Customer Churn Prediction

March 30, 2024

[1]:
```
# importing necessary libraries
import os
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
%matplotlib inline
```

[2]:
```
os.chdir('C:\\Users\\HP\\Downloads')
```

[3]:
```
data=pd.read_csv('Churn_Modelling.csv')
```

[4]:
```
data.head()
```

[4]:

	RowNumber	CustomerId	Surname	CreditScore	Geography	Gender	Age	\
0	1	15634602	Hargrave	619	France	Female	42	
1	2	15647311	Hill	608	Spain	Female	41	
2	3	15619304	Onio	502	France	Female	42	
3	4	15701354	Boni	699	France	Female	39	
4	5	15737888	Mitchell	850	Spain	Female	43	

	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMember	\
0	2	0.00	1	1	1	
1	1	83807.86	1	0	1	
2	8	159660.80	3	1	0	
3	1	0.00	2	0	0	
4	2	125510.82	1	1	1	

	EstimatedSalary	Exited
0	101348.88	1
1	112542.58	0
2	113931.57	1
3	93826.63	0
4	79084.10	0

[5]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
```

```
Data columns (total 14 columns):
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
 0   RowNumber        10000 non-null  int64
 1   CustomerId       10000 non-null  int64
 2   Surname          10000 non-null  object
 3   CreditScore      10000 non-null  int64
 4   Geography        10000 non-null  object
 5   Gender           10000 non-null  object
 6   Age              10000 non-null  int64
 7   Tenure           10000 non-null  int64
 8   Balance          10000 non-null  float64
 9   NumOfProducts    10000 non-null  int64
 10  HasCrCard        10000 non-null  int64
 11  IsActiveMember   10000 non-null  int64
 12  EstimatedSalary  10000 non-null  float64
 13  Exited           10000 non-null  int64
dtypes: float64(2), int64(9), object(3)
memory usage: 1.1+ MB
```

[6]:
```
data.describe()
```

[6]:

	RowNumber	CustomerId	CreditScore	Age	Tenure
count	10000.00000	1.000000e+04	10000.000000	10000.000000	10000.000000
mean	5000.50000	1.569094e+07	650.528800	38.921800	5.012800
std	2886.89568	7.193619e+04	96.653299	10.487806	2.892174
min	1.00000	1.556570e+07	350.000000	18.000000	0.000000
25%	2500.75000	1.562853e+07	584.000000	32.000000	3.000000
50%	5000.50000	1.569074e+07	652.000000	37.000000	5.000000
75%	7500.25000	1.575323e+07	718.000000	44.000000	7.000000
max	10000.00000	1.581569e+07	850.000000	92.000000	10.000000

	Balance	NumOfProducts	HasCrCard	IsActiveMember
count	10000.000000	10000.000000	10000.00000	10000.000000
mean	76485.889288	1.530200	0.70550	0.515100
std	62397.405202	0.581654	0.45584	0.499797
min	0.000000	1.000000	0.00000	0.000000
25%	0.000000	1.000000	0.00000	0.000000
50%	97198.540000	1.000000	1.00000	1.000000
75%	127644.240000	2.000000	1.00000	1.000000
max	250898.090000	4.000000	1.00000	1.000000

	EstimatedSalary	Exited
count	10000.000000	10000.000000
mean	100090.239881	0.203700
std	57510.492818	0.402769
min	11.580000	0.000000

```
25%       51002.110000      0.000000
50%      100193.915000      0.000000
75%      149388.247500      0.000000
max      199992.480000      1.000000
```

[7]:
```
# data type of each columns feature variable

data.dtypes
```

[7]:
```
RowNumber            int64
CustomerId           int64
Surname             object
CreditScore          int64
Geography           object
Gender              object
Age                  int64
Tenure               int64
Balance            float64
NumOfProducts        int64
HasCrCard            int64
IsActiveMember       int64
EstimatedSalary    float64
Exited               int64
dtype: object
```

[8]:
```
# sample of data before deleting the unnecessary columns

data.head()
```

[8]:

	RowNumber	CustomerId	Surname	CreditScore	Geography	Gender	Age	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMember	EstimatedSalary	Exited
0	1	15634602	Hargrave	619	France	Female	42	2	0.00	1	1	1	101348.88	1
1	2	15647311	Hill	608	Spain	Female	41	1	83807.86	1	0	1	112542.58	0
2	3	15619304	Onio	502	France	Female	42	8	159660.80	3	1	0	113931.57	1
3	4	15701354	Boni	699	France	Female	39	1	0.00	2	0	0		
4	5	15737888	Mitchell	850	Spain	Female	43	2	125510.82	1	1	1		

```
3          93826.63       0
4          79084.10       0
```

[9]:
```
# deleting the unnecessary columns (RowNumber, CustomerId, Surname)

data.drop(['RowNumber', 'CustomerId', 'Surname'], axis=1, inplace=True)
```

[10]:
```
# sample of data after deleting the unnecessary columns

data.head()
```

[10]:

	CreditScore	Geography	Gender	Age	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMember	EstimatedSalary	Exited
0	619	France	Female	42	2	0.00	1	1	1	101348.88	1
1	608	Spain	Female	41	1	83807.86	1	0	1	112542.58	0
2	502	France	Female	42	8	159660.80	3	1	0	113931.57	1
3	699	France	Female	39	1	0.00	2	0	0	93826.63	0
4	850	Spain	Female	43	2	125510.82	1	1	1	79084.10	0

[11]:
```
# We can check if the pandas dataframe 'data' has any null values in each of its column using the isnull() function.
# Furthermore, the sum() function tells us the total null values in each column.

