
     # on the decision tree classifier in order to get the pruned tree.
     dec_tree_clf_pruned = DecisionTreeClassifier(criterion = "entropy", \
                                                  max_depth = best_max_depth, \
                                                  ccp_alpha = best_ccp_alpha, \
                                                  random_state = 2102)
```

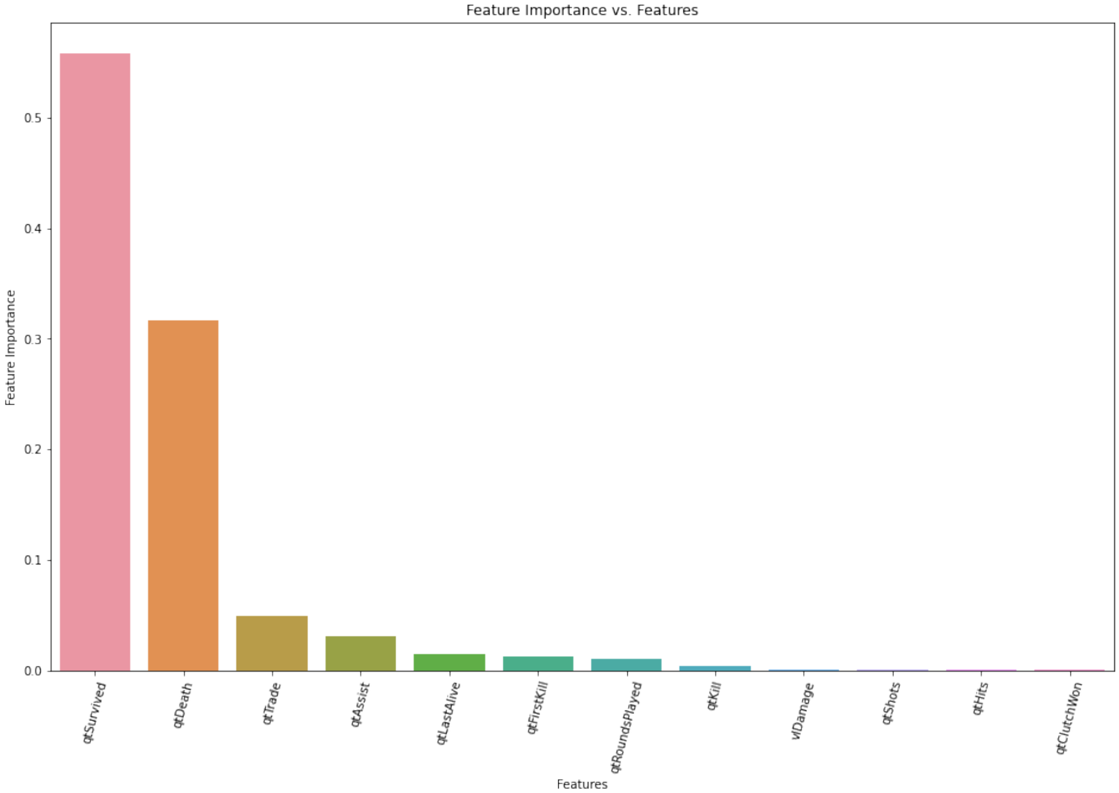
```
dec_tree_clf_pruned.fit(X_dev_scaled, y_dev)

print(f"Score on Dev Data: {dec_tree_clf_pruned.score(X_dev_scaled, y_dev)}")
print(f"Score on Test Data: {dec_tree_clf_pruned.score(X_test_scaled, y_test)}")
```

```
Score on Dev Data: 0.7857001710310241
Score on Test Data: 0.7815208503679477
```

The performance of the model here (Decision Tree Classification) after pruning is better in comparison to when there were no restrictions on the maximum depth of the tree allowed and the value of alpha. Although the accuracy score on the development data might have decreased by a lot (from 100% to 78.5%) but the accuracy on the testing data has increased by more than 5% which shows that we were overfitting the data before. As overfitting the dataset is problematic, we want our model to be balanced w.r.t the specialization and the generalization. This is achieved well after we prune the tree in order to achieve the maximized accuracy score on the test data as well as the development dataset.

1.9: List the top 3 most important features for this trained tree? How would you justify these features being the most important?

```
[ ]: import warnings
     warnings.filterwarnings("ignore")

     feature_names = list(X_dev_scaled.columns)
     feature_importances = dec_tree_clf_pruned.feature_importances_
     feature_importances_map = zip(feature_names, feature_importances)
     sorted_feat_names, sorted_feat_importances = zip(*(sorted(list\
                                                     (filter(lambda x: x[1] !=␣
      ↪0, feature_importances_map)),\
                                                     key = lambda x: x[1],␣
      ↪reverse = True)))

     fig = plt.figure(figsize=(16,10))
     ax = sns.barplot(list(sorted_feat_names), list(sorted_feat_importances))
     ax.set_xlabel("Features")
     ax.set_ylabel("Feature Importance")
     ax.set_title("Feature Importance vs. Features")
     ax.tick_params(axis = 'x', rotation = 75)
```



The top 3 most important features are as follows as shown above: 1. qtSurvived 2. dtDeath 3. qtTrade

Reasons: 1. qtSurvived: As this feature signifies the number of survived rounds in the game, it is directly correlated with the probability that the game would be won or lost. As higher the number of survival, higher the probability of survivavbility in the game which would directly suggest the probability of winning the game and vice-versa, it makes complete logical sense for this feature being a highly important one for determing the winner of the game (flWinner: label of the dataset). 2. dtDeath: As this feature signifies the number of deaths in the game, it is directly related in determing the label or winner of the game under consideration. For instance, if the number of deaths are higher in a game, that would mean that the probability of winning would be less and vice-versa could be a correlation between the two. Thus, having this feature as a highly important one makes complete logical sense to me for determing the winner (label) of the game. 3. qtTrade: This feature signifies the number of trade kills in a game. This is a well-known strategy in combat games and is used a lot to win. This signifies the number of kills that a player makes on behalf of losing one of the teammates so, that the team can win the game. As this seems highly correlated in determining the winner of the game, it makes complete logical sense to me to have this feature as one of the most important features in our dataset in order to determine the label.

1.6 Question 2: Random Forests

[18]:

```
# Additional Imports for this section
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import plot_confusion_matrix
```

2.1: Train a Random Forest model on the development dataset using RandomForestClassifier class in sklearn. Use the default parameters. Evaluate the performance of the model on test dataset. Does this perform better than Decision Tree on the test dataset (compare to results in Q 1.6)?

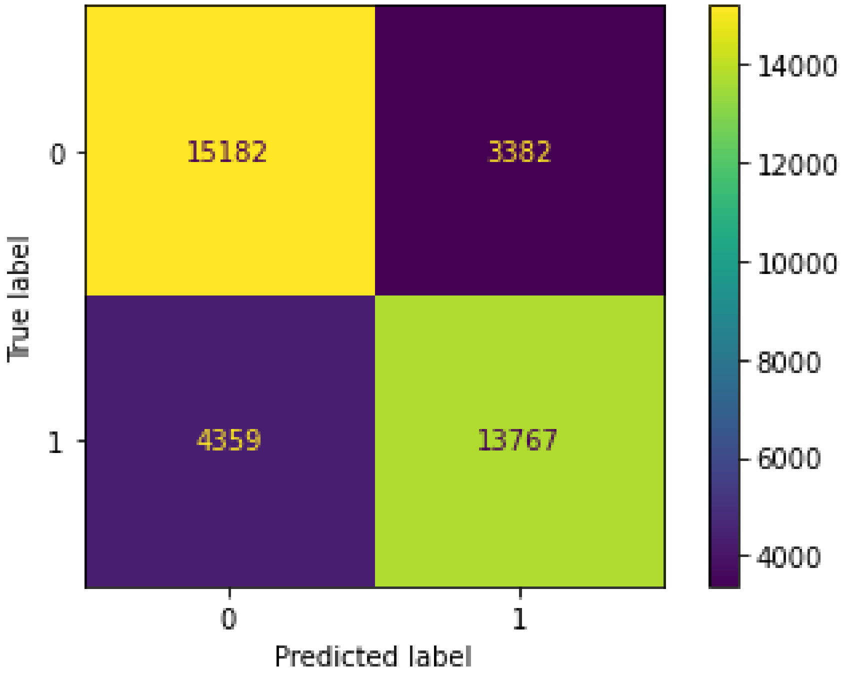
[ ]:

```
random_forest_classifier = RandomForestClassifier(random_state = 2102)
random_forest_classifier.fit(X_dev_scaled, y_dev)

print("For Random Forest Classifier: ")
print(f"Score on Dev Data: {random_forest_classifier.score(X_dev_scaled,␣
 ↪y_dev)}")
print(f"Score on Test Data: {random_forest_classifier.score(X_test_scaled,␣
 ↪y_test)}")

plot_confusion_matrix(random_forest_classifier, X_test_scaled, y_test)
```

```
For Random Forest Classifier:
Score on Dev Data: 0.9999931860149771
Score on Test Data: 0.7890160806759335
```

[ ]:

```
<sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at
0x7f8e22b48f10>
```



Performance Comparison: Firstly, in comparison to the performance of the unpruned decision tree model, the random forest model performs quite well as the accuracy score on the test data is nearly 6% higher than the accuracy score of the decision tree model (in Q1.6). Secondly, the performance of the random forest classifier on the test dataset is quite good (78.9%). Also, by looking at the confusion matrix for the test dataset, we can say that the model performs quite well both in terms of true positives and true negatives. Although we can see that there is a huge number of false positives and false negatives for the trained random forest model, still it performs a lot better in comparison to the decision tree classifier.

2.2: Does all trees in the trained random forest model have pure leaves? How would you verify this?

[ ]:
```
total_num_leaves = 0
total_num_pure_leaves = 0
total_num_impure_leaves = 0

for estimator_idx, estimator in enumerate(random_forest_classifier.estimators_):
    num_leaves = 0
    num_pure_leaves = 0
    tree = estimator.tree_
    num_nodes = tree.node_count
    impurities = tree.impurity

    for node_idx in range(num_nodes):
        if tree.children_left[node_idx] != -1 or tree.children_right[node_idx] !
 ↪= -1:
            continue
        num_leaves += 1
        if impurities[node_idx] == 0:
            num_pure_leaves += 1

    num_impure_leaves = num_leaves - num_pure_leaves
    total_num_leaves += num_leaves
    total_num_pure_leaves += num_pure_leaves
    total_num_impure_leaves += num_impure_leaves

    print(f"For estimator {estimator_idx}:")
    print(f"#Leaves: {num_leaves}, #Pure Leaves: {num_pure_leaves}, #Impure␣
 ↪Leaves: {num_impure_leaves}")

print("\n")
print(f"For all the estimators:")
print(f"#Leaves: {total_num_leaves}")
print(f"#Pure Leaves: {total_num_pure_leaves}, #Impure Leaves:␣
 ↪{total_num_impure_leaves}")
```