data.isnull().sum()
```

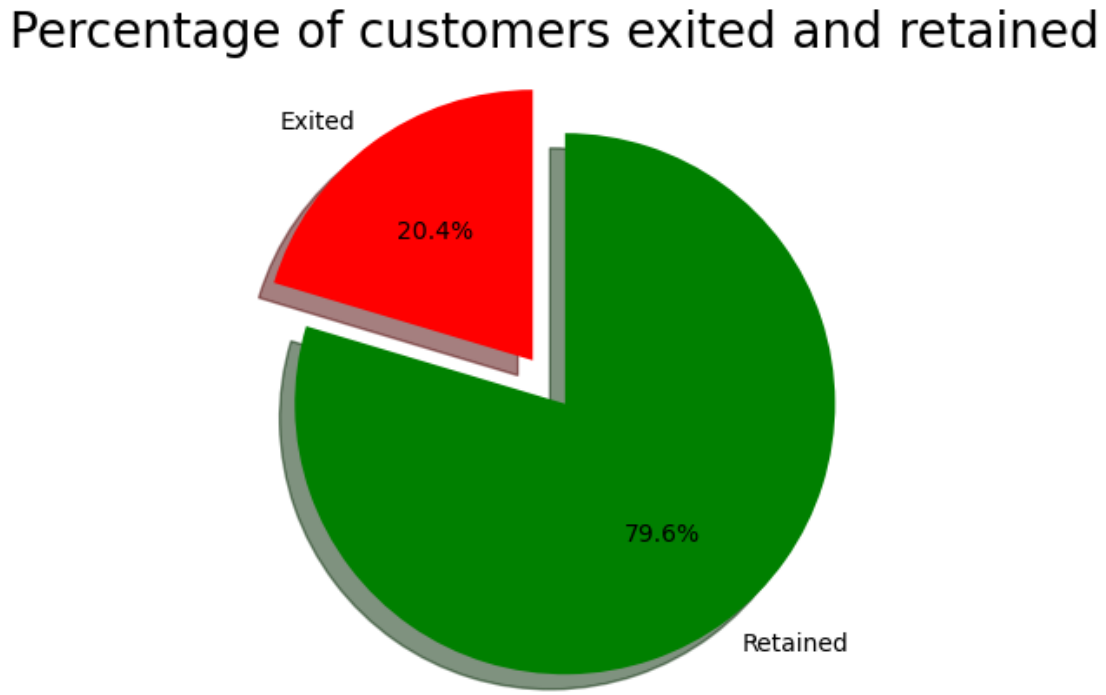
[11]:
```
CreditScore        0
Geography          0
Gender             0
Age                0
Tenure             0
Balance            0
NumOfProducts      0
HasCrCard          0
IsActiveMember     0
EstimatedSalary    0
Exited             0
dtype: int64
```

[12]:
```
# Pie chart to display the amount (percentage) of customers churned and the ones retained
```

```
labels = ['Exited', 'Retained']
sizes = [data.Exited[data['Exited'] == 1].count(), data.Exited[data['Exited']␣
 ↪== 0].count()]
explode = [0.1, 0]

# create and plot the pie chart

plt.pie(sizes, explode=explode, labels=labels, autopct='%1.1f%%', shadow=True,␣
 ↪startangle=90, radius=0.5, colors=['r', 'g'], )
plt.title("Percentage of customers exited and retained", size = 20)
plt.axis('equal')
plt.show()
```



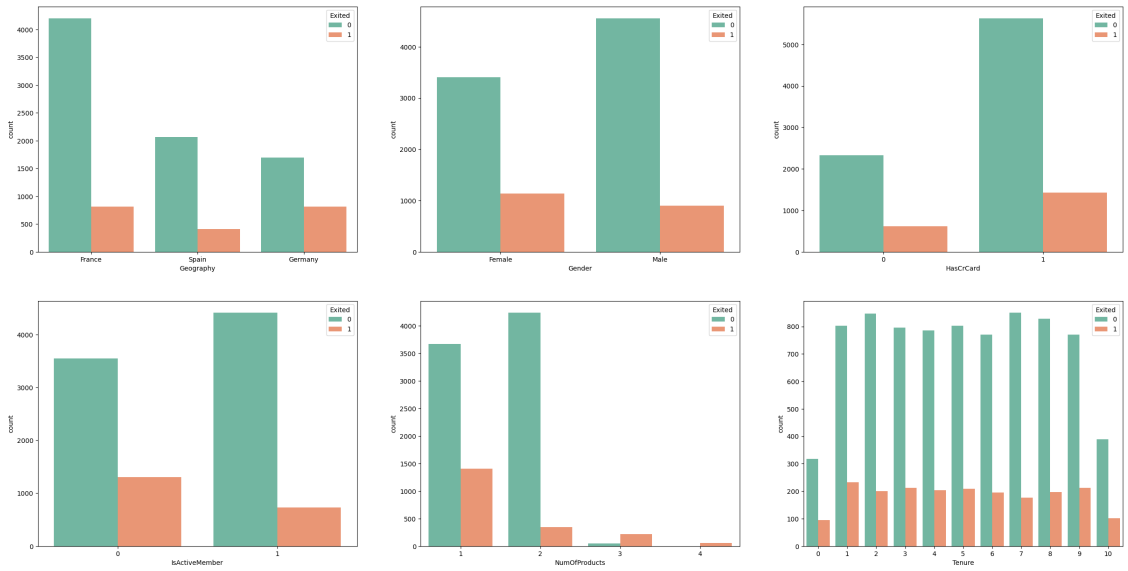
[13]:
```
# Count column plots to map the dependence of 'Exited' column on categorical␣
 ↪features

fig, ax = plt.subplots(2, 3, figsize=(30, 15))

sns.countplot(x='Geography', hue='Exited', data=data, palette='Set2',␣
 ↪ax=ax[0][0])
sns.countplot(x='Gender', hue='Exited', data=data, palette='Set2', ax=ax[0][1])
sns.countplot(x='HasCrCard', hue='Exited', data=data, palette='Set2',␣
 ↪ax=ax[0][2])
```

```
sns.countplot(x='IsActiveMember', hue='Exited', data=data, palette='Set2',␣
 ↪ax=ax[1][0])
sns.countplot(x='NumOfProducts', hue='Exited', data=data, palette='Set2',␣
 ↪ax=ax[1][1])
sns.countplot(x='Tenure', hue='Exited', data=data, palette='Set2', ax=ax[1][2])

plt.show()
```

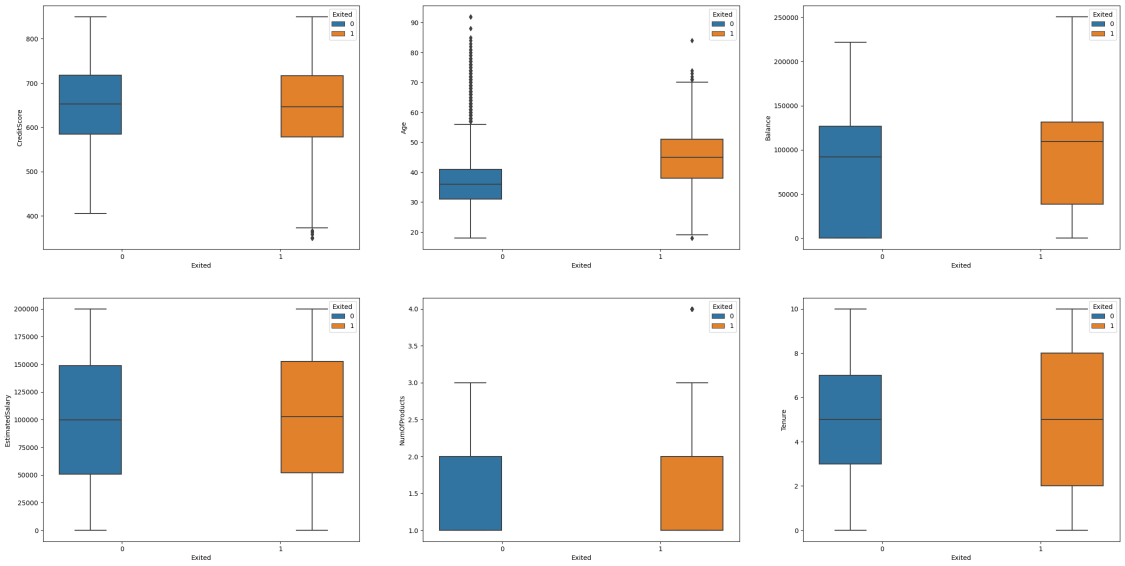


[14]:
```
# Count column plots to map the dependence of 'Exited' column on continuous and␣
 ↪numerical features

fig, ax = plt.subplots(2, 3, figsize=(30, 15))

sns.boxplot(data=data, x='Exited', y='CreditScore', hue='Exited', ax=ax[0][0])
sns.boxplot(data=data, x='Exited', y='Age', hue='Exited', ax=ax[0][1])
sns.boxplot(data=data, x='Exited', y='Balance', hue='Exited', ax=ax[0][2])
sns.boxplot(data=data, x='Exited', y='EstimatedSalary', hue='Exited',␣
 ↪ax=ax[1][0])
sns.boxplot(data=data, x='Exited', y='NumOfProducts', hue='Exited', ax=ax[1][1])
sns.boxplot(data=data, x='Exited', y='Tenure', hue='Exited', ax=ax[1][2])

plt.show()
```



[15]:
```
# list of continuous and categorical variables/features

continuous_vars = ['CreditScore',  'Age', 'Tenure', 'Balance','NumOfProducts',␣
 ↪'EstimatedSalary']
categorical_vars = ['HasCrCard', 'IsActiveMember','Geography', 'Gender']

# separating the train and test data using a 80%-20% split

data_train = data.sample(frac=0.8, random_state=100)
data_test = data.drop(data_train.index)

# check the number of rows in each data set for verification

print('Number of rows in train data: ', len(data_train))
print('Number of rows in test data: ', len(data_test))

print()

data_train = data_train[['Exited'] + continuous_vars + categorical_vars]
data_train.head()
```

```
Number of rows in train data:  8000
Number of rows in test data:  2000
```

[15]:

	Exited	CreditScore	Age	Tenure	Balance	NumOfProducts	\
8018	1	632	23	3	122478.51	1	
9225	0	594	32	4	120074.97	2	
3854	0	687	33	9	135962.40	2	

```
2029       0          520   33       4  156297.58              2
3539       0          667   42       6       0.00              1

      EstimatedSalary  HasCrCard  IsActiveMember Geography  Gender
8018        147230.77          1               0   Germany    Male
9225        162961.79          1               1   Germany  Female
3854        121747.96          1               0   Germany    Male
2029        166102.61          1               1    France    Male
3539         88890.05          1               0    France    Male
```

[16]:
```
# turning 0 values of numerical categorical features into -1
# to introduce negative relation in the calculations

data_train.loc[data_train.HasCrCard == 0, 'HasCrCard'] = -1
data_train.loc[data_train.IsActiveMember == 0, 'IsActiveMember'] = -1

data_train.head()
```

[16]:
```
      Exited  CreditScore  Age  Tenure    Balance  NumOfProducts  \
8018       1          632   23       3  122478.51              1
9225       0          594   32       4  120074.97              2
3854       0          687   33       9  135962.40              2
2029       0          520   33       4  156297.58              2
3539       0          667   42       6       0.00              1

      EstimatedSalary  HasCrCard  IsActiveMember Geography  Gender
8018        147230.77          1              -1   Germany    Male
9225        162961.79          1               1   Germany  Female
3854        121747.96          1              -1   Germany    Male
2029        166102.61          1               1    France    Male
3539         88890.05          1              -1    France    Male
```

[17]:
```
# list of categorical variables

var_list = ['Geography', 'Gender']