```
For estimator 0:
#Leaves: 20785, #Pure Leaves: 20785, #Impure Leaves: 0
For estimator 1:
#Leaves: 20351, #Pure Leaves: 20351, #Impure Leaves: 0
For estimator 2:
#Leaves: 20423, #Pure Leaves: 20423, #Impure Leaves: 0
For estimator 3:
#Leaves: 19585, #Pure Leaves: 19585, #Impure Leaves: 0
For estimator 4:
#Leaves: 20147, #Pure Leaves: 20147, #Impure Leaves: 0
For estimator 5:
#Leaves: 20055, #Pure Leaves: 20055, #Impure Leaves: 0
For estimator 6:
#Leaves: 20279, #Pure Leaves: 20279, #Impure Leaves: 0
For estimator 7:
#Leaves: 20509, #Pure Leaves: 20509, #Impure Leaves: 0
For estimator 8:
#Leaves: 20393, #Pure Leaves: 20393, #Impure Leaves: 0
For estimator 9:
#Leaves: 20323, #Pure Leaves: 20323, #Impure Leaves: 0
For estimator 10:
#Leaves: 20064, #Pure Leaves: 20064, #Impure Leaves: 0
For estimator 11:
#Leaves: 21225, #Pure Leaves: 21225, #Impure Leaves: 0
For estimator 12:
```

```
#Leaves: 20446, #Pure Leaves: 20446, #Impure Leaves: 0
For estimator 13:
#Leaves: 20159, #Pure Leaves: 20159, #Impure Leaves: 0
For estimator 14:
#Leaves: 20417, #Pure Leaves: 20417, #Impure Leaves: 0
For estimator 15:
#Leaves: 19765, #Pure Leaves: 19765, #Impure Leaves: 0
For estimator 16:
#Leaves: 19860, #Pure Leaves: 19860, #Impure Leaves: 0
For estimator 17:
#Leaves: 20571, #Pure Leaves: 20571, #Impure Leaves: 0
For estimator 18:
#Leaves: 19623, #Pure Leaves: 19623, #Impure Leaves: 0
For estimator 19:
#Leaves: 20642, #Pure Leaves: 20642, #Impure Leaves: 0
For estimator 20:
#Leaves: 20636, #Pure Leaves: 20636, #Impure Leaves: 0
For estimator 21:
#Leaves: 19770, #Pure Leaves: 19770, #Impure Leaves: 0
For estimator 22:
#Leaves: 20256, #Pure Leaves: 20256, #Impure Leaves: 0
For estimator 23:
#Leaves: 20149, #Pure Leaves: 20149, #Impure Leaves: 0
For estimator 24:
#Leaves: 19890, #Pure Leaves: 19890, #Impure Leaves: 0
For estimator 25:
#Leaves: 19848, #Pure Leaves: 19848, #Impure Leaves: 0
For estimator 26:
#Leaves: 19877, #Pure Leaves: 19877, #Impure Leaves: 0
For estimator 27:
#Leaves: 20141, #Pure Leaves: 20141, #Impure Leaves: 0
For estimator 28:
#Leaves: 20491, #Pure Leaves: 20491, #Impure Leaves: 0
For estimator 29:
#Leaves: 20192, #Pure Leaves: 20192, #Impure Leaves: 0
For estimator 30:
#Leaves: 20853, #Pure Leaves: 20853, #Impure Leaves: 0
For estimator 31:
#Leaves: 20451, #Pure Leaves: 20451, #Impure Leaves: 0
For estimator 32:
#Leaves: 20526, #Pure Leaves: 20526, #Impure Leaves: 0
For estimator 33:
#Leaves: 20441, #Pure Leaves: 20441, #Impure Leaves: 0
For estimator 34:
#Leaves: 20406, #Pure Leaves: 20406, #Impure Leaves: 0
For estimator 35:
#Leaves: 20609, #Pure Leaves: 20609, #Impure Leaves: 0
For estimator 36:
```

```
#Leaves: 20495, #Pure Leaves: 20495, #Impure Leaves: 0
For estimator 37:
#Leaves: 19760, #Pure Leaves: 19760, #Impure Leaves: 0
For estimator 38:
#Leaves: 19648, #Pure Leaves: 19648, #Impure Leaves: 0
For estimator 39:
#Leaves: 20275, #Pure Leaves: 20275, #Impure Leaves: 0
For estimator 40:
#Leaves: 20532, #Pure Leaves: 20532, #Impure Leaves: 0
For estimator 41:
#Leaves: 20318, #Pure Leaves: 20318, #Impure Leaves: 0
For estimator 42:
#Leaves: 19904, #Pure Leaves: 19904, #Impure Leaves: 0
For estimator 43:
#Leaves: 21019, #Pure Leaves: 21019, #Impure Leaves: 0
For estimator 44:
#Leaves: 20894, #Pure Leaves: 20894, #Impure Leaves: 0
For estimator 45:
#Leaves: 20556, #Pure Leaves: 20556, #Impure Leaves: 0
For estimator 46:
#Leaves: 20976, #Pure Leaves: 20976, #Impure Leaves: 0
For estimator 47:
#Leaves: 19886, #Pure Leaves: 19886, #Impure Leaves: 0
For estimator 48:
#Leaves: 20263, #Pure Leaves: 20263, #Impure Leaves: 0
For estimator 49:
#Leaves: 21101, #Pure Leaves: 21101, #Impure Leaves: 0
For estimator 50:
#Leaves: 20490, #Pure Leaves: 20490, #Impure Leaves: 0
For estimator 51:
#Leaves: 20400, #Pure Leaves: 20400, #Impure Leaves: 0
For estimator 52:
#Leaves: 20658, #Pure Leaves: 20658, #Impure Leaves: 0
For estimator 53:
#Leaves: 20196, #Pure Leaves: 20196, #Impure Leaves: 0
For estimator 54:
#Leaves: 21048, #Pure Leaves: 21048, #Impure Leaves: 0
For estimator 55:
#Leaves: 19955, #Pure Leaves: 19955, #Impure Leaves: 0
For estimator 56:
#Leaves: 20183, #Pure Leaves: 20183, #Impure Leaves: 0
For estimator 57:
#Leaves: 19898, #Pure Leaves: 19898, #Impure Leaves: 0
For estimator 58:
#Leaves: 19919, #Pure Leaves: 19919, #Impure Leaves: 0
For estimator 59:
#Leaves: 20853, #Pure Leaves: 20853, #Impure Leaves: 0
For estimator 60:
```

```
#Leaves: 20189, #Pure Leaves: 20189, #Impure Leaves: 0
For estimator 61:
#Leaves: 19939, #Pure Leaves: 19939, #Impure Leaves: 0
For estimator 62:
#Leaves: 20161, #Pure Leaves: 20161, #Impure Leaves: 0
For estimator 63:
#Leaves: 20387, #Pure Leaves: 20387, #Impure Leaves: 0
For estimator 64:
#Leaves: 20221, #Pure Leaves: 20221, #Impure Leaves: 0
For estimator 65:
#Leaves: 20552, #Pure Leaves: 20552, #Impure Leaves: 0
For estimator 66:
#Leaves: 19512, #Pure Leaves: 19512, #Impure Leaves: 0
For estimator 67:
#Leaves: 20401, #Pure Leaves: 20401, #Impure Leaves: 0
For estimator 68:
#Leaves: 20399, #Pure Leaves: 20399, #Impure Leaves: 0
For estimator 69:
#Leaves: 20319, #Pure Leaves: 20319, #Impure Leaves: 0
For estimator 70:
#Leaves: 19835, #Pure Leaves: 19835, #Impure Leaves: 0
For estimator 71:
#Leaves: 19906, #Pure Leaves: 19906, #Impure Leaves: 0
For estimator 72:
#Leaves: 19722, #Pure Leaves: 19722, #Impure Leaves: 0
For estimator 73:
#Leaves: 19810, #Pure Leaves: 19810, #Impure Leaves: 0
For estimator 74:
#Leaves: 20545, #Pure Leaves: 20545, #Impure Leaves: 0
For estimator 75:
#Leaves: 20288, #Pure Leaves: 20288, #Impure Leaves: 0
For estimator 76:
#Leaves: 19969, #Pure Leaves: 19969, #Impure Leaves: 0
For estimator 77:
#Leaves: 20568, #Pure Leaves: 20568, #Impure Leaves: 0
For estimator 78:
#Leaves: 20176, #Pure Leaves: 20176, #Impure Leaves: 0
For estimator 79:
#Leaves: 20396, #Pure Leaves: 20396, #Impure Leaves: 0
For estimator 80:
#Leaves: 20602, #Pure Leaves: 20602, #Impure Leaves: 0
For estimator 81:
#Leaves: 19656, #Pure Leaves: 19656, #Impure Leaves: 0
For estimator 82:
#Leaves: 19792, #Pure Leaves: 19792, #Impure Leaves: 0
For estimator 83:
#Leaves: 19530, #Pure Leaves: 19530, #Impure Leaves: 0
For estimator 84:
```

```
#Leaves: 20076, #Pure Leaves: 20076, #Impure Leaves: 0
For estimator 85:
#Leaves: 20362, #Pure Leaves: 20362, #Impure Leaves: 0
For estimator 86:
#Leaves: 20399, #Pure Leaves: 20399, #Impure Leaves: 0
For estimator 87:
#Leaves: 20807, #Pure Leaves: 20807, #Impure Leaves: 0
For estimator 88:
#Leaves: 19733, #Pure Leaves: 19733, #Impure Leaves: 0
For estimator 89:
#Leaves: 20372, #Pure Leaves: 20372, #Impure Leaves: 0
For estimator 90:
#Leaves: 20406, #Pure Leaves: 20406, #Impure Leaves: 0
For estimator 91:
#Leaves: 20792, #Pure Leaves: 20792, #Impure Leaves: 0
For estimator 92:
#Leaves: 20316, #Pure Leaves: 20316, #Impure Leaves: 0
For estimator 93:
#Leaves: 20750, #Pure Leaves: 20750, #Impure Leaves: 0
For estimator 94:
#Leaves: 20498, #Pure Leaves: 20498, #Impure Leaves: 0
For estimator 95:
#Leaves: 20545, #Pure Leaves: 20545, #Impure Leaves: 0
For estimator 96:
#Leaves: 19793, #Pure Leaves: 19793, #Impure Leaves: 0
For estimator 97:
#Leaves: 19978, #Pure Leaves: 19978, #Impure Leaves: 0
For estimator 98:
#Leaves: 20404, #Pure Leaves: 20404, #Impure Leaves: 0
For estimator 99:
#Leaves: 20018, #Pure Leaves: 20018, #Impure Leaves: 0