# turning the categorical variables into one-hot vectors

for var in var_list:
  for val in data_train[var].unique():
    data_train[var + '_' + val] = np.where(data_train[var] == val, 1, -1)

data_train = data_train.drop(var_list, axis=1)

data_train.head()
```

[17]:
```
      Exited  CreditScore  Age  Tenure    Balance  NumOfProducts  \
8018       1          632   23       3  122478.51              1
9225       0          594   32       4  120074.97              2
3854       0          687   33       9  135962.40              2
2029       0          520   33       4  156297.58              2
3539       0          667   42       6       0.00              1

      EstimatedSalary  HasCrCard  IsActiveMember  Geography_Germany  \
8018        147230.77          1              -1                  1
9225        162961.79          1               1                  1
3854        121747.96          1              -1                  1
2029        166102.61          1               1                 -1
3539         88890.05          1              -1                 -1

      Geography_France  Geography_Spain  Gender_Male  Gender_Female
8018                -1               -1            1             -1
9225                -1               -1           -1              1
3854                -1               -1            1             -1
2029                 1               -1            1             -1
3539                 1               -1            1             -1
```

[18]:
```
min_values = data_train[continuous_vars].min()
max_values = data_train[continuous_vars].max()

data_train[continuous_vars] = (data_train[continuous_vars] - min_values) /␣
 ↪(max_values - min_values)
data_train.head()
```

[18]:
```
      Exited  CreditScore       Age  Tenure   Balance  NumOfProducts  \
8018       1        0.564  0.067568     0.3  0.488160       0.000000
9225       0        0.488  0.189189     0.4  0.478581       0.333333
3854       0        0.674  0.202703     0.9  0.541903       0.333333
2029       0        0.340  0.202703     0.4  0.622952       0.333333
3539       0        0.634  0.324324     0.6  0.000000       0.000000

      EstimatedSalary  HasCrCard  IsActiveMember  Geography_Germany  \
8018         0.736166          1              -1                  1
9225         0.814829          1               1                  1
3854         0.608740          1              -1                  1
2029         0.830534          1               1                 -1
3539         0.444435          1              -1                 -1

      Geography_France  Geography_Spain  Gender_Male  Gender_Female
8018                -1               -1            1             -1
9225                -1               -1           -1              1
3854                -1               -1            1             -1
2029                 1               -1            1             -1
```

```
3539                1              -1              1              -1
```

[19]:
```
# important libraries

from sklearn.model_selection import GridSearchCV

# models

from sklearn.linear_model import SGDClassifier
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.ensemble import RandomForestClassifier
from xgboost import XGBClassifier

# metrics

from sklearn.metrics import accuracy_score
from sklearn.metrics import classification_report
from sklearn.metrics import roc_auc_score
from sklearn.metrics import roc_curve
```

[20]:
```
# this method will show us the details of each model
# which will help us in deciding the best model

def best_model(model):
  print(model.best_score_)
  print(model.best_params_)
  print(model.best_estimator_)
```

[21]:
```
# SGD classifier
import time
start_time = time.time()

parameters = {'loss': ['hinge', 'log'],
              'max_iter': [50, 100, 200, 300],
              'fit_intercept':[True],
              'penalty':['l2'],
              'tol':[0.00001, 0.0001, 0.000001]}

SGD_grid_model = GridSearchCV(SGDClassifier(),
                              param_grid=parameters,
                              cv=10,
                              refit=True,
                              verbose=0)

SGD_grid_model.fit(data_train.loc[:, data_train.columns != 'Exited'],␣
 ↪data_train.Exited)
```

```
print('[INFO] Time taken: %.1f seconds.\n' % (time.time() - start_time))

best_model(SGD_grid_model)
```

```
C:\Users\HP\anaconda3\Lib\site-
packages\sklearn\linear_model\_stochastic_gradient.py:713: ConvergenceWarning:
Maximum number of iteration reached before convergence. Consider increasing
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packages\sklearn\linear_model\_stochastic_gradient.py:713: ConvergenceWarning:
Maximum number of iteration reached before convergence. Consider increasing
max_iter to improve the fit.
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Maximum number of iteration reached before convergence. Consider increasing
max_iter to improve the fit.
  warnings.warn(
```

```
[INFO] Time taken: 6.5 seconds.

0.80425
{'fit_intercept': True, 'loss': 'hinge', 'max_iter': 50, 'penalty': 'l2', 'tol':
1e-06}
SGDClassifier(max_iter=50, tol=1e-06)
```

```
C:\Users\HP\anaconda3\Lib\site-
packages\sklearn\model_selection\_validation.py:425: FitFailedWarning:
120 fits failed out of a total of 240.
The score on these train-test partitions for these parameters will be set to
nan.
If these failures are not expected, you can try to debug them by setting
error_score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------------
120 fits failed with the following error:
Traceback (most recent call last):
  File "C:\Users\HP\anaconda3\Lib\site-
packages\sklearn\model_selection\_validation.py", line 732, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "C:\Users\HP\anaconda3\Lib\site-packages\sklearn\base.py", line 1144, in
wrapper
    estimator._validate_params()
  File "C:\Users\HP\anaconda3\Lib\site-packages\sklearn\base.py", line 637, in
_validate_params
    validate_parameter_constraints(
  File "C:\Users\HP\anaconda3\Lib\site-
packages\sklearn\utils\_param_validation.py", line 95, in
validate_parameter_constraints
    raise InvalidParameterError(
sklearn.utils._param_validation.InvalidParameterError: The 'loss' parameter of
SGDClassifier must be a str among {'hinge', 'squared_hinge',
'epsilon_insensitive', 'perceptron', 'huber', 'squared_epsilon_insensitive',
'squared_error', 'modified_huber', 'log_loss'}. Got 'log' instead.

  warnings.warn(some_fits_failed_message, FitFailedWarning)
```

```
C:\Users\HP\anaconda3\Lib\site-packages\sklearn\model_selection\_search.py:976:
UserWarning: One or more of the test scores are non-finite: [0.801375 0.801125
0.80425  0.797875 0.797875 0.798125 0.797875 0.79775
 0.797875 0.797875 0.798    0.798625      nan      nan      nan      nan
      nan      nan      nan      nan      nan      nan      nan      nan]
  warnings.warn(
C:\Users\HP\anaconda3\Lib\site-
packages\sklearn\linear_model\_stochastic_gradient.py:713: ConvergenceWarning:
Maximum number of iteration reached before convergence. Consider increasing
max_iter to improve the fit.
  warnings.warn(
```

[22]:
```
# Logistic Regression classifier

start_time = time.time()

parameters = {'C': [0.1, 0.5, 1, 5, 10, 50, 100],
              'max_iter': [50, 100, 200, 300],
              'fit_intercept':[True],
              'intercept_scaling':[1],
              'penalty':['l2'],
              'tol':[0.00001, 0.0001, 0.000001]}

LR_grid_model = GridSearchCV(LogisticRegression(),
                             param_grid=parameters,
                             cv=10,
                             refit=True,
                             verbose=0)

LR_grid_model.fit(data_train.loc[:, data_train.columns != 'Exited'], data_train.
 ↪Exited)

print('[INFO] Time taken: %.1f seconds.\n' % (time.time() - start_time))

best_model(LR_grid_model)
```

```
C:\Users\HP\anaconda3\Lib\site-packages\sklearn\linear_model\_logistic.py:460:
ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
C:\Users\HP\anaconda3\Lib\site-packages\sklearn\linear_model\_logistic.py:460:
ConvergenceWarning: lbfgs failed to converge (status=1):
```

```
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```
C:\Users\HP\anaconda3\Lib\site-packages\sklearn\linear_model\_logistic.py:460:
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```
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  n_iter_i = _check_optimize_result(
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```
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```
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```
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    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
```

```
[INFO] Time taken: 29.0 seconds.

0.813875
{'C': 0.1, 'fit_intercept': True, 'intercept_scaling': 1, 'max_iter': 50,
'penalty': 'l2', 'tol': 1e-05}
LogisticRegression(C=0.1, max_iter=50, tol=1e-05)
```

[23]:
```
# Support Vector Machines (RBF kernel)

start_time = time.time()

parameters = {'C': [1, 10, 50, 100],
              'gamma': [0.1, 0.01, 0.001],
              'probability': [True],
              'kernel': ['rbf']}

SVM_rbf_grid_model = GridSearchCV(SVC(),
                                  parameters,
                                  cv=5,
                                  refit=True,
                                  verbose=0)

SVM_rbf_grid_model.fit(data_train.loc[:, data_train.columns != 'Exited'],␣
 ↪data_train.Exited)

print('[INFO] Time taken: %.1f seconds.\n' % (time.time() - start_time))

best_model(SVM_rbf_grid_model)
```

```
[INFO] Time taken: 571.0 seconds.

0.8466249999999998
{'C': 100, 'gamma': 0.1, 'kernel': 'rbf', 'probability': True}
SVC(C=100, gamma=0.1, probability=True)
```

[24]:
```
# Support Vector Machines (Poly kernel)

start_time = time.time()

parameters = {'C': [1, 10, 50, 100],
              'gamma': [0.1, 0.01, 0.001],
```

```
              'probability': [True],
              'kernel': ['poly'],
              'degree': [2, 3]}

SVM_poly_grid_model = GridSearchCV(SVC(),
                                   parameters,
                                   cv=5,
                                   refit=True,
                                   verbose=0)

SVM_poly_grid_model.fit(data_train.loc[:, data_train.columns != 'Exited'],␣
 ↪data_train.Exited)

print('[INFO] Time taken: %.1f seconds.\n' % (time.time() - start_time))

best_model(SVM_poly_grid_model)
```

```
[INFO] Time taken: 677.9 seconds.

0.852125
{'C': 100, 'degree': 2, 'gamma': 0.1, 'kernel': 'poly', 'probability': True}
SVC(C=100, degree=2, gamma=0.1, kernel='poly', probability=True)
```

[25]:
```
# Random Forest Classifier

start_time = time.time()

parameters = {'max_depth': [6, 7, 8, 9, 10],
              'max_features': [5, 6, 7, 8, 9],
              'n_estimators':[10, 50, 100],
              'min_samples_split': [3, 5, 6, 7]}

RF_grid_model = GridSearchCV(RandomForestClassifier(),
                             parameters,
                             cv=10,
                             refit=True,
                             verbose=0)

RF_grid_model.fit(data_train.loc[:, data_train.columns != 'Exited'], data_train.
 ↪Exited)

print('[INFO] Time taken: %.1f seconds.\n' % (time.time() - start_time))

best_model(RF_grid_model)
```

```
[INFO] Time taken: 3909.0 seconds.

0.865
```

```
{'max_depth': 10, 'max_features': 8, 'min_samples_split': 7, 'n_estimators':
100}
RandomForestClassifier(max_depth=10, max_features=8, min_samples_split=7)
```

[26]:
```
# Extreme Gradient Boost (XGBoost) classifier

start_time = time.time()

parameters = {'max_depth': [5, 6, 7, 8],
              'gamma': [0.01, 0.001, 0.001],
              'min_child_weight': [1, 5, 10],
              'learning_rate': [0.01, 0.05, 0.1, 0.2, 0.3],
              'n_estimators': [5, 10, 20, 100]}

XGB_grid_model = GridSearchCV(XGBClassifier(),
                              parameters,
                              cv=10,
                              refit=True,
                              verbose=0)

XGB_grid_model.fit(data_train.loc[:, data_train.columns != 'Exited'],␣
 ↪data_train.Exited)

print('[INFO] Time taken: %.1f seconds.\n' % (time.time() - start_time))

best_model(XGB_grid_model)
```

```
[INFO] Time taken: 658.1 seconds.