For all the estimators:
#Leaves: 2027509
#Pure Leaves: 2027509, #Impure Leaves: 0
```

As shown above, we can see that all the trees in the trained random forest classifier model have pure leaves. There are no impure leaves to be found. Also, this verification was done by going over all the estimators (trees trained) in the random forest classifier model. And by then going over all the leaves and checking the impurity level of all those leaves, we find the count of the pure leaves and impure leaves for each of the trees formed. Conclusively, after going over all the trees, we find that no tree contained any impure leaves and thus, no tree had an impure leaf (all the leaves were pure).

2.3: Assume you want to improve the performance of this model. Also, assume that you had to pick two hyperparameters that you could tune to improve its performance. Which hyperparameters would you choose and why?

I would choose the hyperparameters “max_depth” and “n_estimators” to be tuned, to improve the performance of the model. This is mainly due to the following reasons: 1. max_depth: This hyperparameter signifies the maximum depth possible of the trees formed as a part of training the random forest classifier. Tuning this hyperparameter could restrict the number of features taken into consideration while forming the trees and thus, would prevent overfitting the development dataset. This, in turn, could result in a better performing model on the test dataset. It’s known to be one of the most important hyperparemeters for the random forest classifier. 2. n_estimators: As the main difference between the decision tree classifier and random forest classifier is that we form many trees (a forest) while training a random forest classifier while just a single tree is formed in a decision tree classifier. Having more estimators would mean having more number of potential trees considering other restrictions placed on the model. As we have more number of trees in our model, it could mean well to cover the dataset in a more specialized manner. As different estimators (trees) could have different features under consideration with different importances, this would cover a lot more range of the labels in the dataset. Thus, I have decided to tune this hyperparameter as it signifies an intrinsic property behind the random forest classifier model and would make the model more comprehensive.

Additionally, I have used bootstrap and warm_start to be true as well but I won’t be tuning them . This is because these parameters have been known to increase the performance of the random forest classifier model. While bootstrap let’s us form different trees in a more comprehensive way by taking different sub-samples of the dataset into consideration, warm_start helps the model take some learnings from the previous trees formed and use those insights to form the next tree (would mean an incremental specialization of the model).

2.4: Now, assume you had to choose up to 5 different values (each) for these two hyperparameters. How would you choose these values that could potentially give you a performance lift?

I would choose the values as follows and the reason for choosing those values have been specified below: 1. max_depth: Values chosen: 5, 7, 9, 11, 13; As the number of features in our dataset is 40, we would like to have the max_depth value specified a little less in comparison to the number of features under consideration. As the pruned decision tree above had a max_depth of 10 and generally a good tree would have less depth, I am taking into consideration some values less than 10 and some values greater than 10 (on the lower end) for hyperparameter as these could be the potential fit for a performance lift. 2. n_estimators: Values chosen: 75, 100, 125, 150, 175; As the default value of the estimators is 100 which was used above to train the random forest classifier with default settings which gave us a decent performance lift in comparison to the decision tree classifier, I want this hyperparameter to be around that. As increasing the number of estimators would form more trees thus, increasing the chance of a performance lift, I have taken most of the values above 100 and just one value below the default value of 100 in order to be sure that having less number of trees won’t be optimal. Also, if the number of estimators are very large, that has the potential to overfit the data so, I don’t take very large values and thus, I take 3 values above 100 with increments of 25 estimators.

2.5: Perform model selection using the chosen values for the hyperparameters. Use cross-validation for finding the optimal hyperparameters. Report on the optimal hyperparameters. Estimate the performance of the optimal model (model trained with optimal hyperparameters) on test dataset? Has the performance improved over your plain-vanilla random forest model trained in Q2.1?

[ ]:

```
param_grid = {
    "bootstrap": [True],
    "warm_start": [True],
    "max_depth": [5, 7, 9, 11, 13],
    "n_estimators": [75, 100, 125, 150, 175]
}

pipe = make_pipeline(GridSearchCV(RandomForestClassifier(oob_score = True,␣
 ↪random_state = 2102), \
                                  param_grid = param_grid, \
                                  cv = 5,
                                  return_train_score = True, \
                                  verbose = 2))
pipe.fit(X_dev_scaled, y_dev)

grid_search_results = pipe.named_steps["gridsearchcv"]
grid_search_result_max_depth = grid_search_results.best_params_['max_depth']
grid_search_result_n_estimators = grid_search_results.
 ↪best_params_['n_estimators']

print(f"Best value of hyperparameter max_depth is:␣
 ↪{grid_search_result_max_depth}")
print(f"Best value of hyperparameter n_estimators is:␣
 ↪{grid_search_result_n_estimators}")
print(f"Best Accuracy Score: {grid_search_results.best_score_}")
print(f"Accuracy Score for Testing Data: {pipe.score(X_test_scaled, y_test) *␣
 ↪100}")
```

```
Fitting 5 folds for each of 25 candidates, totalling 125 fits
[CV] END bootstrap=True, max_depth=5, n_estimators=75, warm_start=True; total
time=  12.0s
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Best value of hyperparameter max_depth is: 13
Best value of hyperparameter n_estimators is: 150
Best Accuracy Score: 0.7895023702507128
Accuracy Score for Testing Data: 78.98064867811392
```

```
[ ]: random_forest_tuned_clf = RandomForestClassifier(oob_score = True, bootstrap =␣
      ↪True, \
                                                 warm_start = True, max_depth = 13, \
                                                 n_estimators = 150,random_state =␣
      ↪2102)
     random_forest_tuned_clf.fit(X_dev_scaled, y_dev)

     print(f"Accuracy Score for Dev Data: {random_forest_tuned_clf.
      ↪score(X_dev_scaled, y_dev) * 100}")
     print(f"Accuracy Score for Testing Data: {random_forest_tuned_clf.
      ↪score(X_test_scaled, y_test) * 100}")
```

```
Accuracy Score for Dev Data: 84.63514517195091
Accuracy Score for Testing Data: 78.98064867811392
```

The optimal hyperparameters found are as follows: 1. max_depth: 13 2. n_estimators: 150

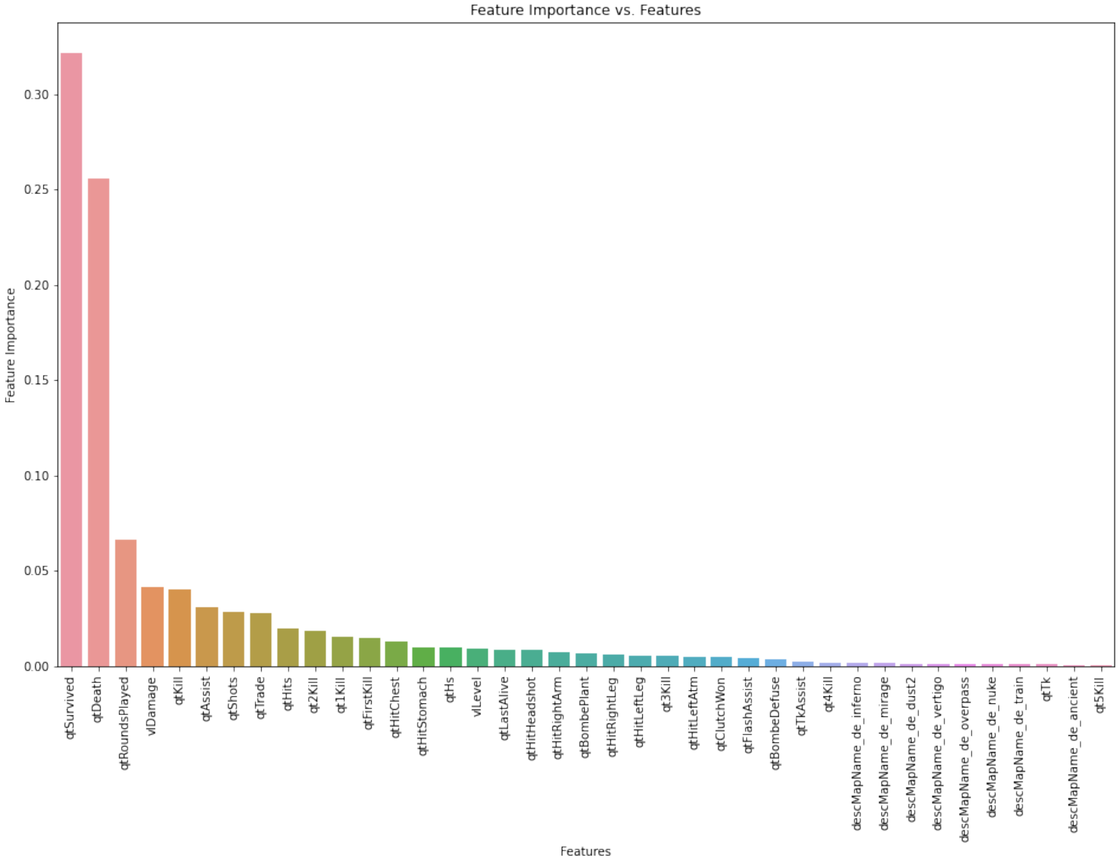
As we can see above, the accuracy score on the testing data for the tuned random forest classifier has increased but very marginally. Although, as the score on the development data has decreased signifying that we are not overfitting the data now and the trained model should now be generalized rather than overfitting the data. I would say that in general the performance of the model has increased but not by much.

2.6: Can you find the top 3 most important features from the model trained in Q2.5? How do these features compare to the important features that you found from Q1.9? If they differ, which feature set makes more sense?

[ ]:
```
import warnings
warnings.filterwarnings("ignore")

feature_names = list(X_dev_scaled.columns)
feature_importances = random_forest_tuned_clf.feature_importances_
feature_importances_map = zip(feature_names, feature_importances)
sorted_feat_names, sorted_feat_importances = zip(*(sorted(list\
                                                    (filter(lambda x: x[1] !=␣
 ↪0, feature_importances_map)),\
                                                    key = lambda x: x[1],␣
 ↪reverse = True)))

fig = plt.figure(figsize=(16,10))
ax = sns.barplot(list(sorted_feat_names), list(sorted_feat_importances))
ax.set_xlabel("Features")
ax.set_ylabel("Feature Importance")
ax.set_title("Feature Importance vs. Features")
ax.tick_params(axis = 'x', rotation = 90)
```



The top 3 most important features from the trained random forest (tuned) classifier model above are as follows: 1. qtSurvived 2. qtDeath 3. qtRoundsPlayed

As we can see, the top 2 most important features match with that of the decision tree classifier but the third one differs. For the decision tree classifier, the third most important feature was "qtTrade" instead of the "qtRoundsPlayed" feature for the random forest classifier model. Furthermore, the feature set for the decision tree classifier makes more sense than that of the random forest classifier. This is mainly because making a trade kill is a very well known technique in the gaming community that is used to make fast kills and thus, win the game. This feature signifying the number of trade kills is thus, heavily tied with the game and thus, should be very helpful in determining the winner of the game. On the other hand, rounds played cannot be directly tied with the winner of the game. Some might argue that higher the number of rounds played, greater the probability of winning but that can't always be true and doesn't seem to be more tied with target variable than the number of trade kills.

1.7 Question 3: Gradient Boosted Trees

[20]:
```
# Additional Imports for this section
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.experimental import enable_hist_gradient_boosting
from sklearn.ensemble import HistGradientBoostingClassifier
from xgboost import XGBClassifier
import time
```

3.1: Choose three hyperparameters to tune GradientBoostingClassifier and HistGradientBoostingClassifier on the development dataset using 5-fold cross validation. Report on the time taken to do model selection for both the models. Also, report the performance of the test dataset from the optimal models.

[ ]:

```
# Gradient Boosting Classifier

# Setting the grid for hyperparameter tuning for GridSearchCV
param_grid = {
    'learning_rate': [0.1, 0.01, 0.001],
    'max_depth': [7, 10, 13],
    'n_estimators': [100, 125, 150]
}

pipe = make_pipeline(GridSearchCV(GradientBoostingClassifier(random_state =␣
 ↪2102), \
                                  param_grid = param_grid, \
                                  cv = 5,
                                  return_train_score = True, \
                                  verbose = 2))

print("For Gradient Boosting Classifier:")
begin_time = time.time()
pipe.fit(X_dev_scaled, y_dev)
end_time = time.time()
print(f"Total time taken for model selection and training the model is:␣
 ↪{(end_time - begin_time)/60} minutes.")

grid_search_results = pipe.named_steps["gridsearchcv"]
grid_search_result_lr = grid_search_results.best_params_['learning_rate']
grid_search_result_max_depth = grid_search_results.best_params_['max_depth']
grid_search_result_n_estimators = grid_search_results.
 ↪best_params_['n_estimators']

print(f"Best value of hyperparameter learning_rate is: {grid_search_result_lr}")
print(f"Best value of hyperparameter max_depth is:␣
 ↪{grid_search_result_max_depth}")
print(f"Best value of hyperparameter n_estimators is:␣
 ↪{grid_search_result_n_estimators}")
print(f"Best Accuracy Score: {grid_search_results.best_score_}")
print(f"Accuracy Score for Testing Data: {pipe.score(X_test_scaled, y_test) *␣
 ↪100}")
```

```
For Gradient Boosting Classifier:
Fitting 5 folds for each of 27 candidates, totalling 135 fits
```

```
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[CV] END ..learning_rate=0.1, max_depth=13, n_estimators=125; total time= 4.0min
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[CV] END ..learning_rate=0.1, max_depth=13, n_estimators=125; total time= 4.1min
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[CV] END ..learning_rate=0.1, max_depth=13, n_estimators=150; total time= 4.9min
[CV] END ..learning_rate=0.1, max_depth=13, n_estimators=150; total time= 4.8min
[CV] END ..learning_rate=0.1, max_depth=13, n_estimators=150; total time= 4.9min
[CV] END ..learning_rate=0.1, max_depth=13, n_estimators=150; total time= 4.9min
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[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=100; total time= 1.4min
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[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=100; total time= 1.5min
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[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=125; total time= 1.8min
[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=125; total time= 1.8min
[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=125; total time= 1.8min
[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=125; total time= 1.8min
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[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=150; total time= 2.2min
[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=150; total time= 2.2min
[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=150; total time= 2.2min
[CV] END ..learning_rate=0.01, max_depth=7, n_estimators=150; total time= 2.2min
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[CV] END .learning_rate=0.01, max_depth=10, n_estimators=100; total time= 2.2min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=100; total time= 2.2min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=100; total time= 2.2min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=100; total time= 2.2min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=125; total time= 2.7min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=125; total time= 2.7min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=125; total time= 2.7min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=125; total time= 2.7min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=125; total time= 2.7min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=150; total time= 3.3min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=150; total time= 3.3min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=150; total time= 3.3min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=150; total time= 3.3min
[CV] END .learning_rate=0.01, max_depth=10, n_estimators=150; total time= 3.3min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=100; total time= 3.4min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=100; total time= 3.4min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=100; total time= 3.3min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=100; total time= 3.4min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=100; total time= 3.4min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=125; total time= 4.2min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=125; total time= 4.2min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=125; total time= 4.1min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=125; total time= 4.2min
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[CV] END .learning_rate=0.01, max_depth=13, n_estimators=150; total time= 5.1min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=150; total time= 5.0min
[CV] END .learning_rate=0.01, max_depth=13, n_estimators=150; total time= 5.1min
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[CV] END .learning_rate=0.001, max_depth=7, n_estimators=100; total time= 1.5min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=100; total time= 1.5min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=100; total time= 1.5min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=100; total time= 1.5min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=125; total time= 1.8min
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[CV] END .learning_rate=0.001, max_depth=7, n_estimators=125; total time= 1.8min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=125; total time= 1.9min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=125; total time= 1.9min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=125; total time= 1.9min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=150; total time= 2.2min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=150; total time= 2.2min
[CV] END .learning_rate=0.001, max_depth=7, n_estimators=150; total time= 2.2min
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[CV] END .learning_rate=0.001, max_depth=7, n_estimators=150; total time= 2.2min
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[CV] END learning_rate=0.001, max_depth=10, n_estimators=100; total time= 2.2min
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[CV] END learning_rate=0.001, max_depth=10, n_estimators=100; total time= 2.2min
[CV] END learning_rate=0.001, max_depth=10, n_estimators=125; total time= 2.7min
[CV] END learning_rate=0.001, max_depth=10, n_estimators=125; total time= 2.7min
[CV] END learning_rate=0.001, max_depth=10, n_estimators=125; total time= 2.7min
[CV] END learning_rate=0.001, max_depth=10, n_estimators=125; total time= 2.7min
[CV] END learning_rate=0.001, max_depth=10, n_estimators=125; total time= 2.8min
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[CV] END learning_rate=0.001, max_depth=10, n_estimators=150; total time= 3.3min
[CV] END learning_rate=0.001, max_depth=10, n_estimators=150; total time= 3.3min
[CV] END learning_rate=0.001, max_depth=10, n_estimators=150; total time= 3.3min
[CV] END learning_rate=0.001, max_depth=10, n_estimators=150; total time= 3.3min
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[CV] END learning_rate=0.001, max_depth=13, n_estimators=100; total time= 3.3min
[CV] END learning_rate=0.001, max_depth=13, n_estimators=100; total time= 3.3min
[CV] END learning_rate=0.001, max_depth=13, n_estimators=125; total time= 4.1min
[CV] END learning_rate=0.001, max_depth=13, n_estimators=125; total time= 4.1min
[CV] END learning_rate=0.001, max_depth=13, n_estimators=125; total time= 4.1min
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[CV] END learning_rate=0.001, max_depth=13, n_estimators=150; total time= 4.9min
[CV] END learning_rate=0.001, max_depth=13, n_estimators=150; total time= 4.9min
[CV] END learning_rate=0.001, max_depth=13, n_estimators=150; total time= 4.9min
[CV] END learning_rate=0.001, max_depth=13, n_estimators=150; total time= 4.9min
Total time taken for model selection and training the model is:
394.04562026262283 minutes.
Best value of hyperparameter learning_rate is: 0.1
Best value of hyperparameter max_depth is: 7
Best value of hyperparameter n_estimators is: 100
Best Accuracy Score: 0.7999482302336326
Accuracy Score for Testing Data: 80.18261106568548
```

[ ]:

```
# Time Analysis for Gradient Boosting
print(f"Average Time Taken across all the 135 fits using Gradient Boosting␣
 ↪Classifier: {394.04562026262283/135} minutes!")
```

```
Average Time Taken across all the 135 fits using Gradient Boosting Classifier:
2.918856446389799 minutes!
```

[ ]:

```
# Hist Gradient Boosting Classifier

# Setting the grid for hyperparameter tuning for GridSearchCV
param_grid = {
    'learning_rate': [0.1, 0.01, 0.005, 0.001, 0.0001],
    'max_depth': [5, 7, 9, 11, 13],
    'l2_regularization': [0, 0.1, 0.01, 0.001, 0.0001]
}

pipe = make_pipeline(GridSearchCV(HistGradientBoostingClassifier(random_state =␣
 ↪2102), \
                                  param_grid = param_grid, \
                                  cv = 5,
                                  return_train_score = True, \
                                  verbose = 2))

print("For Hist Gradient Boosting Classifier:")
begin_time = time.time()
pipe.fit(X_dev_scaled, y_dev)
end_time = time.time()
print(f"Total time taken for model selection and training the model is:␣
 ↪{(end_time - begin_time)/60} minutes.")

grid_search_results = pipe.named_steps["gridsearchcv"]
grid_search_result_lr = grid_search_results.best_params_['learning_rate']
grid_search_result_max_depth = grid_search_results.best_params_['max_depth']
grid_search_result_l2_regs = grid_search_results.
 ↪best_params_['l2_regularization']

print(f"Best value of hyperparameter learning_rate is: {grid_search_result_lr}")
print(f"Best value of hyperparameter max_depth is:␣
 ↪{grid_search_result_max_depth}")
print(f"Best value of hyperparameter l2_regularization is:␣
 ↪{grid_search_result_l2_regs}")
print(f"Best Accuracy Score: {grid_search_results.best_score_}")
print(f"Accuracy Score for Testing Data: {pipe.score(X_test_scaled, y_test) *␣
 ↪100}")
```

```
For Hist Gradient Boosting Classifier:
Fitting 5 folds for each of 125 candidates, totalling 625 fits
[CV] END l2_regularization=0, learning_rate=0.1, max_depth=5; total time=   7.1s
```

```
[CV] END l2_regularization=0, learning_rate=0.1, max_depth=5; total time=   4.6s
[CV] END l2_regularization=0, learning_rate=0.1, max_depth=5; total time=   4.7s
[CV] END l2_regularization=0, learning_rate=0.1, max_depth=5; total time=   4.5s
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[CV] END l2_regularization=0, learning_rate=0.1, max_depth=7; total time=   5.0s
[CV] END l2_regularization=0, learning_rate=0.1, max_depth=7; total time=   5.1s
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5.8s
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8.7s
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6.2s
[CV] END l2_regularization=0, learning_rate=0.1, max_depth=11; total time=
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[CV] END l2_regularization=0, learning_rate=0.1, max_depth=13; total time=
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5.1s
[CV] END l2_regularization=0, learning_rate=0.1, max_depth=13; total time=
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[CV] END l2_regularization=0, learning_rate=0.1, max_depth=13; total time=
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[CV] END l2_regularization=0, learning_rate=0.01, max_depth=5; total time=
9.4s
[CV] END l2_regularization=0, learning_rate=0.01, max_depth=5; total time=
8.1s
[CV] END l2_regularization=0, learning_rate=0.01, max_depth=5; total time=
10.1s
[CV] END l2_regularization=0, learning_rate=0.01, max_depth=5; total time=
9.7s
[CV] END l2_regularization=0, learning_rate=0.01, max_depth=5; total time=
4.9s
[CV] END l2_regularization=0, learning_rate=0.01, max_depth=7; total time=
5.6s
[CV] END l2_regularization=0, learning_rate=0.01, max_depth=7; total time=
6.8s
```

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[CV] END l2_regularization=0, learning_rate=0.01, max_depth=7; total time=
14.0s
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6.5s
[CV] END l2_regularization=0, learning_rate=0.01, max_depth=11; total time=
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[CV] END l2_regularization=0, learning_rate=0.01, max_depth=11; total time=
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5.5s
[CV] END l2_regularization=0, learning_rate=0.01, max_depth=13; total time=
6.5s
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5.6s
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5.0s
[CV] END l2_regularization=0, learning_rate=0.005, max_depth=5; total time=
5.0s
[CV] END l2_regularization=0, learning_rate=0.005, max_depth=7; total time=
5.6s
```

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[CV] END l2_regularization=0, learning_rate=0.005, max_depth=7; total time=
7.9s
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5.6s
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5.6s
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5.6s
[CV] END l2_regularization=0, learning_rate=0.005, max_depth=9; total time=
5.7s
[CV] END l2_regularization=0, learning_rate=0.005, max_depth=9; total time=
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[CV] END l2_regularization=0, learning_rate=0.005, max_depth=9; total time=
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[CV] END l2_regularization=0, learning_rate=0.005, max_depth=9; total time=
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[CV] END l2_regularization=0, learning_rate=0.005, max_depth=11; total time=
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[CV] END l2_regularization=0, learning_rate=0.005, max_depth=11; total time=
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[CV] END l2_regularization=0, learning_rate=0.005, max_depth=13; total time=
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[CV] END l2_regularization=0, learning_rate=0.005, max_depth=13; total time=
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[CV] END l2_regularization=0, learning_rate=0.005, max_depth=13; total time=
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[CV] END l2_regularization=0, learning_rate=0.001, max_depth=5; total time=
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[CV] END l2_regularization=0, learning_rate=0.001, max_depth=7; total time=
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[CV] END l2_regularization=0, learning_rate=0.001, max_depth=7; total time=
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[CV] END l2_regularization=0, learning_rate=0.001, max_depth=7; total time=
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[CV] END l2_regularization=0, learning_rate=0.001, max_depth=9; total time=
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[CV] END l2_regularization=0, learning_rate=0.001, max_depth=13; total time=
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5.3s
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5.7s
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[CV] END l2_regularization=0.0001, learning_rate=0.01, max_depth=9; total time=
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```

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[CV] END l2_regularization=0.0001, learning_rate=0.005, max_depth=7; total time=
5.6s
```

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5.7s
[CV] END l2_regularization=0.0001, learning_rate=0.005, max_depth=9; total time=
5.6s
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time=   5.6s
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time=   5.6s
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time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.005, max_depth=11; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.005, max_depth=11; total
time=   5.6s
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time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.005, max_depth=13; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.005, max_depth=13; total
time=   5.7s
[CV] END l2_regularization=0.0001, learning_rate=0.005, max_depth=13; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.005, max_depth=13; total
time=   5.6s
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5.1s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=5; total time=
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5.0s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=5; total time=
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5.7s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=7; total time=
5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=7; total time=
5.7s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=7; total time=
5.6s
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[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=7; total time=
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[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=9; total time=
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[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=9; total time=
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[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=9; total time=
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[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=9; total time=
5.6s
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5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=11; total
time=   5.7s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=11; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=11; total
time=   5.7s
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time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=11; total
time=   5.6s
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time=   5.7s
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time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.001, max_depth=13; total
time=   5.7s
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time=   5.6s
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time=   5.7s
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time=   5.1s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=5; total
time=   5.0s
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time=   5.1s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=5; total
time=   5.0s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=5; total
time=   5.1s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=7; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=7; total
time=   5.5s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=7; total
time=   5.6s
```

```
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=7; total
time=   5.6s
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time=   5.6s
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time=   5.7s
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time=   5.6s
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time=   5.7s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=9; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=9; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=11; total
time=   5.7s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=11; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=11; total
time=   5.7s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=11; total
time=   5.7s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=11; total
time=   5.6s
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time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=13; total
time=   5.5s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=13; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=13; total
time=   5.6s
[CV] END l2_regularization=0.0001, learning_rate=0.0001, max_depth=13; total
time=   5.6s
Total time taken for model selection and training the model is: 66.7500392238299
minutes.
Best value of hyperparameter learning_rate is: 0.1
Best value of hyperparameter max_depth is: 7
Best value of hyperparameter l2_regularization is: 0.01
Best Accuracy Score: 0.8011679086201141
Accuracy Score for Testing Data: 80.03270645952576
```

[ ]:

```
# Time Analysis for Hist Gradient Boosting
print(f"Average Time Taken across all the 625 fits using Hist Gradient Boosting␣
 ↪Classifier: {66.7500392238299/625} minutes!")
```

```
Average Time Taken across all the 625 fits using Hist Gradient Boosting
Classifier: 0.10680006275812784 minutes!
```

Summarizing the results for the two models above: 1. Gradient Boosting: Total Time Taken for model selection: 394.045 minutes. Accuracy score on Test dataset: 80.18%. The performance of this model has improved from the random forest classifier. 2. Hist Gradient Boosting: Total Time Taken for model selection: 66.75 minutes. Accuracy score on Test dataset: 80.03%. The performance of this model has improved from the random forest classifier.

3.2: Train an XGBoost model by tuning 3 hyperparameters using 5 fold cross-validation. Compare the performance of the trained XGBoost model on the test dataset against the performances obtained from 3.1

[ ]:

```
# XGB Classifier

# Setting the grid for hyperparameter tuning for GridSearchCV
param_grid = {
    'eta': [0.001, 0.01, 0.1],
    'max_depth': [5, 7, 10],
    'gamma': [0, 3, 7]
}

pipe = make_pipeline(GridSearchCV(XGBClassifier(random_state = 2102), \
                                  param_grid = param_grid, \
                                  cv = 5,
                                  return_train_score = True, \
                                  verbose = 2))

print("For XGB Classifier:")
begin_time = time.time()
pipe.fit(X_dev_scaled, y_dev)
end_time = time.time()
print(f"Total time taken for model selection and training the model is:␣
 ↪{(end_time - begin_time)/60} minutes.")

grid_search_results = pipe.named_steps["gridsearchcv"]
grid_search_result_lr = grid_search_results.best_params_['eta']
grid_search_result_max_depth = grid_search_results.best_params_['max_depth']
grid_search_result_gamma = grid_search_results.best_params_['gamma']

print(f"Best value of hyperparameter eta is: {grid_search_result_lr}")
print(f"Best value of hyperparameter max_depth is:␣
 ↪{grid_search_result_max_depth}")
print(f"Best value of hyperparameter gamma is: {grid_search_result_gamma}")
print(f"Best Accuracy Score: {grid_search_results.best_score_}")
print(f"Accuracy Score for Testing Data: {pipe.score(X_test_scaled, y_test) *␣
 ↪100}")
```

```
For XGB Classifier:
Fitting 5 folds for each of 27 candidates, totalling 135 fits
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=  22.8s
```

```
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=  23.3s
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=  23.1s
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=  23.4s
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=  22.7s
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  35.3s
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  35.6s
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  36.1s
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  42.3s
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  35.4s
[CV] END …eta=0.001, gamma=0, max_depth=10; total time= 1.0min
[CV] END …eta=0.001, gamma=0, max_depth=10; total time= 1.0min
[CV] END …eta=0.001, gamma=0, max_depth=10; total time=  59.1s
[CV] END …eta=0.001, gamma=0, max_depth=10; total time=  59.4s
[CV] END …eta=0.001, gamma=0, max_depth=10; total time=  58.7s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=  22.7s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=  22.7s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=  22.8s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=  22.8s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=  22.9s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  35.6s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  35.4s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  35.4s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  35.2s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  35.3s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  59.0s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  58.7s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  58.9s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  58.8s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  58.7s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=  22.7s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=  22.6s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=  22.7s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=  22.7s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=  22.6s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  35.3s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  35.2s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  35.2s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  35.1s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  35.1s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  58.5s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  58.6s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  58.4s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  58.0s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  58.8s
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=  22.7s
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=  22.6s
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=  22.8s
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=  22.6s
```

```
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=  22.7s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  35.2s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  35.2s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  35.0s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  35.0s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  35.1s
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  59.2s
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  58.5s
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  58.8s
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  59.1s
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  58.3s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=  22.7s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=  22.5s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=  22.7s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=  22.6s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=  22.6s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  35.3s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  35.4s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  35.4s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  35.0s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  35.2s
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[CV] END …eta=0.01, gamma=3, max_depth=10; total time=  58.5s
[CV] END …eta=0.01, gamma=3, max_depth=10; total time=  58.8s
[CV] END …eta=0.01, gamma=3, max_depth=10; total time= 1.1min
[CV] END …eta=0.01, gamma=3, max_depth=10; total time=  58.4s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=  22.6s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=  22.6s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=  22.6s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=  22.6s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=  22.7s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  35.2s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  35.2s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  35.3s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  35.2s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  35.1s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  58.4s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  58.7s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  58.2s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  58.0s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  58.5s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=  22.6s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=  22.5s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=  22.7s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=  22.6s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=  22.6s
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  35.2s
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  35.2s
```

```
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  35.0s
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  35.1s
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  35.0s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  59.1s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  58.3s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  58.6s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  59.1s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  58.3s
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=  26.6s
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=  22.6s
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=  22.7s
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=  22.5s
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=  22.5s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  35.3s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  35.1s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  35.3s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  35.2s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  35.3s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  58.7s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  58.4s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  58.6s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  58.8s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  58.6s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=  22.6s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=  22.5s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=  22.6s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=  22.5s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=  22.6s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  35.2s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  35.1s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  35.1s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  35.0s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  34.9s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  58.2s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  58.5s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  58.2s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  57.7s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  58.6s
Total time taken for model selection and training the model is:
90.82600705623626 minutes.
Best value of hyperparameter eta is: 0.001
Best value of hyperparameter max_depth is: 7
Best value of hyperparameter gamma is: 7
Best Accuracy Score: 0.8005001243443853
Accuracy Score for Testing Data: 80.48787135459253
```

```
[ ]: # Time Analysis for XG Boost Classifier
     print(f"Average Time Taken across all the 135 fits using XG Boost Classifier:␣
      ↪{90.82600705623626/135} minutes!")
```

```
Average Time Taken across all the 135 fits using XG Boost Classifier:
0.672785237453602 minutes!
```

```
[ ]: # Creating XGBoost model with the best hyperparameters found above
     xgb_clf = XGBClassifier(eta = 0.001, max_depth = 7, gamma = 7, random_state =␣
      ↪2102)
     xgb_clf.fit(X_dev_scaled, y_dev)

     print(f"Accuracy Score for Dev Data: {xgb_clf.score(X_dev_scaled, y_dev) *␣
      ↪100}")
     print(f"Accuracy Score for Testing Data: {xgb_clf.score(X_test_scaled, y_test)␣
      ↪* 100}")
```

```
Accuracy Score for Dev Data: 81.67855707053155
Accuracy Score for Testing Data: 80.48787135459253
```

The performance of the XG Boost Classifier with the best hyperparameters found from the Grid Search above is found to be little better than the Gradient Boosting Classifier and Hist Gradient Boosting Classifier. This is based on the fact that the accuracy score on the test dataset found with the XG Boost Classifier is 80.49% while with the Gradient Boosting it was 80.18% and with the Hist Gradient Boosting, it was 80.03%. Although the difference is not much as XG Boost performs marginally better than the Gradient Boosting and Hist Gradient Boosting models.

3.3: Compare the results on the test dataset from XGBoost, HistGradientBoostingClassifier, GradientBoostingClassifier with results from Q1.6 and Q2.1. Which model tends to perform the best and which one does the worst? How big is the difference between the two? Which model would you choose among these 5 models and why?

For all the values below, the performance is measured in terms of the accuracy score: 1. Decision Tree Classifier: 73.03% 2. Tuned Decision Tree Classifier: 78.15% 3. Random Forest Classifier: 78.9% 4. Tuned Random Forest Classifier: 78.98% 5. Gradient Boosting Classifier: 80.18% 6. Hist Gradient Boosting Classifier: 80.03% 7. XG Boost Classifier: 80.49%

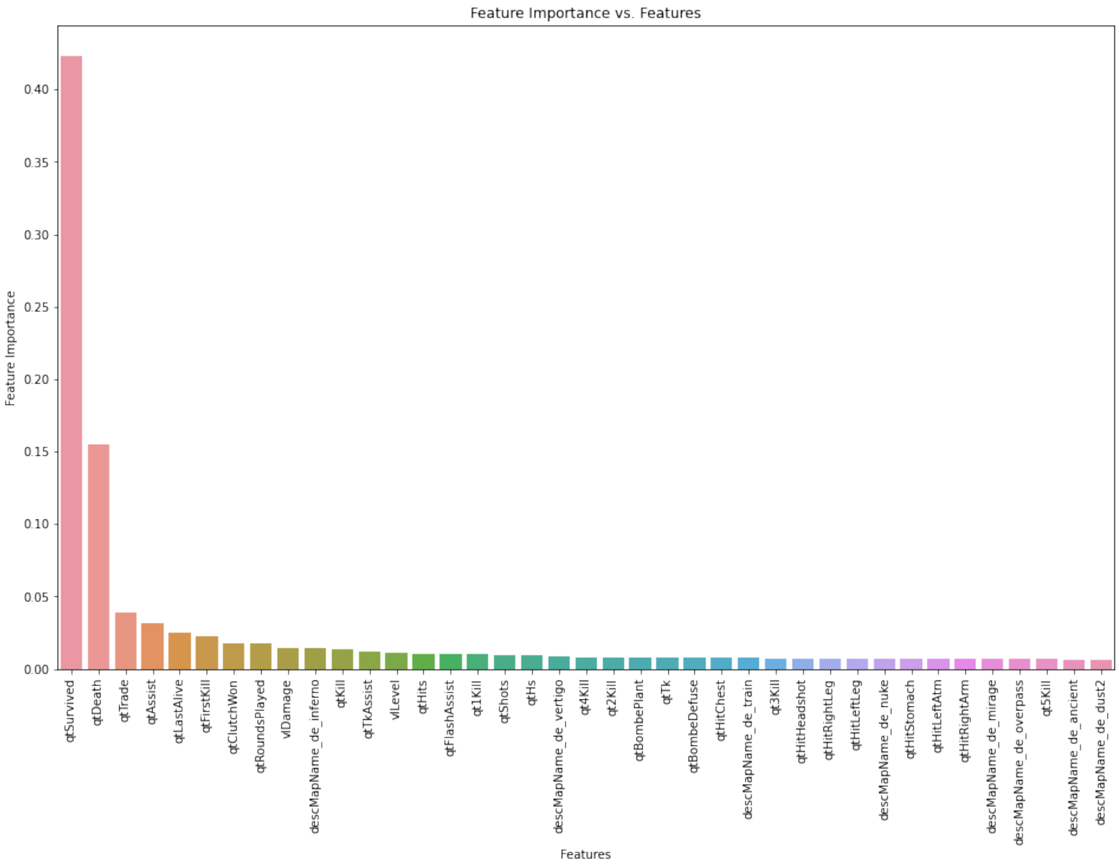
The model that tends to perform the best is the XG Boost Classifier and the model that seems to perform the worst is the Decision Tree Classifier. The performance difference (Accuracy score difference) for these two models is quite large (if not huge) with an improve in performance of 80.49 - 73.03 = 7.46%.

I would choose the XG Boost Classifier because of the following reasons: 1. As the XG Boost Classifier performs the best according to the accuracy score among all the 5 models trained, I will choose this model. Although the performance difference between the Gradient Boosting, Hist Gradient Boosting and XG Boost Classifier is quite less, still, XG Boost performs the best among these three. 2. As time taken by the Gradient Boosting Classifier is huge in comparison to the Hist Gradient Boosting and XG Boost Classifier, I wouldn't take that model as I have another model that fits the data even better (albeit marginally). Also, Hist Gradient Boosting Classifier takes the least time so, I could have chosen that but as the XG Boost performs marginally better and has

GPU support as well, I would consider XG Boost as my model going forward for this classification task.

3.4: Can you list the top 3 features from the trained XGBoost model? How do they differ from the features found from Random Forest and Decision Tree? Which one would you trust the most?

[ ]:
```
import warnings
warnings.filterwarnings("ignore")

feature_names = list(X_dev_scaled.columns)
feature_importances = xgb_clf.feature_importances_
feature_importances_map = zip(feature_names, feature_importances)
sorted_feat_names, sorted_feat_importances = zip(*(sorted(list\
                                                    (filter(lambda x: x[1] !=␣
 ↪0, feature_importances_map)),\
                                                    key = lambda x: x[1],␣
 ↪reverse = True)))

fig = plt.figure(figsize = (16,10))
ax = sns.barplot(list(sorted_feat_names), list(sorted_feat_importances))
ax.set_xlabel("Features")
ax.set_ylabel("Feature Importance")
ax.set_title("Feature Importance vs. Features")
ax.tick_params(axis = 'x', rotation = 90)
```



The top 3 features for the tuned XG Boost Classifier is as follows: 1. qtSurvived 2. qtDeath 3. qtTrade

This is the same 3 most important features as that of the Decision Tree Classifier but the third one differs from the Random Forest Classifier (qtRoundsPlayed instead of qtTrade). I would trust the feature set from Decision Tree Classifier and XG Boost as the better one. This is primarly because of the fact that qtTrade is a known strategy for winning the combat games and is found to be quite useful for winning the game if the players are efficient with it. So, this serves as a better correlation feature in comparison to some arbitrary number of rounds played. Some might argue that more the number of rounds played, higher the probability of winning, but that is not always the case and we don't know that for sure. In comparison to that, the number of trade kills ties up with the game data pretty well and is a known technique. Thus, I would choose the current feature set as the best one.

3.5: Can you choose the top 7 features (as given by feature importances from XGBoost) and repeat Q3.2? Does this model perform better than the one trained in Q3.2? Why or why not is the performance better?

[ ]:
```
top_7_features = list(sorted_feat_names[:7])
print(f"We will consider the following features for training now:␣
 ↪{top_7_features}")
```

```
# Setting the grid for hyperparameter tuning for GridSearchCV
param_grid = {
    'eta': [0.001, 0.01, 0.1],
    'max_depth': [5, 7, 10],
    'gamma': [0, 3, 7]
}

pipe = make_pipeline(GridSearchCV(XGBClassifier(random_state = 2102), \
                                  param_grid = param_grid, \
                                  cv = 5,
                                  return_train_score = True, \
                                  verbose = 2))

print("For XGB Classifier:")
begin_time = time.time()
pipe.fit(X_dev_scaled[top_7_features], y_dev)
end_time = time.time()
print(f"Total time taken for model selection and training the model is:␣
 ↪{(end_time - begin_time)/60} minutes.")

grid_search_results = pipe.named_steps["gridsearchcv"]
grid_search_result_lr = grid_search_results.best_params_['eta']
grid_search_result_max_depth = grid_search_results.best_params_['max_depth']
grid_search_result_gamma = grid_search_results.best_params_['gamma']

print(f"Best value of hyperparameter eta is: {grid_search_result_lr}")
print(f"Best value of hyperparameter max_depth is:␣
 ↪{grid_search_result_max_depth}")
print(f"Best value of hyperparameter gamma is: {grid_search_result_gamma}")
print(f"Best Accuracy Score: {grid_search_results.best_score_}")
print(f"Accuracy Score for Testing Data: {pipe.
 ↪score(X_test_scaled[top_7_features], y_test) * 100}")
```

```
We will consider the following features for training now: ['qtSurvived',
'qtDeath', 'qtTrade', 'qtAssist', 'qtLastAlive', 'qtFirstKill', 'qtClutchWon']
For XGB Classifier:
Fitting 5 folds for each of 27 candidates, totalling 135 fits
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=  10.3s
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=   9.6s
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.001, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  11.5s
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  11.5s
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  11.5s
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  11.6s
```

```
[CV] END …eta=0.001, gamma=0, max_depth=7; total time=  11.4s
[CV] END …eta=0.001, gamma=0, max_depth=10; total time=  17.3s
[CV] END …eta=0.001, gamma=0, max_depth=10; total time=  16.6s
[CV] END …eta=0.001, gamma=0, max_depth=10; total time=  16.6s
[CV] END …eta=0.001, gamma=0, max_depth=10; total time=  16.6s
[CV] END …eta=0.001, gamma=0, max_depth=10; total time=  16.7s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=   8.6s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=   7.9s
[CV] END …eta=0.001, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  11.3s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  11.3s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  11.4s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  11.5s
[CV] END …eta=0.001, gamma=3, max_depth=7; total time=  11.5s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  16.2s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  16.4s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  16.5s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  16.8s
[CV] END …eta=0.001, gamma=3, max_depth=10; total time=  16.2s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=   7.9s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=   7.9s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=   8.0s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=   7.9s
[CV] END …eta=0.001, gamma=7, max_depth=5; total time=   7.9s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  11.2s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  11.2s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  11.1s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  11.3s
[CV] END …eta=0.001, gamma=7, max_depth=7; total time=  11.4s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  16.4s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  16.9s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  16.9s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  16.3s
[CV] END …eta=0.001, gamma=7, max_depth=10; total time=  16.6s
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=   7.9s
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=   7.9s
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  11.5s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  11.4s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  11.5s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  11.5s
[CV] END …eta=0.01, gamma=0, max_depth=7; total time=  11.4s
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  16.6s
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  16.6s
```

```
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  16.5s
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  16.5s
[CV] END …eta=0.01, gamma=0, max_depth=10; total time=  16.7s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  17.0s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  11.4s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  11.4s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  11.5s
[CV] END …eta=0.01, gamma=3, max_depth=7; total time=  11.5s
[CV] END …eta=0.01, gamma=3, max_depth=10; total time=  16.1s
[CV] END …eta=0.01, gamma=3, max_depth=10; total time=  16.3s
[CV] END …eta=0.01, gamma=3, max_depth=10; total time=  16.6s
[CV] END …eta=0.01, gamma=3, max_depth=10; total time=  17.5s
[CV] END …eta=0.01, gamma=3, max_depth=10; total time=  16.3s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=   7.9s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=7, max_depth=5; total time=   8.0s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  11.3s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  11.3s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  11.8s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  11.3s
[CV] END …eta=0.01, gamma=7, max_depth=7; total time=  11.3s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  16.5s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  17.4s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  17.0s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  16.4s
[CV] END …eta=0.01, gamma=7, max_depth=10; total time=  16.7s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=0, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  11.5s
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  11.4s
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  11.5s
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  11.6s
[CV] END …eta=0.1, gamma=0, max_depth=7; total time=  11.4s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  16.7s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  16.7s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  16.7s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  16.6s
[CV] END …eta=0.1, gamma=0, max_depth=10; total time=  16.7s
```

```
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=3, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  11.3s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  11.3s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  11.4s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  11.5s
[CV] END …eta=0.1, gamma=3, max_depth=7; total time=  11.5s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  16.1s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  16.4s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  16.6s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  16.8s
[CV] END …eta=0.1, gamma=3, max_depth=10; total time=  16.2s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=   7.9s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=   8.0s
[CV] END …eta=0.1, gamma=7, max_depth=5; total time=   7.9s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  11.4s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  11.2s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  11.2s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  11.3s
[CV] END …eta=0.1, gamma=7, max_depth=7; total time=  11.4s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  16.6s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  17.0s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  17.0s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  16.4s
[CV] END …eta=0.1, gamma=7, max_depth=10; total time=  16.7s
Total time taken for model selection and training the model is:
29.212776001294454 minutes.
Best value of hyperparameter eta is: 0.001
Best value of hyperparameter max_depth is: 7
Best value of hyperparameter gamma is: 3
Best Accuracy Score: 0.7985853905130114
Accuracy Score for Testing Data: 80.39247751430908
```

This model performs marginally worse than the one trained in Q3.2 part of this section. Although the difference is quite less but still it performs marginally worse. This could be attributed to the fact that we have removed some features from the dataset that had some impact on the accuracy. Although those features might not have been very important but still had some say in determining the winner of the game. Maybe taking 10 most important features would resolve this! We have to be very careful in throwing away the data when it's needed to not to impact the performance of the model. This case here shows that quite reasonably.

1.8 Question 4: Calibration

[21]:

```python
# Additional imports for this section
from sklearn.metrics import brier_score_loss
from sklearn.calibration import CalibratedClassifierCV
from sklearn.metrics import plot_confusion_matrix
from sklearn.calibration import CalibrationDisplay
```

4.1: Estimate the brier score for the XGBoost model (trained with optimal hyperparameters from Q3.2) scored on the test dataset.

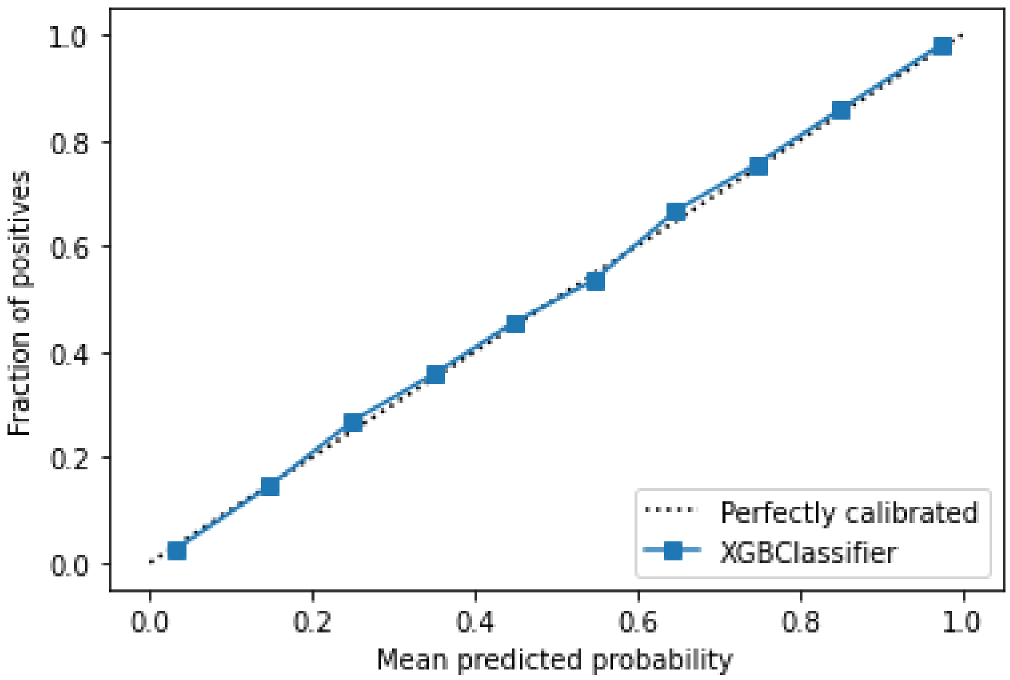
[22]:

```python
import warnings
warnings.filterwarnings("ignore")

xgb_clf = XGBClassifier(eta = 0.001, max_depth = 7, gamma = 7, random_state =␣
 ↪2102)
xgb_clf.fit(X_dev_scaled, y_dev)
pred_probs = xgb_clf.predict_proba(X_test_scaled)[:, 1]

print(f"Brier Score for Optimal XGBoost Classifier: {brier_score_loss(y_test,␣
 ↪pred_probs)}")
```

```
Brier Score for Optimal XGBoost Classifier: 0.12852021752037557
```

[24]:

```python
xgb_clf_disp = CalibrationDisplay.from_estimator(xgb_clf, X_test_scaled,␣
 ↪y_test, n_bins = 10)
plt.show()
```



4.2: Calibrate the trained XGBoost model using isotonic regression as well as Platt scaling. Plot predicted v.s. actual on test datasets from both the calibration methods

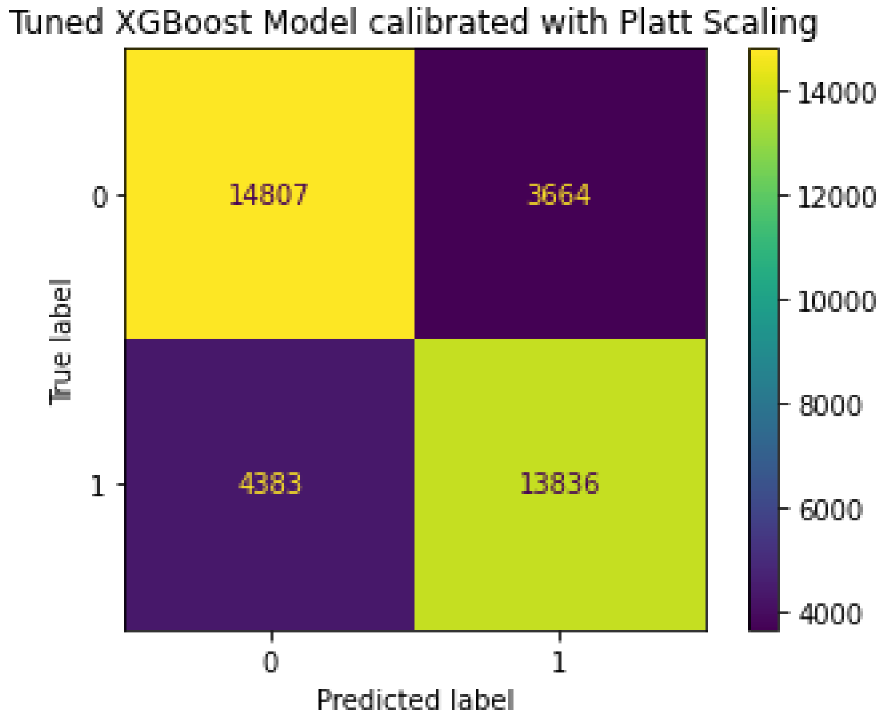
[22]:
```
# Splitting the data first
X_train, X_calib, y_train, y_calib = train_test_split(X_dev_scaled, y_dev,␣
 ↪test_size = 0.2, random_state = 2102)
```

[23]:
```
xgb_clf = XGBClassifier(eta = 0.001, max_depth = 7, gamma = 7, random_state =␣
 ↪2102)
xgb_clf.fit(X_train, y_train)

xgb_platt_calib = CalibratedClassifierCV(xgb_clf, cv = "prefit", method =␣
 ↪"sigmoid")
xgb_platt_calib.fit(X_calib, y_calib)

plot_confusion_matrix(xgb_platt_calib, X_test_scaled, y_test)
plt.title("Tuned XGBoost Model calibrated with Platt Scaling")
plt.show()
```

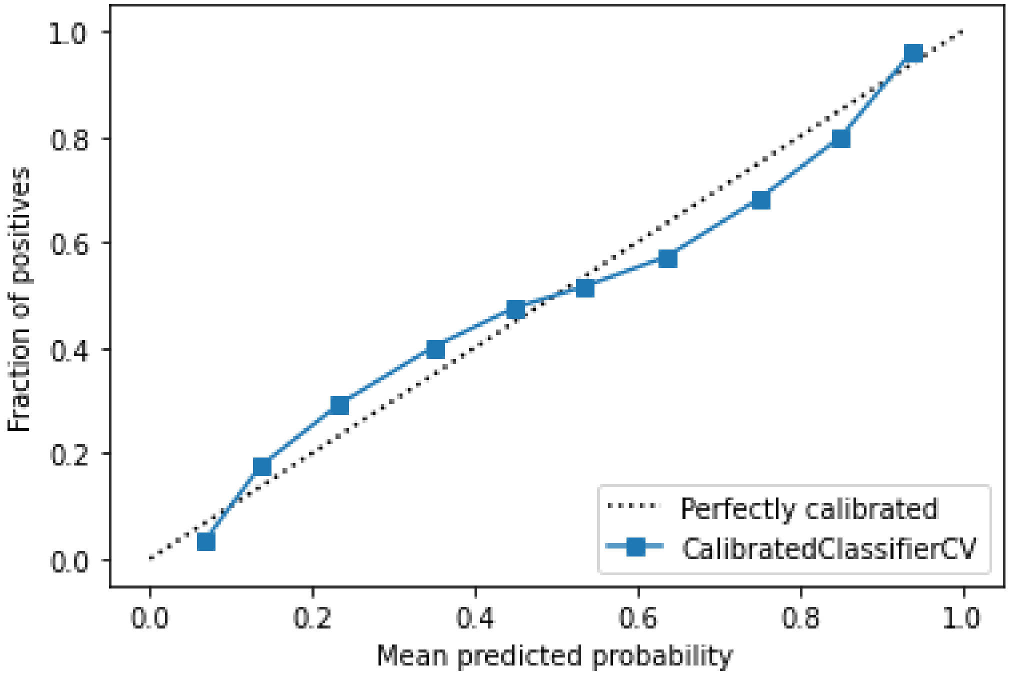
```
/usr/local/lib/python3.7/dist-packages/xgboost/sklearn.py:1224: UserWarning: The
use of label encoder in XGBClassifier is deprecated and will be removed in a
future release. To remove this warning, do the following: 1) Pass option
use_label_encoder=False when constructing XGBClassifier object; and 2) Encode
your labels (y) as integers starting with 0, i.e. 0, 1, 2, …, [num_class - 1].
  warnings.warn(label_encoder_deprecation_msg, UserWarning)
```

```
[20:33:39] WARNING: ../src/learner.cc:1115: Starting in XGBoost 1.3.0, the
default evaluation metric used with the objective 'binary:logistic' was changed
from 'error' to 'logloss'. Explicitly set eval_metric if you'd like to restore
the old behavior.
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/deprecation.py:87:
FutureWarning: Function plot_confusion_matrix is deprecated; Function
`plot_confusion_matrix` is deprecated in 1.0 and will be removed in 1.2. Use one
of the class methods: ConfusionMatrixDisplay.from_predictions or
ConfusionMatrixDisplay.from_estimator.
  warnings.warn(msg, category=FutureWarning)
```

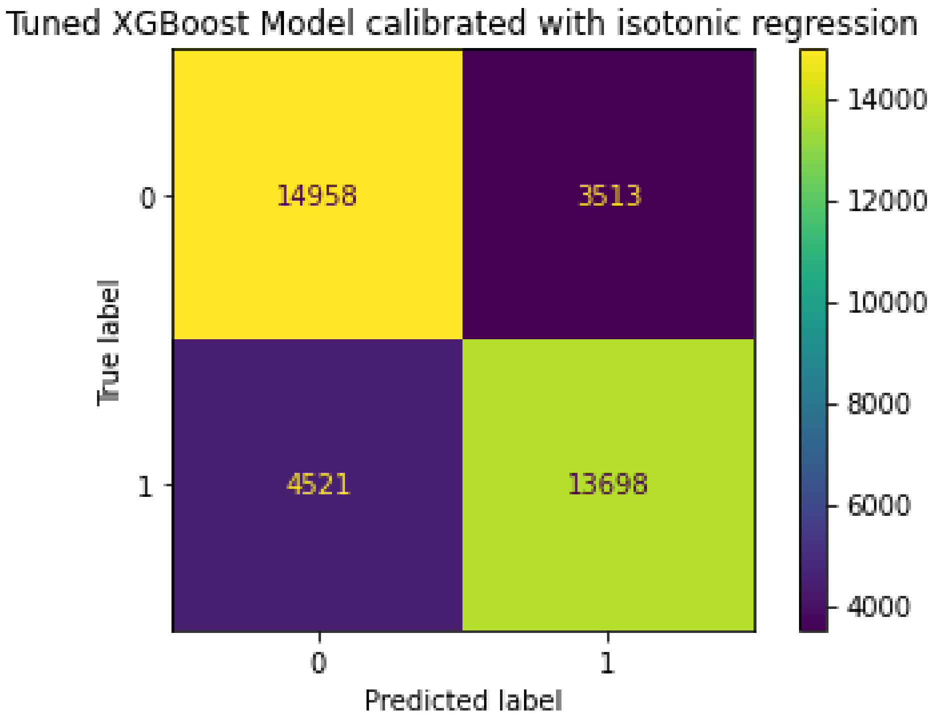


[24]:
```
xgb_clf_platt_disp = CalibrationDisplay.from_estimator(xgb_platt_calib,␣
 ↪X_test_scaled, y_test, n_bins = 10)
plt.show()
```

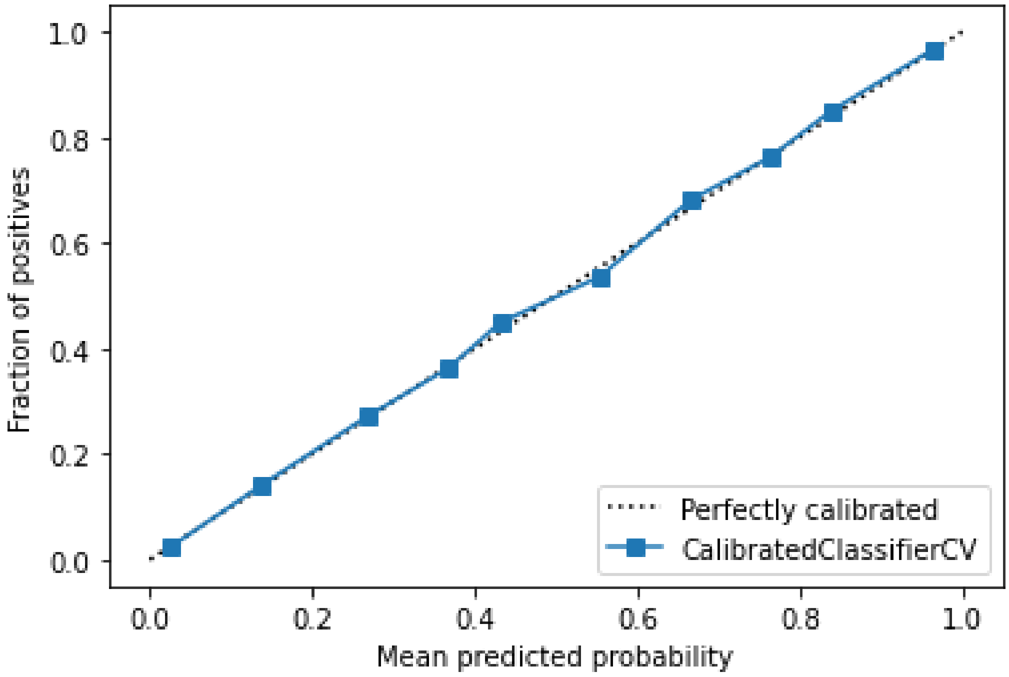


```
[25]: xgb_isotonic_calib = CalibratedClassifierCV(xgb_clf, cv = "prefit", method =␣
       ↪"isotonic")
      xgb_isotonic_calib.fit(X_calib, y_calib)

      plot_confusion_matrix(xgb_isotonic_calib, X_test_scaled, y_test)
      plt.title("Tuned XGBoost Model calibrated with isotonic regression")
      plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/deprecation.py:87:
FutureWarning: Function plot_confusion_matrix is deprecated; Function
`plot_confusion_matrix` is deprecated in 1.0 and will be removed in 1.2. Use one
of the class methods: ConfusionMatrixDisplay.from_predictions or
ConfusionMatrixDisplay.from_estimator.
  warnings.warn(msg, category=FutureWarning)
```



```
[26]: xgb_clf_isotonic_disp = CalibrationDisplay.from_estimator(xgb_isotonic_calib,␣
       ↪X_test_scaled, y_test, n_bins = 10)
      plt.show()
```



4.3: Report brier scores from both the calibration methods. Do the calibration methods help in having better predicted probabilities?

```
[27]: pred_probs_xgb_platt = xgb_platt_calib.predict_proba(X_test_scaled)[:, 1]
pred_probs_xgb_isotonic = xgb_isotonic_calib.predict_proba(X_test_scaled)[:, 1]

print("Brier Score for Tuned XG Boost Model with Platt Scaling : ", \
      brier_score_loss(y_test, pred_probs_xgb_platt))
print("Brier Score for Tuned XG Boost Model with Isotonic Regression : ", \
      brier_score_loss(y_test, pred_probs_xgb_isotonic))
```

```
Brier Score for Tuned XG Boost Model with Platt Scaling :  0.14143479698968298
Brier Score for Tuned XG Boost Model with Isotonic Regression :
0.13948244201592852
```

As the Brier scores increase marginally after applying the calibration methods, we can surely say that the calibration methods don't help in getting better predicted probabilities. This is bolstered by the fact that the original probabilities were already very near to perfect calibration according to the plot in 4.1. Thus, there was not much scope for improvement in terms of getting better prediction probabilities after applying the calibration methods which can also be supported by the plots provided in 4.2. Thus, for our use case here where the data was quite balanced originally, we can say that calibration methods don't help us in getting better prediction probabilities.

END OF ASSIGNMENT