0.8626249999999999
{'gamma': 0.001, 'learning_rate': 0.1, 'max_depth': 5, 'min_child_weight': 5,
'n_estimators': 100}
XGBClassifier(base_score=None, booster=None, callbacks=None,
              colsample_bylevel=None, colsample_bynode=None,
              colsample_bytree=None, device=None, early_stopping_rounds=None,
              enable_categorical=False, eval_metric=None, feature_types=None,
              gamma=0.001, grow_policy=None, importance_type=None,
              interaction_constraints=None, learning_rate=0.1, max_bin=None,
              max_cat_threshold=None, max_cat_to_onehot=None,
              max_delta_step=None, max_depth=5, max_leaves=None,
              min_child_weight=5, missing=nan, monotone_constraints=None,
              multi_strategy=None, n_estimators=100, n_jobs=None,
              num_parallel_tree=None, random_state=None, …)
```

[28]:
```
# SGD classifier

sgd_model = SGDClassifier(alpha=0.0001, average=False, class_weight=None,
                          early_stopping=False, epsilon=0.1, eta0=0.0,
```

```
                           fit_intercept=True, l1_ratio=0.15,
                           learning_rate='optimal', loss='log_loss',␣
 ↪max_iter=300,
                           n_iter_no_change=5, n_jobs=None, penalty='l2',
                           power_t=0.5, random_state=None, shuffle=True,
                           tol=1e-06, validation_fraction=0.1, verbose=0,
                           warm_start=False)

sgd_model.fit(data_train.loc[:, data_train.columns != 'Exited'], data_train.
 ↪Exited)
```

[28]:
```
SGDClassifier(loss='log_loss', max_iter=300, tol=1e-06)
```

[29]:
```
# Logistic Regression

lr_model = LogisticRegression(C=0.1, class_weight=None, dual=False,
                              fit_intercept=True, intercept_scaling=1,
                              l1_ratio=None, max_iter=50, multi_class='auto',
                              n_jobs=None, penalty='l2', random_state=None,
                              solver='lbfgs', tol=1e-05, verbose=0,
                              warm_start=False)

lr_model.fit(data_train.loc[:, data_train.columns != 'Exited'], data_train.
 ↪Exited)
```

[29]:
```
LogisticRegression(C=0.1, max_iter=50, tol=1e-05)
```

[30]:
```
# SVM (RBF kernel)

svm_rbf_model = SVC(C=100, break_ties=False, cache_size=200, class_weight=None,
                    coef0=0.0, decision_function_shape='ovr', degree=3,
                    gamma=0.1, kernel='rbf', max_iter=-1, probability=True,
                    random_state=None, shrinking=True, tol=0.001,
                    verbose=False)

svm_rbf_model.fit(data_train.loc[:, data_train.columns != 'Exited'], data_train.
 ↪Exited)
```

[30]:
```
SVC(C=100, gamma=0.1, probability=True)
```

[31]:
```
# SVM (Poly kernel)

svm_poly_model = SVC(C=100, break_ties=False, cache_size=200, class_weight=None,
                     coef0=0.0, decision_function_shape='ovr', degree=2,
                     gamma=0.1, kernel='poly', max_iter=-1, probability=True,
                     random_state=None, shrinking=True, tol=0.001,
                     verbose=False)
```

```
svm_poly_model.fit(data_train.loc[:, data_train.columns != 'Exited'],␣
 ↪data_train.Exited)
```

[31]:
```
SVC(C=100, degree=2, gamma=0.1, kernel='poly', probability=True)
```

[33]:
```
# Random Forest classifier

rf_model = RandomForestClassifier(bootstrap=True, ccp_alpha=0.0,
                                  class_weight=None, criterion='gini',
                                  max_depth=9, max_features=9,
                                  max_leaf_nodes=None, max_samples=None,
                                  min_impurity_decrease=0.0,
                                  min_samples_leaf=1,
                                  min_samples_split=7,
                                  min_weight_fraction_leaf=0.0, n_estimators=50,
                                  n_jobs=None, oob_score=False,
                                  random_state=None, verbose=0,
                                  warm_start=False)

rf_model.fit(data_train.loc[:, data_train.columns != 'Exited'], data_train.
 ↪Exited)
```

[33]:
```
RandomForestClassifier(max_depth=9, max_features=9, min_samples_split=7,
                       n_estimators=50)
```

[34]:
```
# XGBoost classifier

xgb_model = XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
                          colsample_bynode=1, colsample_bytree=1, gamma=0.001,
                          learning_rate=0.1, max_delta_step=0, max_depth=5,
                          min_child_weight=1, missing=None, n_estimators=100,
                          n_jobs=1, nthread=None, objective='binary:logistic',
                          random_state=0, reg_alpha=0, reg_lambda=1,
                          scale_pos_weight=1, seed=None, silent=None,
                          subsample=1, verbosity=1)

xgb_model.fit(data_train.loc[:, data_train.columns != 'Exited'], data_train.
 ↪Exited)
```

[34]:
```
XGBClassifier(base_score=0.5, booster='gbtree', callbacks=None,
              colsample_bylevel=1, colsample_bynode=1, colsample_bytree=1,
              device=None, early_stopping_rounds=None, enable_categorical=False,
              eval_metric=None, feature_types=None, gamma=0.001,
              grow_policy=None, importance_type=None,
              interaction_constraints=None, learning_rate=0.1, max_bin=None,
              max_cat_threshold=None, max_cat_to_onehot=None, max_delta_step=0,
```

```
                max_depth=5, max_leaves=None, min_child_weight=1, missing=None,
                monotone_constraints=None, multi_strategy=None, n_estimators=100,
                n_jobs=1, nthread=None, num_parallel_tree=None, …)
```

[35]:
```
print('[INFO] SGD classifier:\n')
print(classification_report(data_train.Exited, sgd_model.predict(data_train.
  ↪loc[:, data_train.columns != 'Exited'])))
```

```
[INFO] SGD classifier:

              precision    recall  f1-score   support

           0       0.83      0.96      0.89      6382
           1       0.59      0.23      0.33      1618

    accuracy                           0.81      8000
   macro avg       0.71      0.59      0.61      8000
weighted avg       0.78      0.81      0.78      8000
```

[36]:
```
print('[INFO] Logistic Regression classifier:\n')
print(classification_report(data_train.Exited, lr_model.predict(data_train.loc[:
  ↪, data_train.columns != 'Exited'])))
```

```
[INFO] Logistic Regression classifier:

              precision    recall  f1-score   support

           0       0.82      0.98      0.89      6382
           1       0.69      0.15      0.25      1618

    accuracy                           0.81      8000
   macro avg       0.75      0.57      0.57      8000
weighted avg       0.79      0.81      0.76      8000
```

[37]:
```
print('[INFO] SVM (RBF) classifier:\n')
print(classification_report(data_train.Exited, svm_rbf_model.predict(data_train.
  ↪loc[:, data_train.columns != 'Exited'])))
```

```
[INFO] SVM (RBF) classifier:

              precision    recall  f1-score   support

           0       0.86      0.98      0.92      6382
           1       0.84      0.38      0.53      1618

    accuracy                           0.86      8000
   macro avg       0.85      0.68      0.72      8000
```

```
weighted avg       0.86      0.86      0.84      8000
```

[38]:
```
print('[INFO] SVM (Poly) classifier:\n')
print(classification_report(data_train.Exited, svm_poly_model.
  ↪predict(data_train.loc[:, data_train.columns != 'Exited'])))
```

```
[INFO] SVM (Poly) classifier:

              precision    recall  f1-score   support

           0       0.86      0.98      0.91      6382
           1       0.81      0.36      0.50      1618

    accuracy                           0.85      8000
   macro avg       0.83      0.67      0.71      8000
weighted avg       0.85      0.85      0.83      8000
```

[39]:
```
print('[INFO] Random Forest classifier:\n')
print(classification_report(data_train.Exited, rf_model.predict(data_train.loc[:
  ↪, data_train.columns != 'Exited'])))
```

```
[INFO] Random Forest classifier:

              precision    recall  f1-score   support

           0       0.90      0.98      0.94      6382
           1       0.88      0.57      0.69      1618

    accuracy                           0.90      8000
   macro avg       0.89      0.77      0.81      8000
weighted avg       0.89      0.90      0.89      8000
```

[41]:
```
def get_roc(y, predict_vals, prob_values):
  roc_score = roc_auc_score(y, predict_vals)
  false_positives, true_positives, _ = roc_curve(y, prob_values)
  return (roc_score, false_positives, true_positives)
```

[46]:
```
y = data_train.Exited
X = data_train.loc[:, data_train.columns != 'Exited']

roc_sgd, false_sgd, true_sgd = get_roc(y, sgd_model.predict(X), sgd_model.
  ↪predict_proba(X)[:, 1])
roc_lr, false_lr, true_lr = get_roc(y, lr_model.predict(X), lr_model.
  ↪predict_proba(X)[:, 1])
```

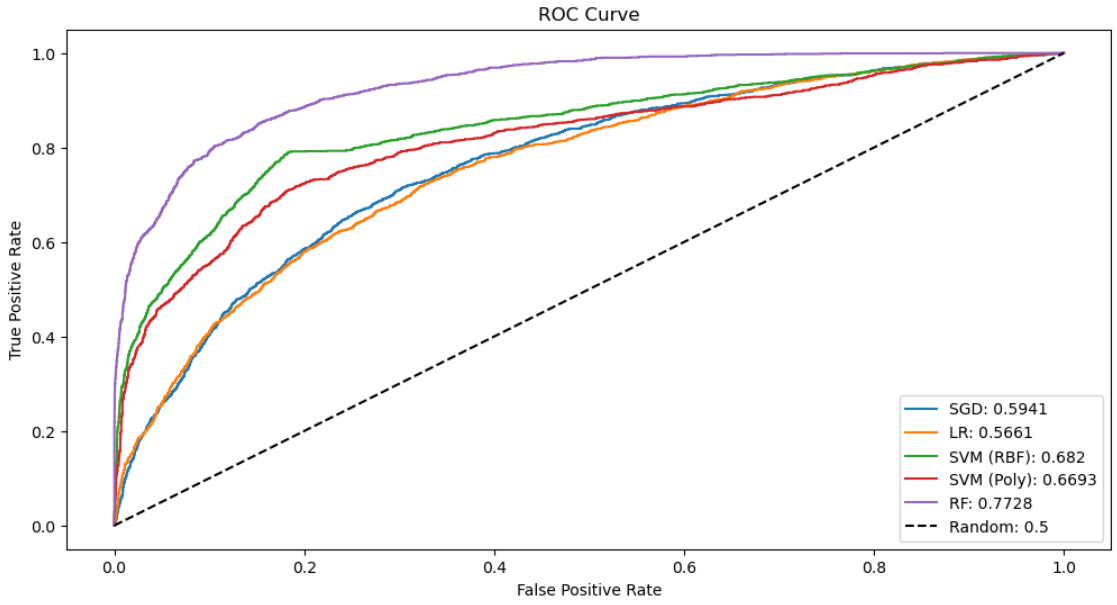
```
roc_svm_rbf, false_svm_rbf, true_svm_rbf = get_roc(y, svm_rbf_model.predict(X),␣
 ↪svm_rbf_model.predict_proba(X)[:, 1])
roc_svm_poly, false_svm_poly, true_svm_poly = get_roc(y, svm_poly_model.
 ↪predict(X), svm_poly_model.predict_proba(X)[:, 1])
roc_rf, false_rf, true_rf = get_roc(y, rf_model.predict(X), rf_model.
 ↪predict_proba(X)[:, 1])
```

[50]:
```
plt.figure(figsize = (12,6), linewidth = 2)

plt.plot(false_sgd, true_sgd, label = 'SGD: ' + str(round(roc_sgd, 4)))
plt.plot(false_lr, true_lr, label = 'LR: ' + str(round(roc_lr, 4)))
plt.plot(false_svm_rbf, true_svm_rbf, label = 'SVM (RBF): ' +␣
 ↪str(round(roc_svm_rbf, 4)))
plt.plot(false_svm_poly, true_svm_poly, label = 'SVM (Poly): ' +␣
 ↪str(round(roc_svm_poly, 4)))
plt.plot(false_rf, true_rf, label = 'RF: ' + str(round(roc_rf, 4)))
plt.plot([0, 1], [0, 1], 'k--', label = 'Random: 0.5')

plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve')
plt.legend(loc='best')

plt.show()
```



[ ]:
```
data_test = data_test[['Exited'] + continuous_vars + categorical_vars]

# Change the 0 in categorical variables to -1

data_test.loc[data_test.HasCrCard == 0, 'HasCrCard'] = -1
data_test.loc[data_test.IsActiveMember == 0, 'IsActiveMember'] = -1

var_list = ['Geography', 'Gender']

for var in var_list:
    for val in data_test[var].unique():
        data_test[var + '_' + val] = np.where(data_test[var] == val, 1, -1)

# Drop the original categorical columns after one-hot encoding
data_test = data_test.drop(var_list, axis=1)

# Ensure that all one hot encoded variables that appear in the train data␣
 ↪appear in the subsequent data
for column in data_train.columns:
    if column not in data_test.columns:
        data_test[column] = -1

# Reorder columns to match the order in the training dataset
data_test = data_test[data_train.columns]

# MinMax scaling of the continuous variables based on min and max from the␣
 ↪train data
data_test[continuous_vars] = (data_test[continuous_vars] - min_values) /␣
 ↪(max_values - min_values)
```

[54]:
```
data_test = data_test.mask(np.isinf(data_test))
data_test = data_test.dropna()

print(data_test.shape)
```

```
(2000, 14)
```

[56]:
```
print(classification_report(data_test.Exited,  rf_model.predict(data_test.loc[:
 ↪, data_test.columns != 'Exited'])))
```

```
              precision    recall  f1-score   support

           0       0.88      0.97      0.92      1581
           1       0.79      0.49      0.60       419

    accuracy                           0.87      2000
   macro avg       0.83      0.73      0.76      2000
weighted avg       0.86      0.87      0.85      2000
```

[57]:
```
roc_rf_test, false_rf_test, true_rf_test = get_roc(data_test.Exited,
                                                   rf_model.predict(data_test.
 ↪loc[:, data_test.columns != 'Exited']),
                                                   rf_model.
 ↪predict_proba(data_test.loc[:, data_test.columns != 'Exited'])[:,1])
```

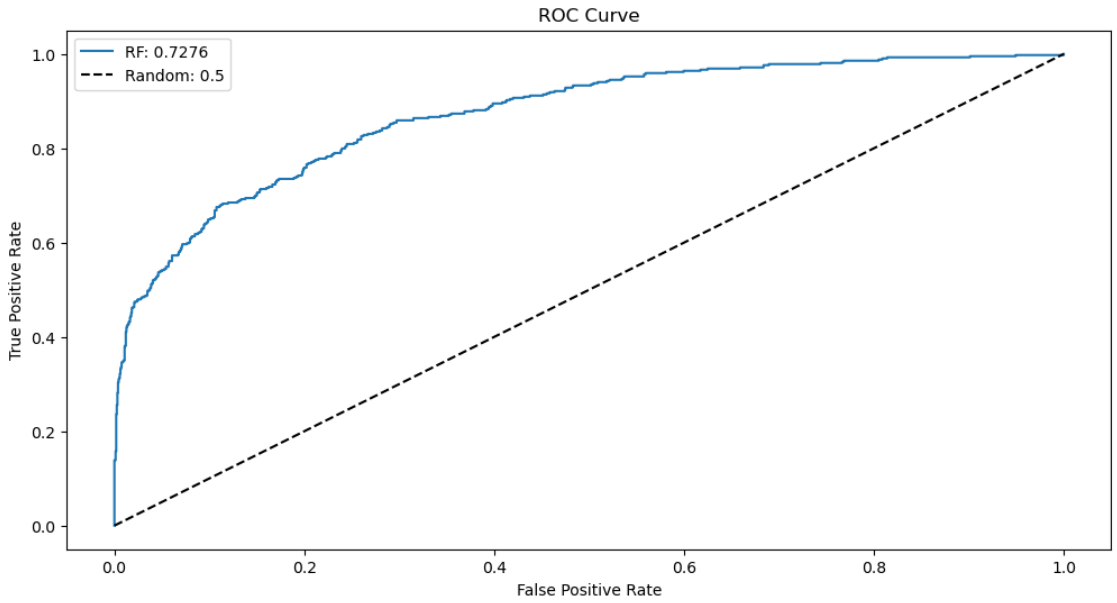
[58]:
```
plt.figure(figsize = (12,6), linewidth = 2)

plt.plot(false_rf_test,
         true_rf_test,
         label = 'RF: ' + str(round(roc_rf_test, 4)))

plt.plot([0, 1], [0, 1], 'k--', label = 'Random: 0.5')

plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve')
plt.legend(loc='best')

plt.show()
```



[ ]: