Finance

```python
# import libraries

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import (accuracy_score, classification_report,
f1_score,
  roc_auc_score, roc_curve, auc, confusion_matrix, make_scorer)
from sklearn.manifold import TSNE
from sklearn.decomposition import PCA
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.naive_bayes import GaussianNB
from sklearn.linear_model import LogisticRegression, SGDClassifier
from sklearn.ensemble import RandomForestClassifier
from xgboost import XGBClassifier
import phik
import pickle
import math
from imblearn.over_sampling import RandomOverSampler
from imblearn.under_sampling import RandomUnderSampler
from tensorflow.keras.models import Sequential, Model
from tensorflow.keras.layers import Dense, Input, Dropout,
BatchNormalization
from tensorflow.keras.regularizers import L1L2
from tensorflow.keras.callbacks import EarlyStopping
from sklearn.ensemble import IsolationForest
from tensorflow.keras.optimizers import Adam, SGD, Adadelta, RMSprop
from tensorflow_addons.metrics import F1Score
from tensorflow.keras.utils import to_categorical
from keras_tuner import BayesianOptimization

# Upload data
finance_train_df = pd.read_csv('train_data.csv')
finance_test_hidden_df = pd.read_csv('test_data_hidden.csv')
finance_test_df = pd.read_csv('test_data.csv')
```

Project Task: Week 1

```python
# df shapes
print(finance_train_df.shape)
print(finance_test_hidden_df.shape)
print(finance_test_df.shape)
```

```
(227845, 31)
(56962, 31)
(56962, 30)
```

```
# sample data
finance_train_df.head()
```

```
       Time        V1        V2        V3        V4        V5        
V6  \
0   38355.0  1.043949  0.318555  1.045810  2.805989 -0.561113 -
0.367956   
1   22555.0 -1.665159  0.808440  1.805627  1.903416 -0.821627  
0.934790   
2    2431.0 -0.324096  0.601836  0.865329 -2.138000  0.294663 -
1.251553   
3   86773.0 -0.258270  1.217501 -0.585348 -0.875347  1.222481 -
0.311027   
4  127202.0  2.142162 -0.494988 -1.936511 -0.818288 -0.025213 -
1.027245   

         V7        V8        V9  ...       V21       V22       V23       
V24  \
0  0.032736 -0.042333 -0.322674  ... -0.240105 -0.680315  0.085328  
0.684812   
1 -0.824802  0.975890  1.747469  ... -0.335332 -0.510994  0.035839  
0.147565   
2  1.072114 -0.334896  1.071268  ...  0.012220  0.352856 -0.341505 -
0.145791   
3  1.073860 -0.161408  0.200665  ... -0.424626 -0.781158  0.019316  
0.178614   
4 -0.151627 -0.305750 -0.869482  ...  0.010115  0.021722  0.079463 -
0.480899   

        V25       V26       V27       V28  Amount  Class  
0  0.318620 -0.204963  0.001662  0.037894   49.67      0  
1 -0.529358 -0.566950 -0.595998 -0.220086   16.94      0  
2  0.094194 -0.804026  0.229428 -0.021623    1.00      0  
3 -0.315616  0.096665  0.269740 -0.020635   10.78      0  
4  0.023846 -0.279076 -0.030121 -0.043888   39.96      0  

[5 rows x 31 columns]
```

We have 28 features (encoded-> result of PCA output), timestamp and amount with class labels (0,1) as froud and non-froud.

EDA

```
# info
finance_train_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 227845 entries, 0 to 227844
```

```
Data columns (total 31 columns):
 #   Column  Non-Null Count   Dtype  
---  ------  --------------   -----  
 0   Time    227845 non-null  float64
 1   V1      227845 non-null  float64
 2   V2      227845 non-null  float64
 3   V3      227845 non-null  float64
 4   V4      227845 non-null  float64
 5   V5      227845 non-null  float64
 6   V6      227845 non-null  float64
 7   V7      227845 non-null  float64
 8   V8      227845 non-null  float64
 9   V9      227845 non-null  float64
 10  V10     227845 non-null  float64
 11  V11     227845 non-null  float64
 12  V12     227845 non-null  float64
 13  V13     227845 non-null  float64
 14  V14     227845 non-null  float64
 15  V15     227845 non-null  float64
 16  V16     227845 non-null  float64
 17  V17     227845 non-null  float64
 18  V18     227845 non-null  float64
 19  V19     227845 non-null  float64
 20  V20     227845 non-null  float64
 21  V21     227845 non-null  float64
 22  V22     227845 non-null  float64
 23  V23     227845 non-null  float64
 24  V24     227845 non-null  float64
 25  V25     227845 non-null  float64
 26  V26     227845 non-null  float64
 27  V27     227845 non-null  float64
 28  V28     227845 non-null  float64
 29  Amount  227845 non-null  float64
 30  Class   227845 non-null  int64  
dtypes: float64(30), int64(1)
memory usage: 53.9 MB
```

```
finance_train_df.isna().all().sum()
```

```
0
```

```
finance_train_df.columns
```

```
Index(['Time', 'V1', 'V2', 'V3', 'V4', 'V5', 'V6', 'V7', 'V8', 'V9',
'V10',
       'V11', 'V12', 'V13', 'V14', 'V15', 'V16', 'V17', 'V18', 'V19',
'V20',
       'V21', 'V22', 'V23', 'V24', 'V25', 'V26', 'V27', 'V28',
'Amount',
       'Class'],
      dtype='object')
```

There is no missing values and we have numeric data present.

```
# get statistical info
stats_data = finance_train_df.describe()
stats_data
```

```
                Time             V1             V2             V3  \
count  227845.000000  227845.000000  227845.000000  227845.000000
mean    94752.853076      -0.003321      -0.001652       0.001066
std     47500.410602       1.963028       1.661178       1.516107
min         0.000000     -56.407510     -72.715728     -32.965346
25%     54182.000000      -0.922851      -0.598040      -0.889246
50%     84607.000000       0.012663       0.066665       0.182170
75%    139340.000000       1.314821       0.804401       1.029449
max    172792.000000       2.454930      22.057729       9.382558

                  V4             V5             V6             V7  \
count  227845.000000  227845.000000  227845.000000  227845.000000
mean       -0.000374       0.000877       0.000770      -0.000035
std         1.415061       1.367074       1.325341       1.220384
min        -5.683171     -42.147898     -26.160506     -43.557242
25%        -0.848884      -0.690811      -0.767803      -0.554761
50%        -0.019309      -0.055243      -0.273025       0.040409
75%         0.744822       0.610852       0.400298       0.570631
max        16.875344      34.801666      22.529298      36.877368

                  V8             V9  ...            V21            V22
\
count  227845.000000  227845.000000  ...  227845.000000  227845.000000

mean        0.001625      -0.000391  ...       0.000563       0.001234

std         1.192648       1.097367  ...       0.734187       0.724544

min       -73.216718     -13.434066  ...     -34.830382     -10.933144

25%        -0.207838      -0.643365  ...      -0.228031      -0.540792

50%         0.022928      -0.050932  ...      -0.028807       0.008697

75%         0.327854       0.596671  ...       0.186852       0.529535

max        20.007208      15.594995  ...      27.202839      10.503090


                 V23            V24            V25            V26  \
count  227845.000000  227845.000000  227845.000000  227845.000000
mean       -0.001002       0.000254       0.000218      -0.001128
std         0.625165       0.606012       0.521348       0.482314
```

```
min       -44.807735      -2.836627     -10.295397      -2.604551
25%        -0.162264      -0.354099      -0.317450      -0.327910
50%        -0.011614       0.041212       0.016221      -0.053257
75%         0.147067       0.440051       0.351214       0.239885
max        22.528412       4.022866       6.070850       3.463246

                 V27            V28         Amount          Class
count  227845.000000  227845.000000  227845.000000  227845.000000
mean       -0.000346       0.000498      88.522327       0.001729
std         0.400286       0.331184     248.100141       0.041548
min       -22.565679     -11.710896       0.000000       0.000000
25%        -0.070986      -0.053117       5.590000       0.000000
50%         0.001315       0.011216      22.000000       0.000000
75%         0.091105       0.078458      77.070000       0.000000
max        12.152401      33.847808   19656.530000       1.000000

[8 rows x 31 columns]
```

```
finance_train_df[finance_train_df['Class'] == 0].describe()
```

```
                Time             V1             V2             V3  \
count  227451.000000  227451.000000  227451.000000  227451.000000
mean    94778.158337       0.005102      -0.008137       0.013458
std     47497.567552       1.932798       1.645089       1.457120
min         0.000000     -56.407510     -72.715728     -32.965346
25%     54208.000000      -0.920154      -0.599136      -0.883556
50%     84617.000000       0.015404       0.064922       0.184336
75%    139354.000000       1.315404       0.801069       1.030604
max    172792.000000       2.454930      18.183626       9.382558

                  V4             V5             V6             V7  \
count  227451.000000  227451.000000  227451.000000  227451.000000
mean       -0.008269       0.006550       0.003117       0.009964
std         1.398253       1.342508       1.322856       1.156654
min        -5.683171     -42.147898     -26.160506     -31.764946
25%        -0.850301      -0.688601      -0.766491      -0.552208
50%        -0.021897      -0.054227      -0.272081       0.041373
75%         0.739027       0.611240       0.401261       0.571178
max        16.875344      34.801666      22.529298      36.877368

                  V8             V9  ...            V21            V22
\
count  227451.000000  227451.000000  ...  227451.000000  227451.000000

mean        0.000961       0.004161  ...      -0.000736       0.001222

std         1.154287       1.087586  ...       0.712756       0.722077

min       -73.216718      -6.290730  ...     -34.830382     -10.933144
```

```
25%        -0.207839      -0.640614  ...      -0.228124      -0.540768

50%         0.022618      -0.049554  ...      -0.029115       0.008584

75%         0.326785       0.597654  ...       0.186010       0.529325

max        18.709255      15.594995  ...      22.580675      10.503090


                 V23            V24            V25            V26  \
count  227451.000000  227451.000000  227451.000000  227451.000000
mean       -0.000959       0.000431       0.000151      -0.001214
std         0.621716       0.606126       0.520723       0.482369
min       -44.807735      -2.836627     -10.295397      -2.604551
25%        -0.162080      -0.353897      -0.317450      -0.328061
50%        -0.011555       0.041289       0.016128      -0.053348
75%         0.146966       0.440280       0.351009       0.239648
max        22.528412       4.022866       6.070850       3.463246

                 V27            V28         Amount     Class
count  227451.000000  227451.000000  227451.000000  227451.0
mean       -0.000628       0.000349      88.455144       0.0
std         0.396085       0.330667     248.066088       0.0
min       -22.565679     -11.710896       0.000000       0.0
25%        -0.071007      -0.053107       5.640000       0.0
50%         0.001194       0.011169      22.000000       0.0
75%         0.090640       0.078171      77.000000       0.0
max        12.152401      33.847808   19656.530000       0.0

[8 rows x 31 columns]
```

```
finance_train_df[finance_train_df['Class'] == 1].describe()
```

```
                Time          V1          V2          V3
V4  \
count     394.000000  394.000000  394.000000  394.000000  394.000000

mean    80144.459391   -4.865812    3.741947   -7.152669    4.557039

std     46947.027931    6.948331    4.413446    7.239645    2.917991

min       472.000000  -30.552380   -8.402154  -31.103685   -1.313275

25%     41250.500000   -5.972454    1.180534   -8.813291    2.331443

50%     74647.500000   -2.331289    2.744670   -5.154274    4.146134

75%    122960.500000   -0.442917    5.204418   -2.215501    6.390866
```

```
max    170348.000000    2.132386   22.057729    2.250210   12.114672


               V5          V6          V7          V8          V9  ...
\
count  394.000000  394.000000  394.000000  394.000000  394.000000  ...

mean    -3.274295   -1.354128   -5.772326    0.384907   -2.628401  ...

std      5.442972    1.930181    7.463612    7.306385    2.576605  ...

min    -22.105532   -5.773192  -43.557242  -41.044261  -13.434066  ...

25%     -4.801176   -2.492665   -8.589239   -0.169625   -3.880445  ...

50%     -1.621234   -1.373933   -3.016983    0.615604   -2.179119  ...

75%      0.065251   -0.356945   -1.009233    1.757590   -0.790027  ...

max     11.095089    6.474115    5.802537   20.007208    3.353525  ...


              V21         V22         V23         V24         V25
V26  \
count  394.000000  394.000000  394.000000  394.000000  394.000000
394.000000
mean     0.750538    0.008633   -0.025738   -0.101968    0.038909
0.048557
std      4.233532    1.609687    1.697116    0.526688    0.805024
0.447566
min    -22.797604   -8.887017  -19.254328   -2.028024   -4.781606   -
1.152671
25%      0.040122   -0.554402   -0.339114   -0.436065   -0.318323   -
0.255973
50%      0.615305    0.091214   -0.075809   -0.060737    0.076685
0.000308
75%      1.325559    0.623456    0.287309    0.291641    0.464751
0.404597
max     27.202839    8.361985    5.466230    1.091435    2.208209
1.246604

              V27         V28      Amount  Class
count  394.000000  394.000000  394.000000  394.0
mean     0.162197    0.086224  127.306523    1.0
std      1.438879    0.548258  264.533907    0.0
min     -7.263482   -1.552593    0.000000    1.0
25%     -0.009170   -0.116723    1.000000    1.0
50%      0.404295    0.147380   11.395000    1.0
75%      0.850654    0.387926  106.385000    1.0
```

```
max      3.052358    1.779364  2125.870000    1.0

[8 rows x 31 columns]
```

From the above statistical data, we can see, there are differences between both the class labels based on the mean, min & max values for different features and amount also. So these features can be useful.

Check all the latent features and parameters with their mean and standard deviation. Value are close to 0 centered (mean) with unit standard deviation

```
stats_data.iloc[1:3, 1:-2].T
```

```
         mean       std
V1  -0.003321  1.963028
V2  -0.001652  1.661178
V3   0.001066  1.516107
V4  -0.000374  1.415061
V5   0.000877  1.367074
V6   0.000770  1.325341
V7  -0.000035  1.220384
V8   0.001625  1.192648
V9  -0.000391  1.097367
V10 -0.000794  1.087268
V11  0.002083  1.021904
V12  0.000010  0.999581
V13  0.000080  0.995449
V14  0.000928  0.959575
V15 -0.000737  0.916011
V16  0.000433  0.875795
V17 -0.000007  0.851222
V18 -0.000831  0.838685
V19 -0.000191  0.812614
V20  0.000671  0.772535
V21  0.000563  0.734187
V22  0.001234  0.724544
V23 -0.001002  0.625165
V24  0.000254  0.606012
V25  0.000218  0.521348
V26 -0.001128  0.482314
V27 -0.000346  0.400286
V28  0.000498  0.331184
```

We can see most of the values of features (V1- V28) are having mean and std close to 0 and 1 resectively.

Check the class count for each class. It's a class Imbalance problem.

```
print('Class counts')
print(finance_train_df['Class'].value_counts())
print(finance_train_df['Class'].value_counts(normalize = True))
```

```
Class counts
0    227451
1       394
Name: Class, dtype: int64
0    0.998271
1    0.001729
Name: Class, dtype: float64
```

```
finance_train_df[finance_train_df['Amount'] <= 0].size
```

```
45477
```

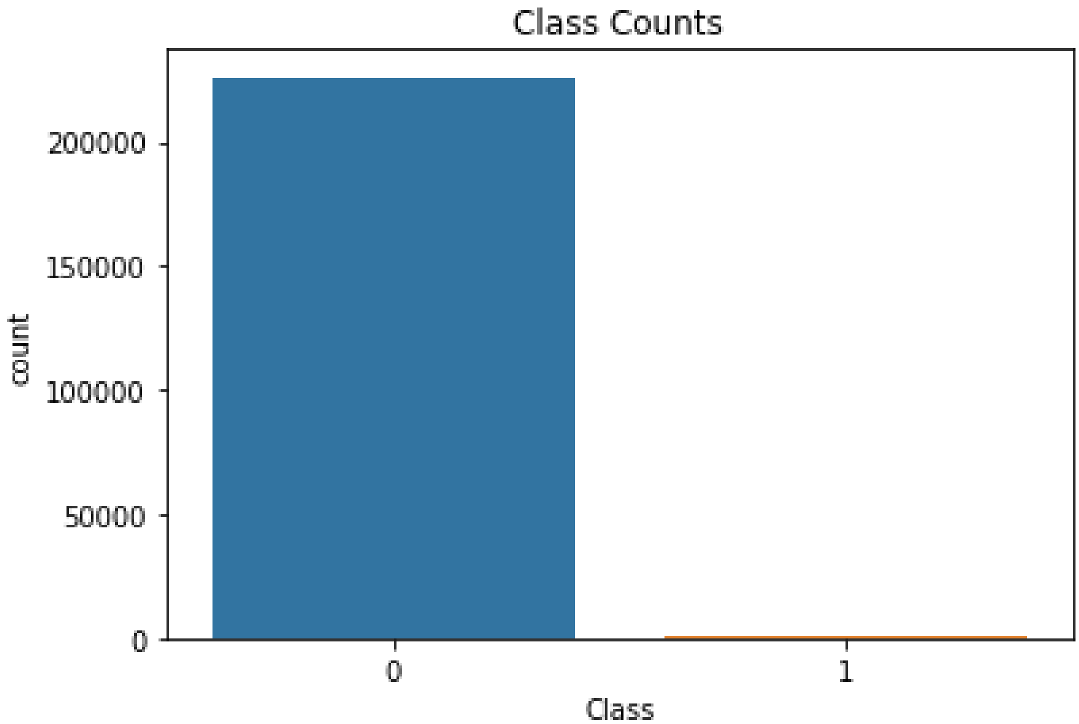
We have 45477 invalid data as well, lets get rid of them. (transactions can be made only with positive number amounts)

```
finance_train_df = finance_train_df[finance_train_df['Amount'] > 0]
```

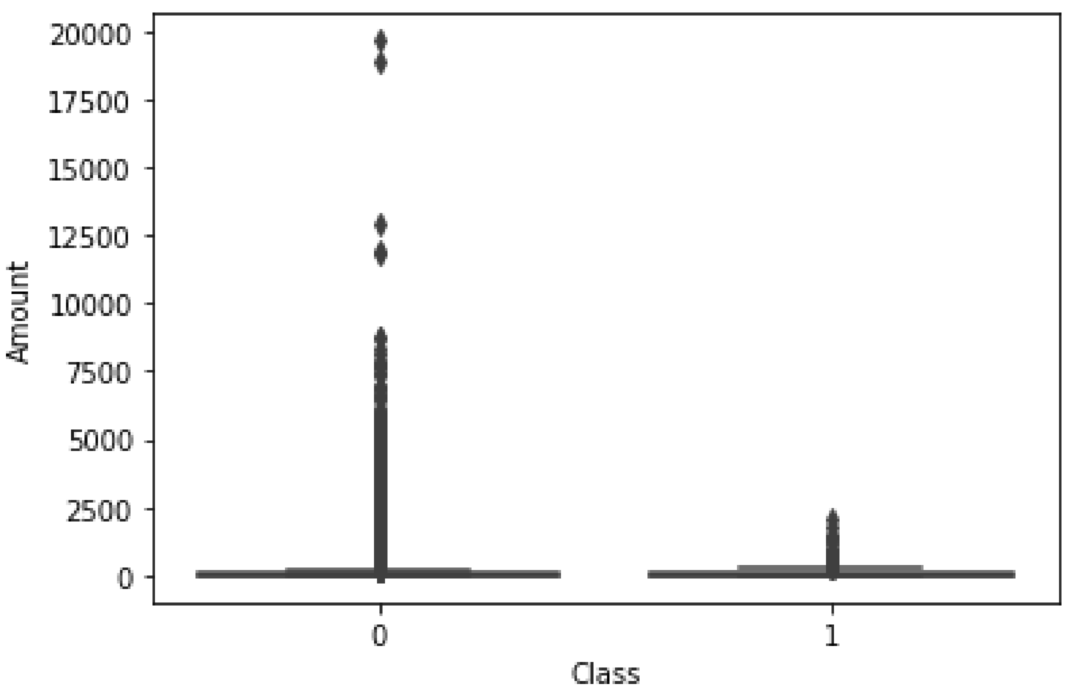
```
print('Class counts')
print(finance_train_df['Class'].value_counts())
print(finance_train_df['Class'].value_counts(normalize = True))
```

```
Class counts
0    226001
1       377
Name: Class, dtype: int64
0    0.998335
1    0.001665
Name: Class, dtype: float64
```

```
sns.countplot(x = finance_train_df['Class'])
plt.title('Class Counts')
plt.show()
```




```
sns.boxplot(x='Class', y='Amount', data=finance_train_df)
plt.show()
```




```
finance_train_df.groupby('Class')['Amount'].sum() /
finance_train_df['Amount'].sum()
```

```
Class
0    0.997513
1    0.002487
Name: Amount, dtype: float64
```

From the above result and plot, we can see, we have highly imbalanced data where non-froud count is way higher than the number of frouds.

Also we have 99.8% non-foundulant and 0.2% froudulant transactions.

Find if there is any connection between Time, Amount, and the transaction being fraudulent.

Lets try some plotting to get some insights on the class, time and amount relationships. Lets try plotting on sample of data.

We can also try to find the relation between other encoded features and class labels.

```
class0_amt_med = finance_train_df[finance_train_df['Class'] == 0]
['Amount'].median()
class1_amt_med = finance_train_df[finance_train_df['Class'] == 1]
['Amount'].median()

print('Median amount for class 0 ', class0_amt_med)
print('Median amount for class 1 ', class1_amt_med)
```

```
Median amount for class 0  22.5
Median amount for class 1  18.0
```

```
finance_train_df.groupby('Class')['Amount'].describe()
```

```
          count         mean         std   min   25%   50%     75%
max
Class

0      226001.0   89.022663  248.759075  0.01  5.99  22.5   77.95
19656.53
1         377.0  133.047135  269.028423  0.01  1.00  18.0  112.45
2125.87
```

We can see, for class 1 (froud), amount has comparatively higher mean value, but has less median (50%) value.

Lets sample the train data and proceed with further EDA.

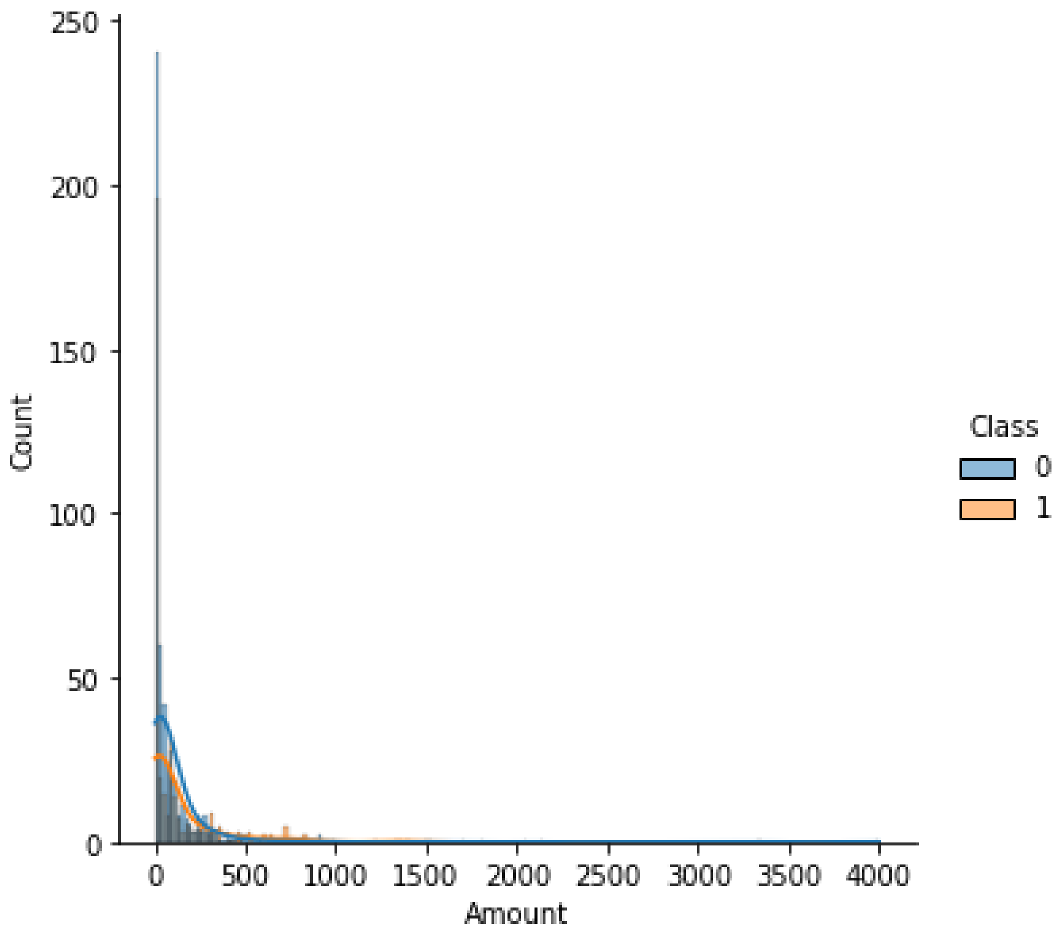
```
sample_data = finance_train_df.sample(frac=1)

data0 = sample_data[sample_data['Class'] == 0][:500]
data1 = sample_data[sample_data['Class'] == 1]
data = pd.concat([data0, data1], axis=0)
print(data.shape)
```

```
(877, 31)
```

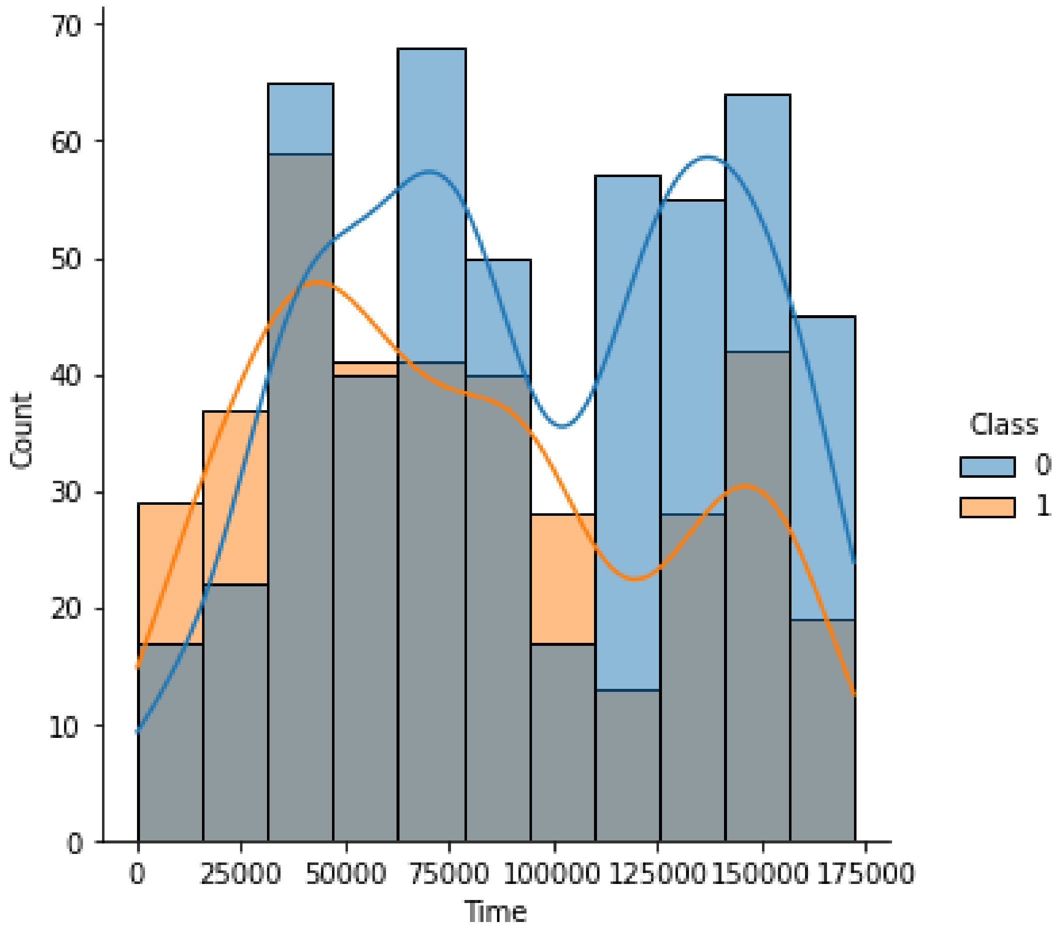
```
data['Class'].value_counts()
```

```
0    500
1    377
Name: Class, dtype: int64
```

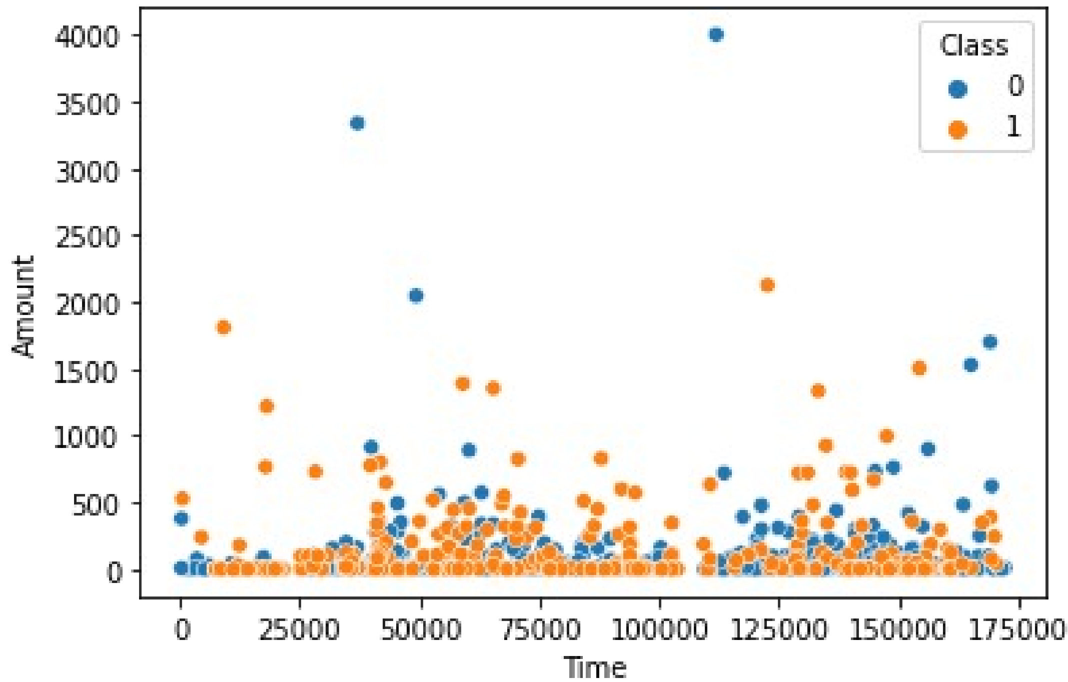
```
sns.displot(data, x= 'Amount', hue= 'Class', kde=True)
plt.show()
```




```
sns.displot(data, x= 'Time', hue= 'Class', kde= True)
plt.show()
```




```
sns.scatterplot(data=data, x="Time", y="Amount", hue="Class")
plt.show()
```



From the above two plots, we cant find any specific relationship between the three data.

But from the scatterplot, we can see, most of the froud transactions have less amount, but still few of them has large amount.

Also, there are certain timestamps, where froud counts are more than the non-froud counts as compared to other timestamps.

```
corr = data.corr()['Class']['Amount']
corr
```

```
0.06042151045900016
```

We dont get much inference from the correlation. We can try phik library to get the relationship between class, time and amount.

```
corr = data.phik_matrix().loc['Class', ['Time', 'Amount',
'Class']].to_dict()
corr
```

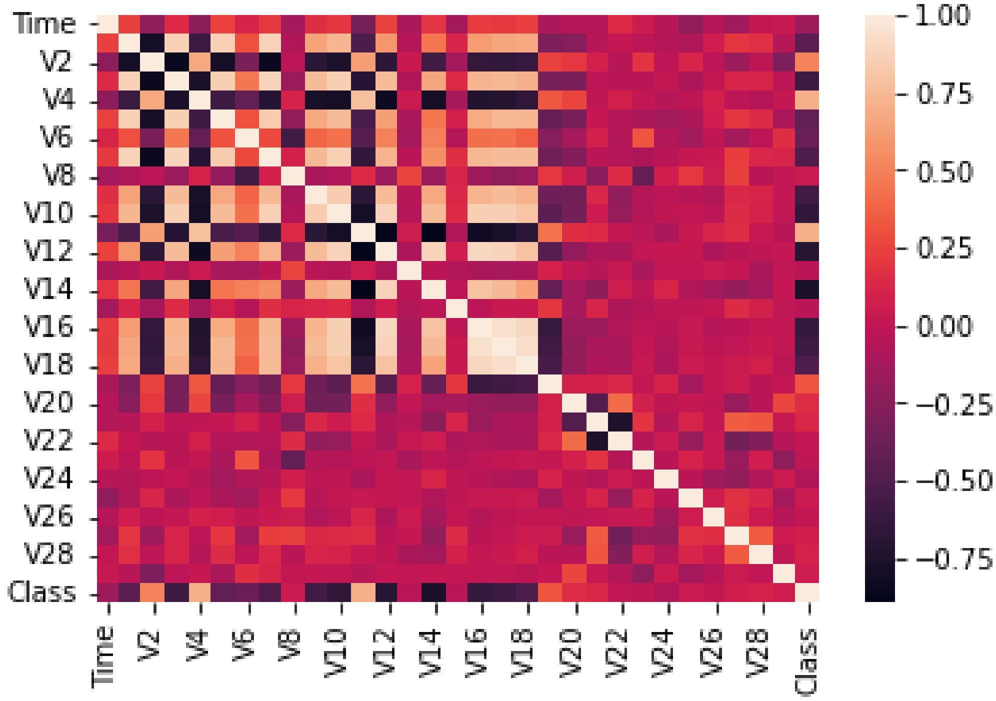
```
interval columns not set, guessing: ['Time', 'V1', 'V2', 'V3', 'V4',
'V5', 'V6', 'V7', 'V8', 'V9', 'V10', 'V11', 'V12', 'V13', 'V14',
'V15', 'V16', 'V17', 'V18', 'V19', 'V20', 'V21', 'V22', 'V23', 'V24',
'V25', 'V26', 'V27', 'V28', 'Amount', 'Class']
```

```
{'Time': 0.30580993495716885, 'Amount': 0.13369615362211948, 'Class':
1.0}
```

We can see, time got higher correlation value than amount for class labels.

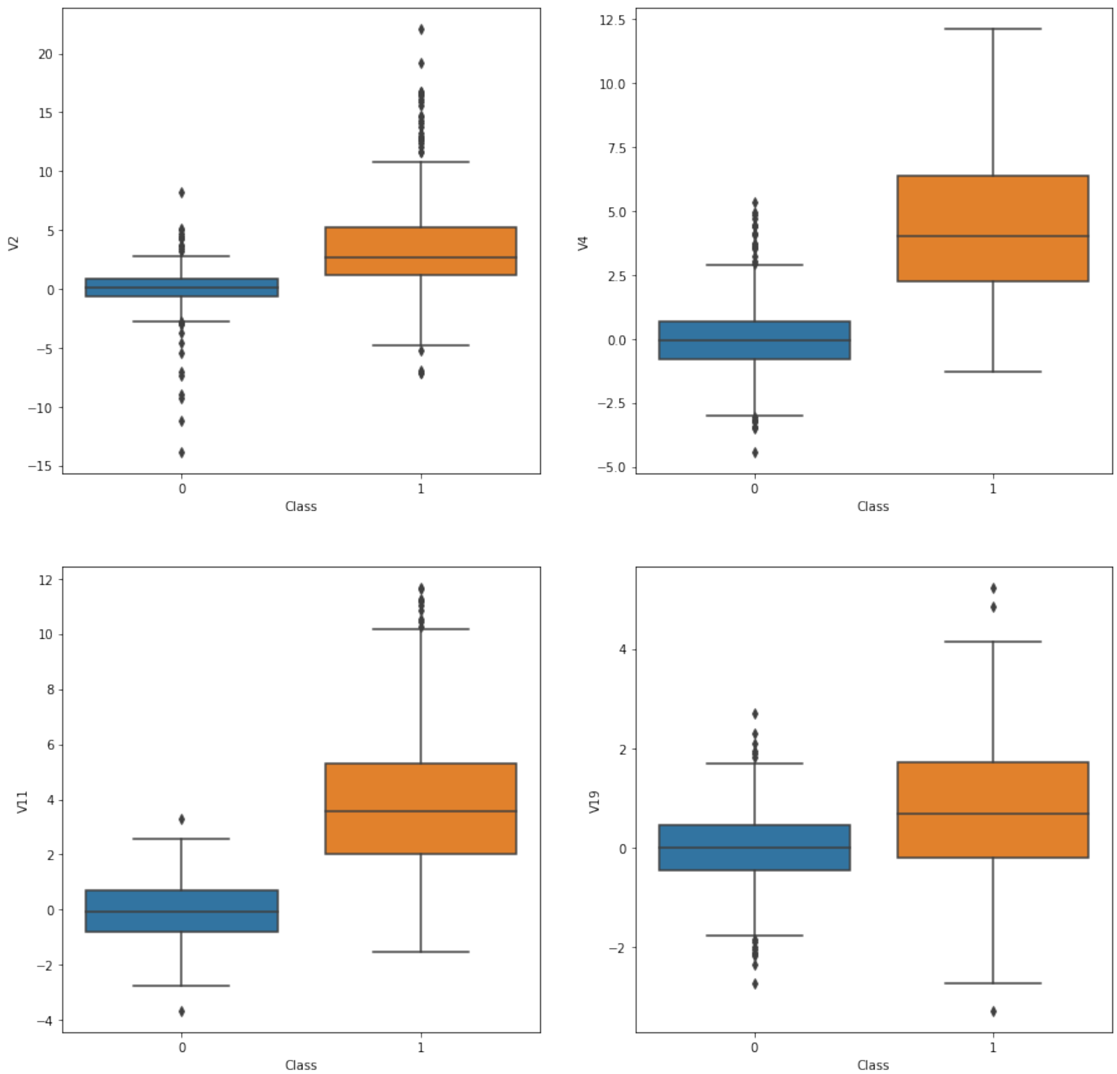
Lets find out the relationship between other features and class labels.

```
corr = data.corr()
sns.heatmap(corr)
plt.show()
```



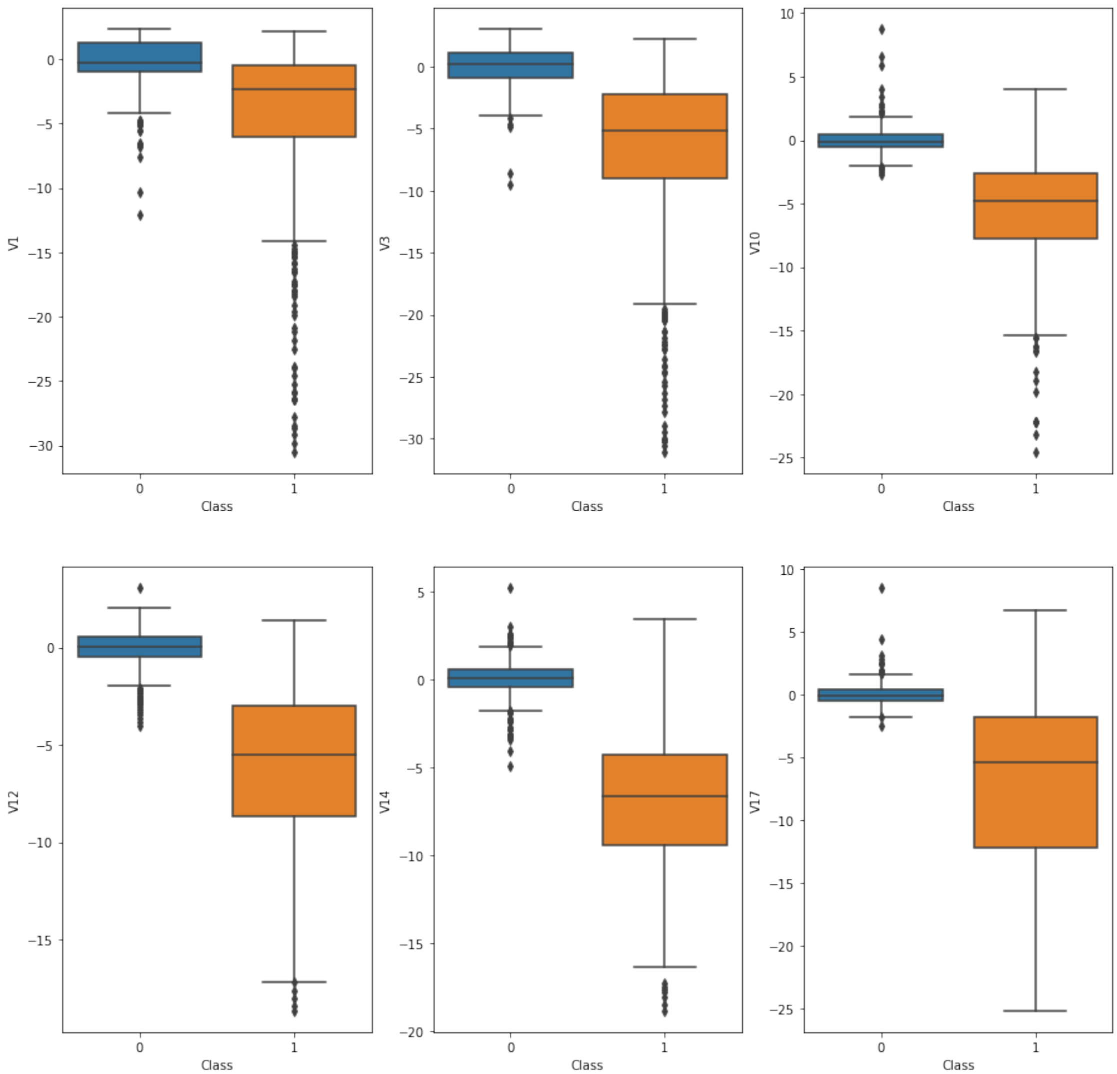
All the features are correlated with each other and for amount, there are few possitively correlated features and some are negatively correlated.

```
fig, ax = plt.subplots(2,2, figsize=(15,15))
y = 0;
for i, f in enumerate(['V2', 'V4', 'V11', 'V19']):
  i, j = divmod(y, 2)
  sns.boxplot(y=f, x= 'Class', data= data, ax= ax[i, j])
  y += 1

plt.show()
```



Above features are negatively correlated with the class label, so low value indicates class 0.

```
fig, ax = plt.subplots(2,3, figsize=(15,15))
y = 0;
for i, f in enumerate(['V1', 'V3', 'V10', 'V12', 'V14', 'V17']):
  i, j = divmod(y, 3)
  sns.boxplot(y=f, x= 'Class', data= data, ax= ax[i, j])
  y += 1

plt.show()
```



Above features are positively correlated with the class label. So higher value indicates class 0.

We can see, there are some features which properly classifies both the class labels.

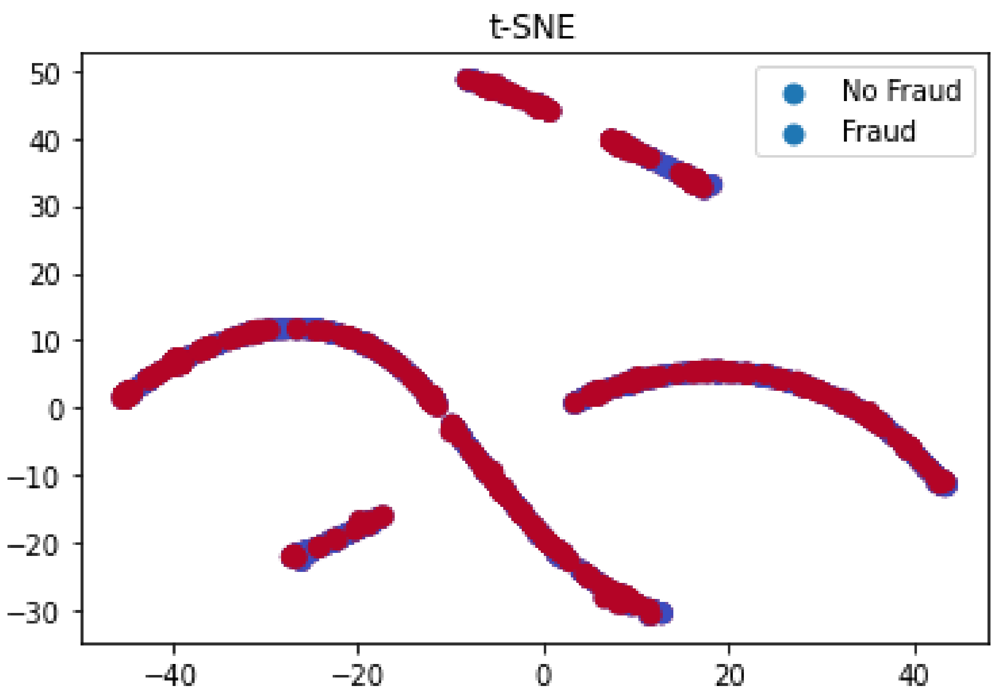
So we can consider these useful features on modeling.

Now lets try to visualize the features with TSNE.

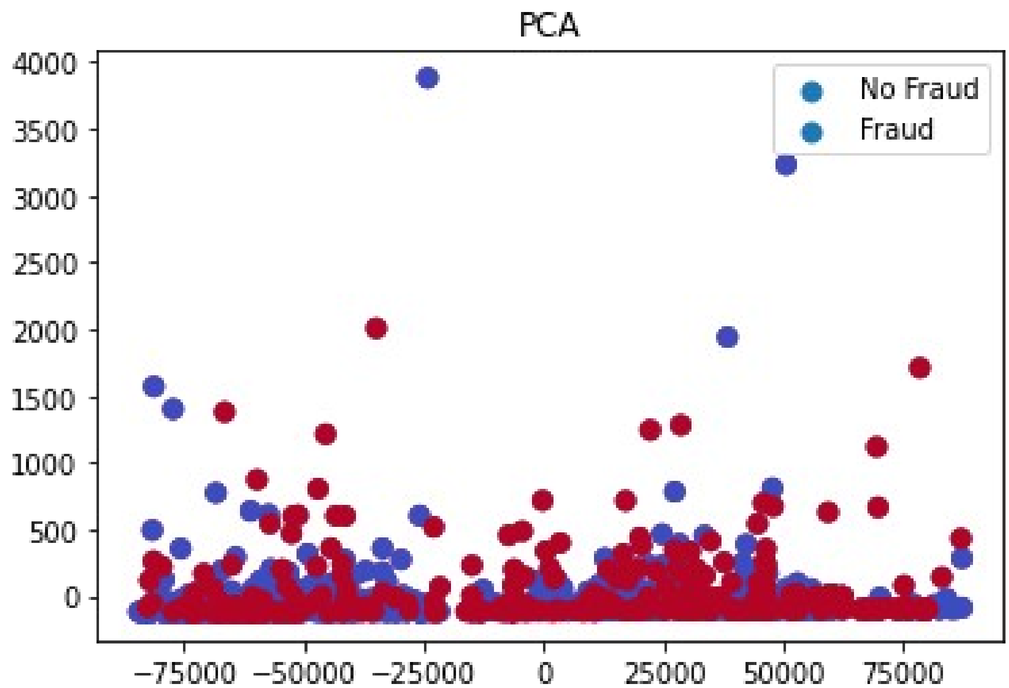
```
X = data.drop('Class', axis=1)
y = data['Class']

X_tsne = TSNE(n_components=2, random_state=42).fit_transform(X.values)
plt.scatter(X_tsne[:,0], X_tsne[:,1], c=(y == 0), cmap='coolwarm',
label='No Fraud', linewidths=2)
plt.scatter(X_tsne[:,0], X_tsne[:,1], c=(y == 1), cmap='coolwarm',
label='Fraud', linewidths=2)
plt.title('t-SNE')
```

```
plt.legend()
plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/manifold/_t_sne.py:783:
FutureWarning: The default initialization in TSNE will change from
'random' to 'pca' in 1.2.
  FutureWarning,
/usr/local/lib/python3.7/dist-packages/sklearn/manifold/_t_sne.py:793:
FutureWarning: The default learning rate in TSNE will change from
200.0 to 'auto' in 1.2.
  FutureWarning,
```




```
X_pca = PCA(n_components=2, random_state=42).fit_transform(X.values)
plt.scatter(X_pca[:,0], X_pca[:,1], c=(y == 0), cmap='coolwarm',
label='No Fraud', linewidths=2)
plt.scatter(X_pca[:,0], X_pca[:,1], c=(y == 1), cmap='coolwarm',
label='Fraud', linewidths=2)
plt.title('PCA')
plt.legend()
plt.show()
```



Use techniques like undersampling or oversampling before running Naïve Bayes, Logistic Regression or SVM.

We can go for both oversampling and undersampling approach and compare the result. But before that, lets standardize the data as we have time and amount with higher scale than others.

```
train_X = finance_train_df.drop(['Class'], axis=1)
train_y = finance_train_df['Class']

test_X = finance_test_hidden_df.drop(['Class'], axis=1)
test_y = finance_test_hidden_df['Class']

stdsc = StandardScaler()

train_X = stdsc.fit_transform(train_X)
test_X = stdsc.transform(test_X)

train_y.reset_index(drop= True, inplace=True)

train_df = pd.DataFrame(train_X)
train_df.columns = finance_train_df.columns[:-1]
train_df['Class'] = train_y
train_df.to_pickle('finance_train.pkl')
```

Oversampling

```
osmp = RandomOverSampler(sampling_strategy= 'minority')
train_X_ovr, train_y_ovr = osmp.fit_resample(train_X, train_y)
```

```
print(train_X_ovr.shape)
print(train_y_ovr.shape)
print(train_y_ovr.value_counts())
```

```
(452002, 30)
(452002,)
0    226001
1    226001
Name: Class, dtype: int64
```

```
train_ovr_df = pd.DataFrame(train_X_ovr)
train_ovr_df.columns = finance_train_df.columns[:-1]
train_ovr_df['Class'] = train_y_ovr

train_ovr_df.shape
```

```
(452002, 31)
```

Undersampling

```
usmp = RandomUnderSampler(sampling_strategy=0.5)
train_X_udr, train_y_udr = usmp.fit_resample(train_X, train_y)

print(train_X_udr.shape)
print(train_y_udr.shape)
print(train_y_udr.value_counts())
```

```
(1131, 30)
(1131,)
0    754
1    377
Name: Class, dtype: int64
```

```
train_udr_df = pd.DataFrame(train_X_udr)
train_udr_df.columns = finance_train_df.columns[:-1]
train_udr_df['Class'] = train_y_udr

train_udr_df.shape
```

```
(1131, 31)
```

```
test_df = pd.DataFrame(test_X)
test_df.columns = finance_train_df.columns[:-1]
test_df['Class'] = test_y

test_df.shape
```

```
(56962, 31)
```

```
train_ovr_df.to_pickle('finance_ovr_train.pkl')
train_udr_df.to_pickle('finance_udr_train.pkl')
test_df.to_pickle('finance_test.pkl')
```

We have standardized, over and under sampled our data and saved it as pickle files for future purposes.

Following are the matrices for evaluating the model performance: Precision, Recall, F1-Score, AUC-ROC curve. Use F1-Score as the evaluation criteria for this project

```
def getPerformance(y_train, y_pred_train, y_test, y_pred_test, name):
  print('\nModel performance ' + name)
  print('\naccuracy score train', accuracy_score(y_train,
y_pred_train))
  print('accuracy score test', accuracy_score(y_test, y_pred_test))
  print('\nTrain classification report: ' + name + '\n')
  print(classification_report(y_train, y_pred_train))
  print('\nTest classification report: ' + name + '\n')
  print(classification_report(y_test, y_pred_test))
  print('\n')
  sns.heatmap(confusion_matrix(y_train, y_pred_train), annot= True,
cbar= False)
  plt.title('Train confusion matrix: ' + name)
  plt.show()
  sns.heatmap(confusion_matrix(y_test, y_pred_test), annot= True,
cbar= False)
  plt.title('Test confusion matrix: ' + name)
  plt.show()
  print('\nroc auc score train {}'.format(roc_auc_score(y_train,
y_pred_train)))
  fpr, tpr, th = roc_curve(y_train, y_pred_train)
  auc_val = auc(fpr, tpr)
  plt.title(name + ' Train Receiver Operating Characteristic Curve')
  plt.plot(fpr, tpr, label='area = {:.3f}'.format(auc_val))
  plt.legend(loc = 'lower right')
  plt.plot([0, 1], [0, 1],'r--')
  plt.ylabel('True Positive Rate')
  plt.xlabel('False Positive Rate')
  plt.show()
  print('\nroc auc score test {}'.format(roc_auc_score(y_test,
y_pred_test)))
  fpr, tpr, th = roc_curve(y_test, y_pred_test)
  auc_val = auc(fpr, tpr)
  plt.title(name + ' Test Receiver Operating Characteristic Curve')
  plt.plot(fpr, tpr, label='area = {:.3f}'.format(auc_val))
  plt.legend(loc = 'lower right')
  plt.plot([0, 1], [0, 1],'r--')
  plt.ylabel('True Positive Rate')
  plt.xlabel('False Positive Rate')
  plt.show()
```

Modeling Techniques

We can try out different models like naive bayes, svm, logistic regression and also three based models like random forest and xgboot with both the data (oversampled and undersampled). In addition to that we can do hyper-parameter tunning in parallel.

Before that lets upload our processed data.

```
train_ovr_df = pd.read_pickle('finance_ovr_train.pkl')
train_udr_df = pd.read_pickle('finance_udr_train.pkl')
test_df = pd.read_pickle('finance_test.pkl')
```

```
train_ovr_X = train_ovr_df.drop(['Class'], axis=1)
train_ovr_y = train_ovr_df['Class']

train_udr_X = train_udr_df.drop(['Class'], axis=1)
train_udr_y = train_udr_df['Class']

test_X = test_df.drop(['Class'], axis=1)
test_y = test_df['Class']
```

```
x_ovr_train, x_ovr_test, y_ovr_train, y_ovr_test =
train_test_split(train_ovr_X, train_ovr_y,

stratify= train_ovr_y,

test_size= 0.2, random_state= 0)
```

```
x_udr_train, x_udr_test, y_udr_train, y_udr_test =
train_test_split(train_udr_X, train_udr_y,

stratify= train_udr_y,

test_size= 0.2, random_state= 0)
```

```
print(x_ovr_train.shape)
print(x_ovr_test.shape)
print(y_ovr_train.shape)
print(y_ovr_test.shape)
```

```
(361601, 30)
(90401, 30)
(361601,)
(90401,)
```

```
print(x_udr_train.shape)
print(x_udr_test.shape)
print(y_udr_train.shape)
print(y_udr_test.shape)
```

```
(904, 30)
(227, 30)
(904,)
(227,)
```

```
print(test_X.shape)
print(test_y.shape)
```

```
(56962, 30)
(56962,)
```

```
def buildModel(model, params, x_train, y_train, x_test, y_test,
test_x, test_y, model_name):
  print('Building model ' + model_name + '.......')
  gs = GridSearchCV(model, params, refit=True,
scoring=make_scorer(f1_score , average='macro'))
  gs.fit(x_train, y_train)
  y_train_pred = gs.predict(x_train)
  y_test_pred = gs.predict(x_test)
  print('\nBest score ', gs.best_score_)
  print('Best param ', gs.best_params_)
  best_model = gs.best_estimator_
  print('Best model ', best_model)
  getPerformance(y_train, y_train_pred, y_test, y_test_pred,
model_name)
  test_y_pred = best_model.predict(test_X)
  print('\nTest accuracy score {} \n'.format(accuracy_score(test_y,
test_y_pred)))
  print('Classification report\n')
  print(classification_report(test_y, test_y_pred))
  print('\nCompleted for ' + model_name)
  print('Saving model as ' + model_name + '.pkl')
  pickle.dump(best_model, open(model_name + '.pkl', 'wb'))
```

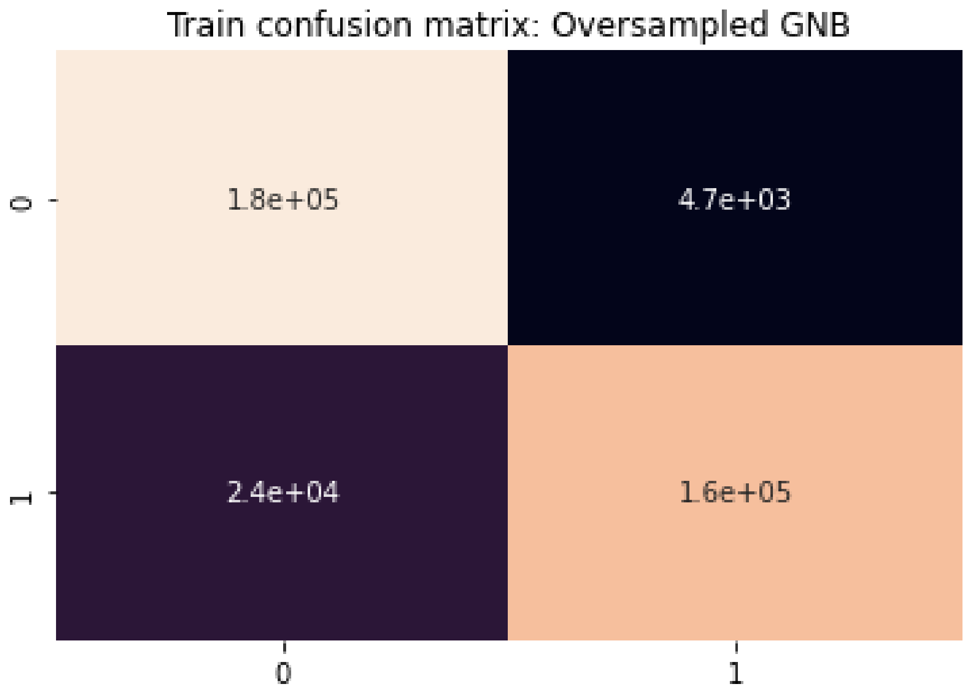
Naive Bayes

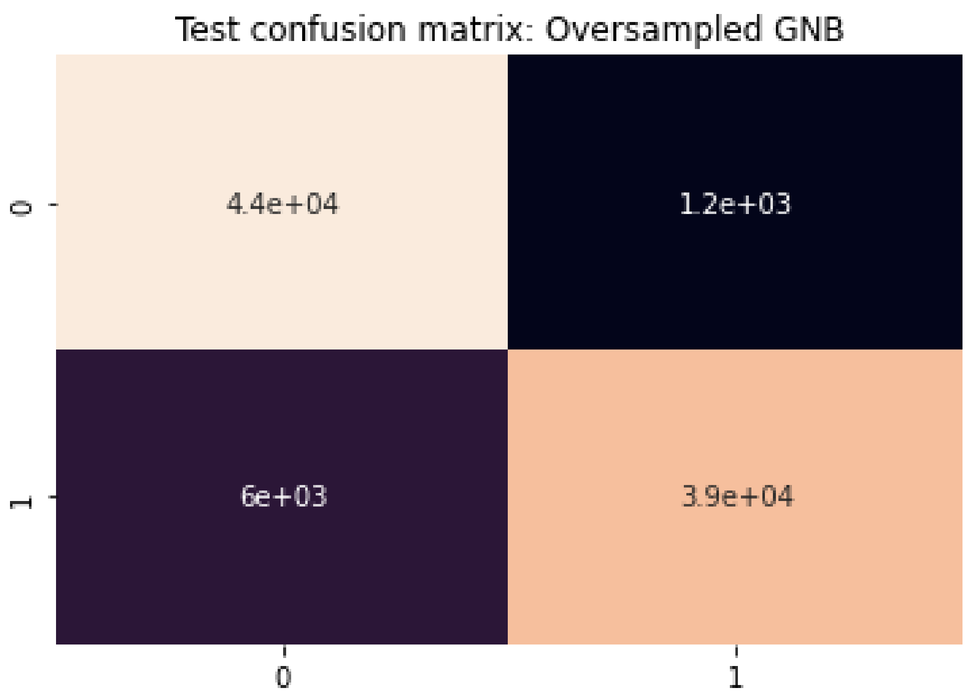
Naive Bayes with over sampled data

```
gnb_ovr = GaussianNB()

gnb_params = {'var_smoothing': np.logspace(0,-9, num=100), 'priors':
[[0.5, 0.5], [0.25, 0.75], [0.75,0.25]]}

buildModel(gnb_ovr, gnb_params, x_ovr_train, y_ovr_train, x_ovr_test,
y_ovr_test, test_X, test_y, 'Oversampled GNB')
```

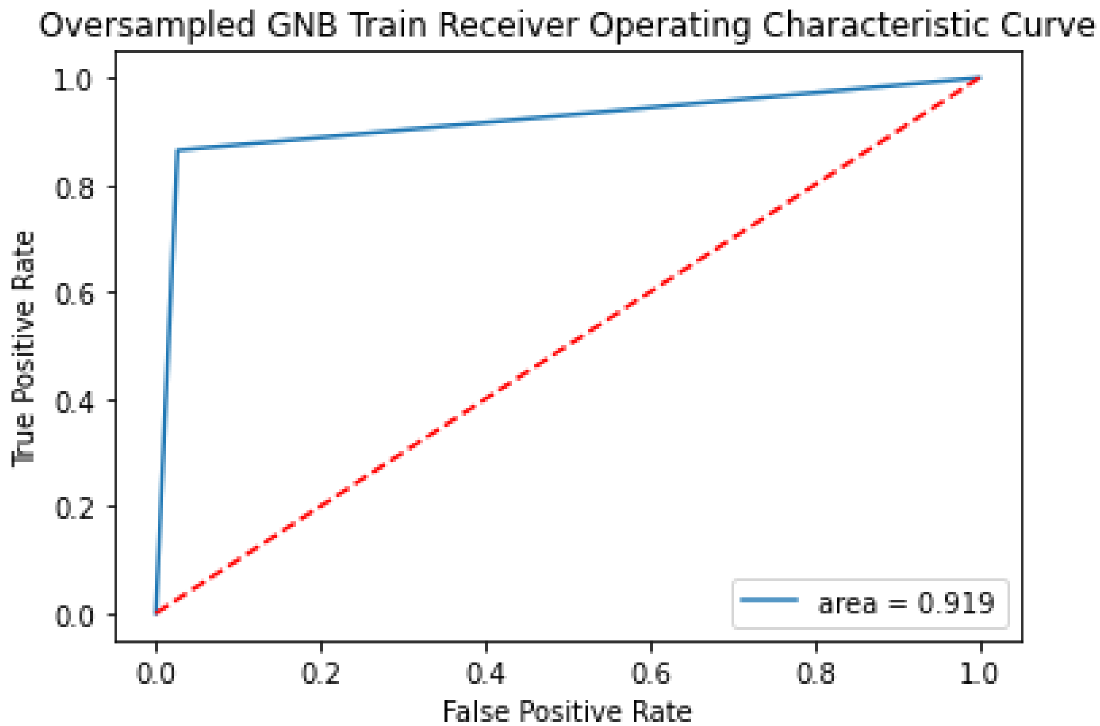
```
Building model Oversampled GNB.......

Best score  0.9189955854298983
Best param  {'priors': [0.25, 0.75], 'var_smoothing':
0.0006579332246575676}
Best model  GaussianNB(priors=[0.25, 0.75],
```

```
var_smoothing=0.0006579332246575676)

Model performance Oversampled GNB

accuracy score train 0.9192452454500956
accuracy score test 0.9205429143482926

Train classification report: Oversampled GNB

              precision    recall  f1-score   support

           0       0.88      0.97      0.92    180800
           1       0.97      0.86      0.91    180801

    accuracy                           0.92    361601
   macro avg       0.92      0.92      0.92    361601
weighted avg       0.92      0.92      0.92    361601


Test classification report: Oversampled GNB

              precision    recall  f1-score   support

           0       0.88      0.97      0.92     45201
           1       0.97      0.87      0.92     45200

    accuracy                           0.92     90401
   macro avg       0.93      0.92      0.92     90401
weighted avg       0.93      0.92      0.92     90401
```

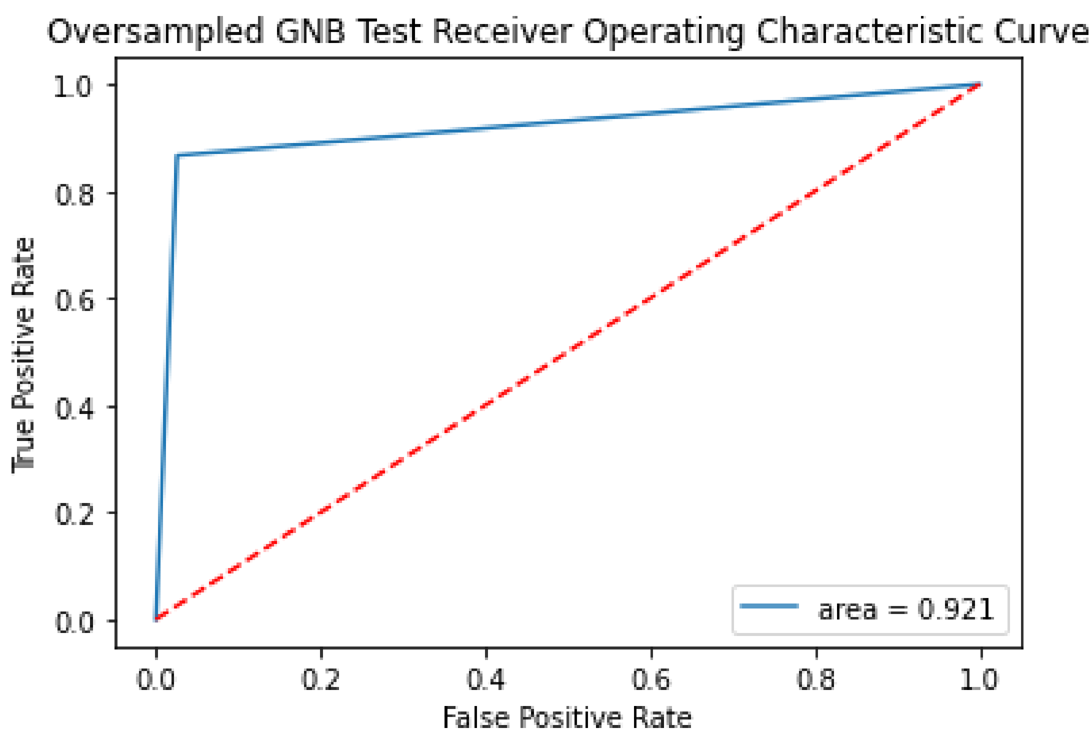





```
roc auc score train 0.919245396426169
```



roc auc score test 0.9205423187931663



Test accuracy score 0.9732628770057231

```
Classification report

              precision    recall  f1-score   support

           0       1.00      0.97      0.99     56864
           1       0.05      0.82      0.10        98

    accuracy                           0.97     56962
   macro avg       0.53      0.89      0.54     56962
weighted avg       1.00      0.97      0.98     56962


Completed for Oversampled GNB
Saving model as Oversampled GNB.pkl
```

We are getting very good performance on the oversampled data and wih the test data, it gave reasonable f1-score.

Naive Bayes with under sampled data

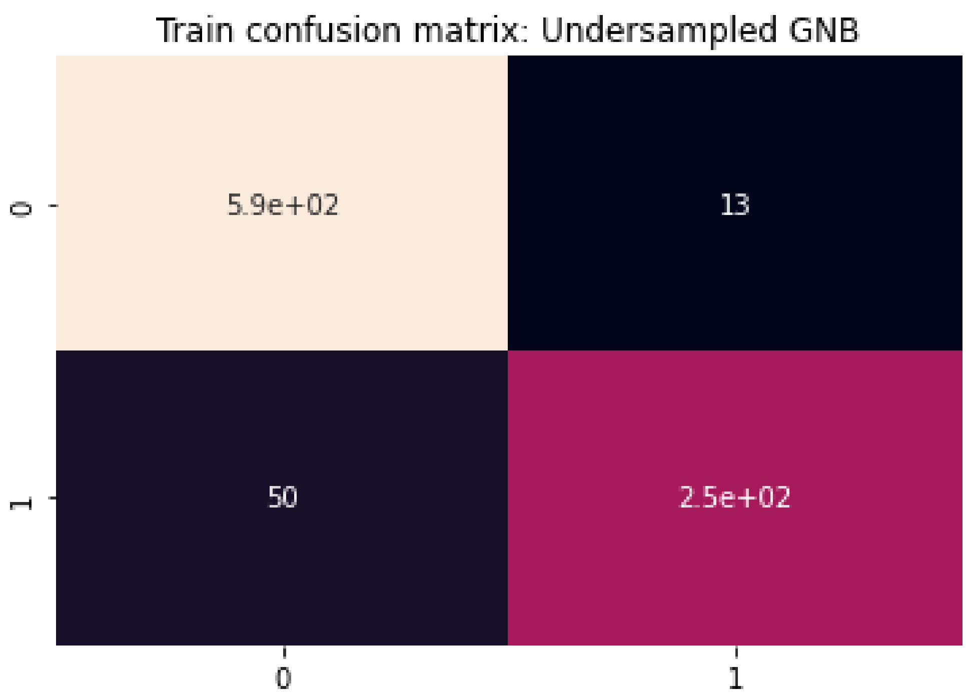
```
gnb_udr = GaussianNB()

gnb_params = {'var_smoothing': np.logspace(0,-9, num=100), 'priors':
[[0.5, 0.5], [0.25, 0.75], [0.75,0.25]]}

buildModel(gnb_udr, gnb_params, x_udr_train, y_udr_train, x_udr_test,
y_udr_test, test_X, test_y, 'Undersampled GNB')
```

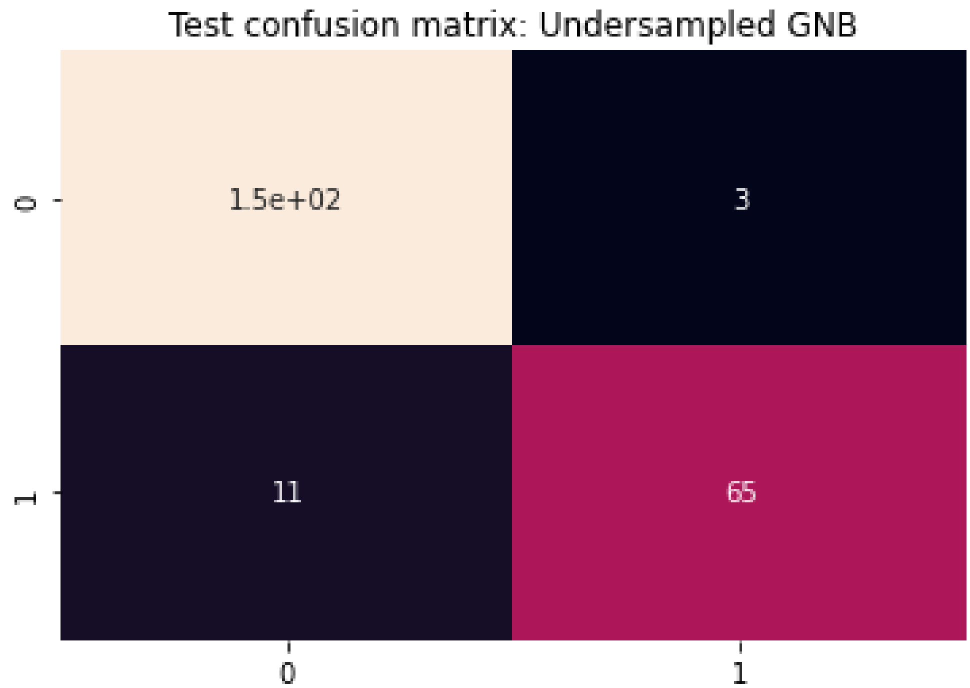
```
Building model Undersampled GNB.......

Best score  0.9200576725202432
Best param  {'priors': [0.5, 0.5], 'var_smoothing':
0.004328761281083057}
Best model  GaussianNB(priors=[0.5, 0.5],
var_smoothing=0.004328761281083057)

Model performance Undersampled GNB

accuracy score train 0.9303097345132744
accuracy score test 0.9383259911894273

Train classification report: Undersampled GNB

              precision    recall  f1-score   support

           0       0.92      0.98      0.95       603
           1       0.95      0.83      0.89       301

    accuracy                           0.93       904
```

	precision	recall	f1-score	support
macro avg	0.94	0.91	0.92	904
weighted avg	0.93	0.93	0.93	904

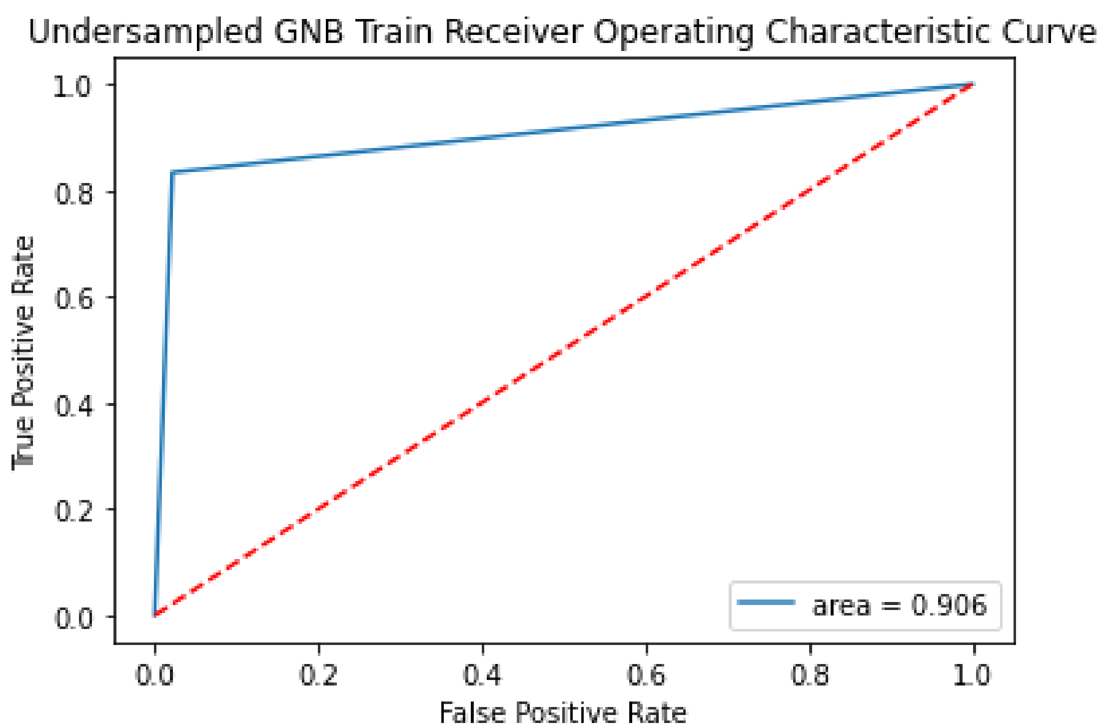
Test classification report: Undersampled GNB

	precision	recall	f1-score	support
0	0.93	0.98	0.95	151
1	0.96	0.86	0.90	76
accuracy			0.94	227
macro avg	0.94	0.92	0.93	227
weighted avg	0.94	0.94	0.94	227

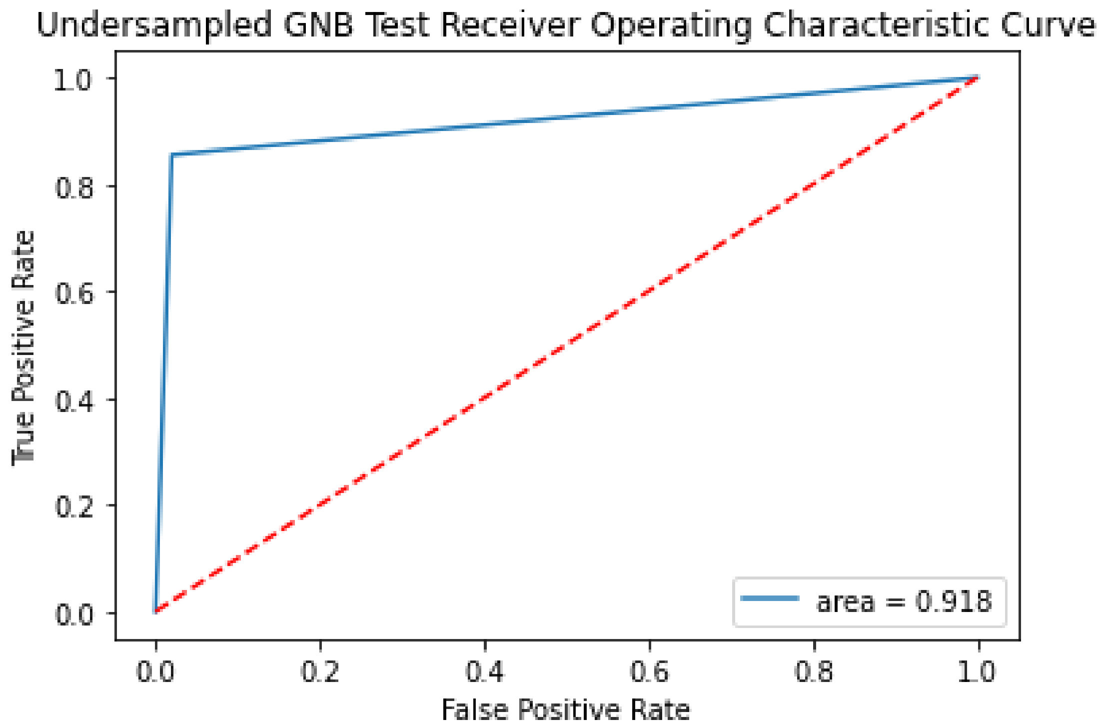




roc auc score train 0.9061640854421139



roc auc score test 0.9176978041129313




```
Test accuracy score 0.9698219865875496

Classification report

              precision    recall  f1-score   support

           0       1.00      0.97      0.98     56864
           1       0.04      0.82      0.09        98

    accuracy                           0.97     56962
   macro avg       0.52      0.89      0.53     56962
weighted avg       1.00      0.97      0.98     56962


Completed for Undersampled GNB
Saving model as Undersampled GNB.pkl
```

Undersampled Gaussian Naive Bayes performed better than the oversampled model in terms of f1-score on training data. But for the test, both gave similar performance. We can choose oversampled naive bayes model.

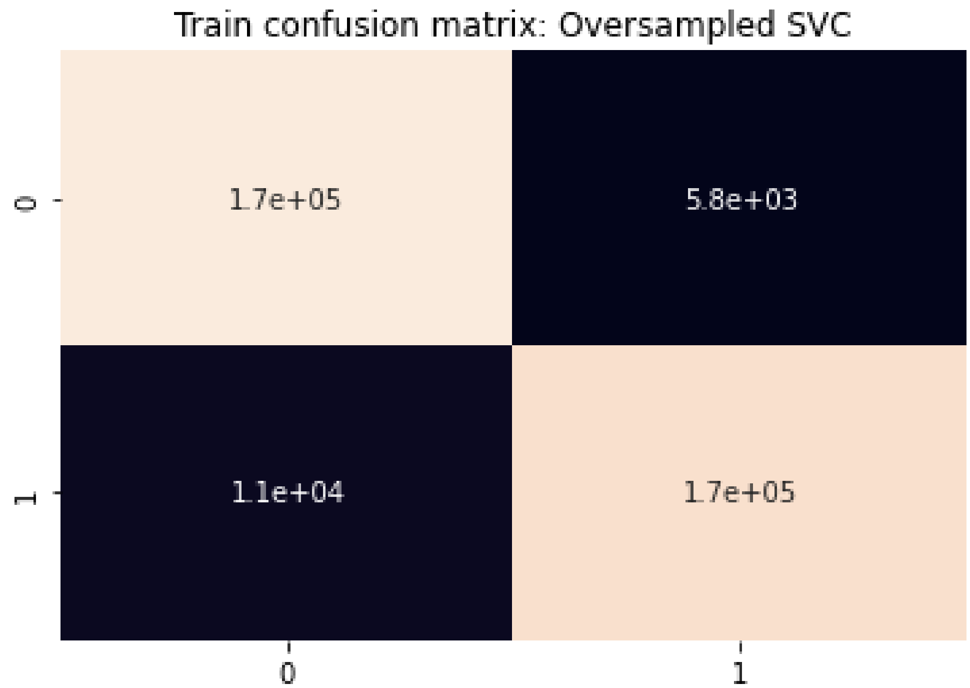
SVC

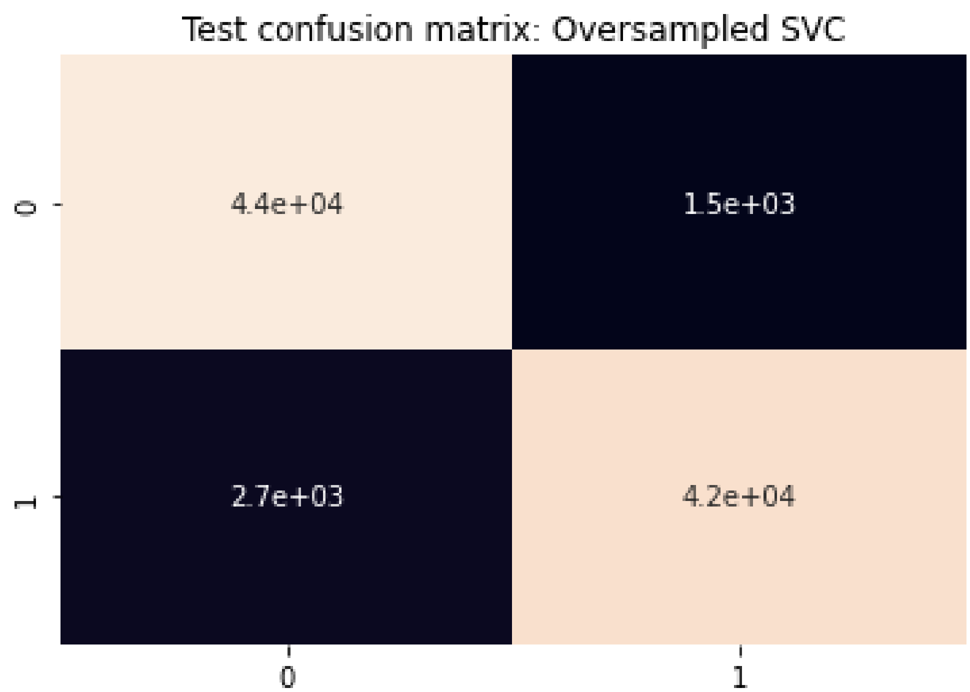
SVC with oversampled data

```
svc_ovr = SGDClassifier(loss='hinge', class_weight='balanced')
```

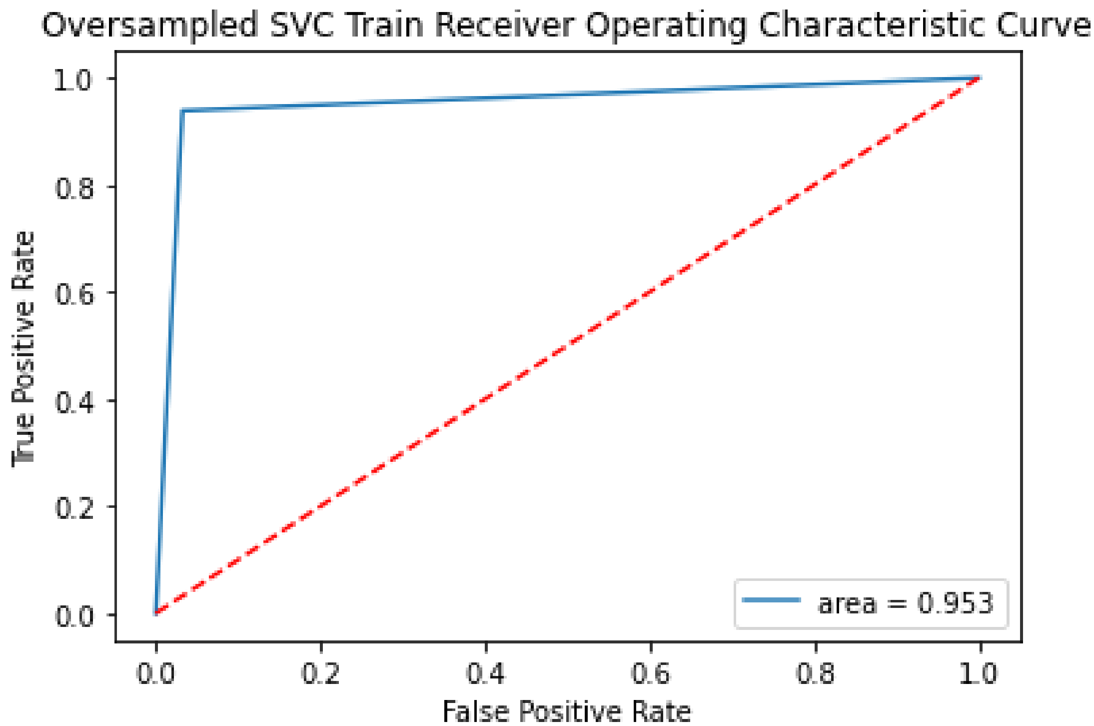
```
svc_params = {'alpha' : [0.0001, 0.001, 0.01, 0.1], 'penalty' : ['l2',
'l1', 'none']}

buildModel(svc_ovr, svc_params, x_ovr_train, y_ovr_train, x_ovr_test,
y_ovr_test, test_X, test_y, 'Oversampled SVC')
```

```
Building model Oversampled SVC.......

Best score  0.9580153162855138
Best param  {'alpha': 0.0001, 'penalty': 'l1'}
Best model  SGDClassifier(class_weight='balanced', penalty='l1')

Model performance Oversampled SVC

accuracy score train 0.9531859701715427
accuracy score test 0.9534075950487273

Train classification report: Oversampled SVC

              precision    recall  f1-score   support

           0       0.94      0.97      0.95    180800
           1       0.97      0.94      0.95    180801

    accuracy                           0.95    361601
   macro avg       0.95      0.95      0.95    361601
weighted avg       0.95      0.95      0.95    361601


Test classification report: Oversampled SVC

              precision    recall  f1-score   support

           0       0.94      0.97      0.95     45201
           1       0.97      0.94      0.95     45200

    accuracy                           0.95     90401
   macro avg       0.95      0.95      0.95     90401
weighted avg       0.95      0.95      0.95     90401
```

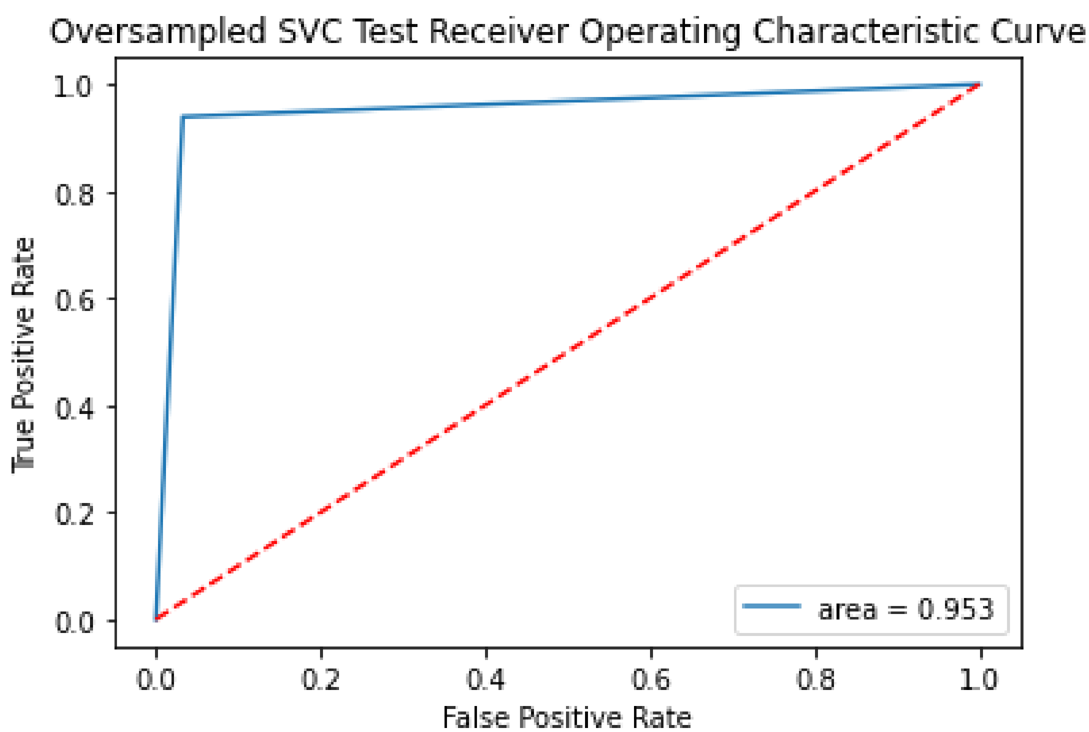





```
roc auc score train 0.95318601020016
```




```
roc auc score test 0.9534074411091616
```




```
Test accuracy score 0.966960429760191
```

```
Classification report

              precision    recall  f1-score   support

           0       1.00      0.97      0.98     56864
           1       0.04      0.89      0.08        98

    accuracy                           0.97     56962
   macro avg       0.52      0.93      0.53     56962
weighted avg       1.00      0.97      0.98     56962


Completed for Oversampled SVC
Saving model as Oversampled SVC.pkl
```

SVC gave similar performance as undersampled the naive bayes model till now. Lets try out the undersampled svc.

Undersampled SVC

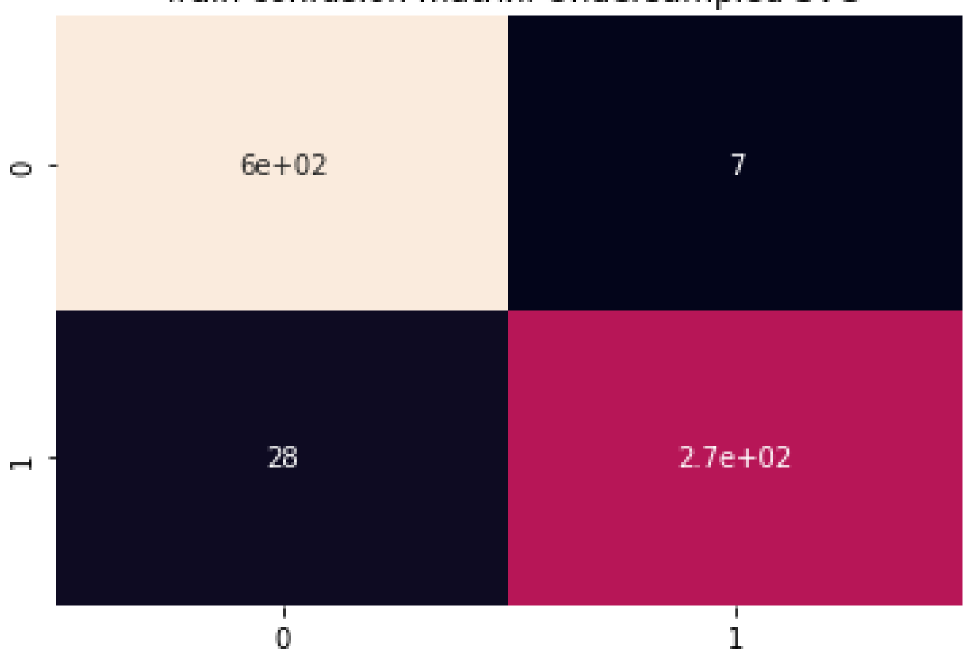
```
svc_udr = SGDClassifier(loss='hinge', class_weight='balanced')

svc_params = {'alpha' : [0.0001, 0.001, 0.01, 0.1], 'penalty' : ['l2', 'l1', 'none']}

buildModel(svc_udr, svc_params, x_udr_train, y_udr_train, x_udr_test, y_udr_test, test_X, test_y, 'Undersampled SVC')
```

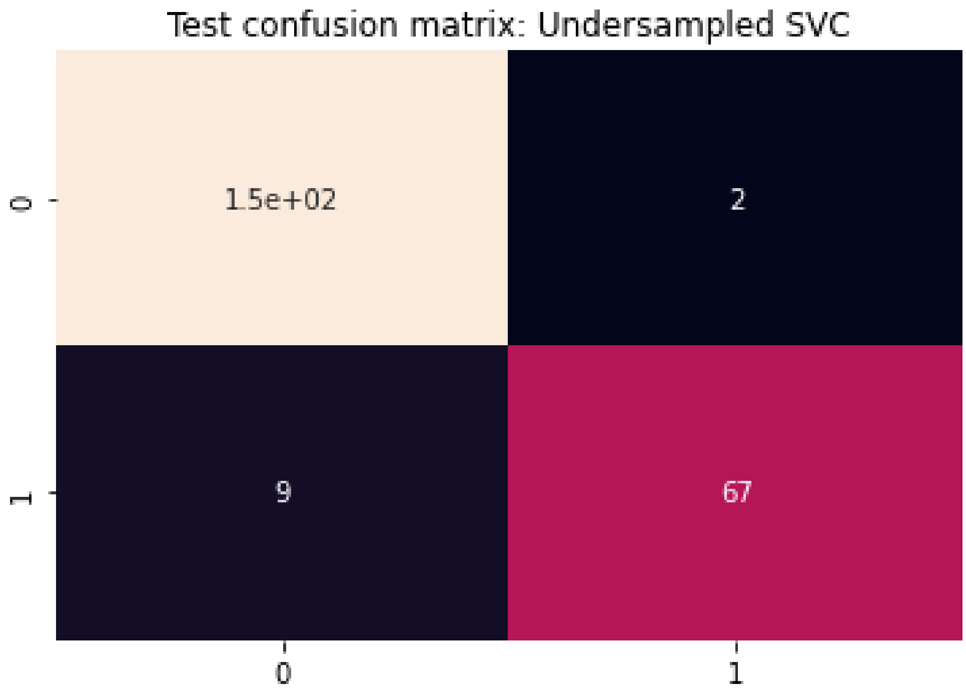
```
Building model Undersampled SVC.......

Best score  0.947805054083058
Best param  {'alpha': 0.1, 'penalty': 'l2'}
Best model  SGDClassifier(alpha=0.1, class_weight='balanced')

Model performance Undersampled SVC

accuracy score train 0.9612831858407079
accuracy score test 0.9515418502202643

Train classification report: Undersampled SVC

              precision    recall  f1-score   support

           0       0.96      0.99      0.97       603
           1       0.97      0.91      0.94       301

    accuracy                           0.96       904
   macro avg       0.97      0.95      0.96       904
weighted avg       0.96      0.96      0.96       904
```

Test classification report: Undersampled SVC

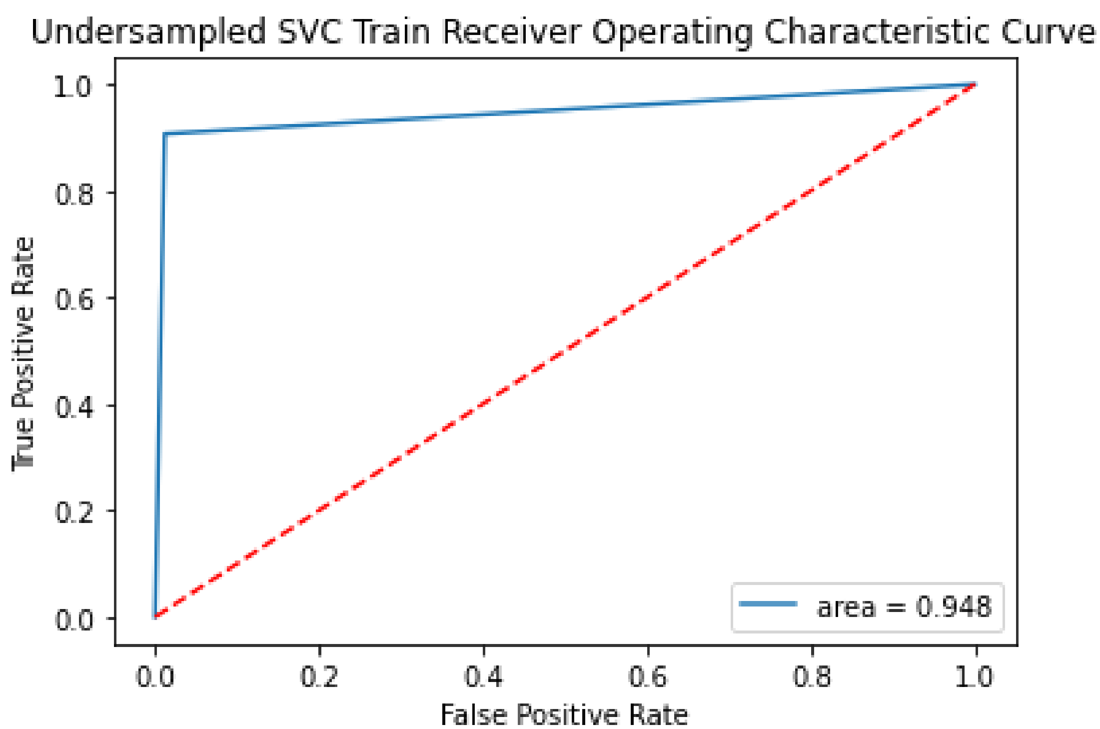
	precision	recall	f1-score	support
0	0.94	0.99	0.96	151
1	0.97	0.88	0.92	76
accuracy			0.95	227
macro avg	0.96	0.93	0.94	227
weighted avg	0.95	0.95	0.95	227

Train confusion matrix: Undersampled SVC

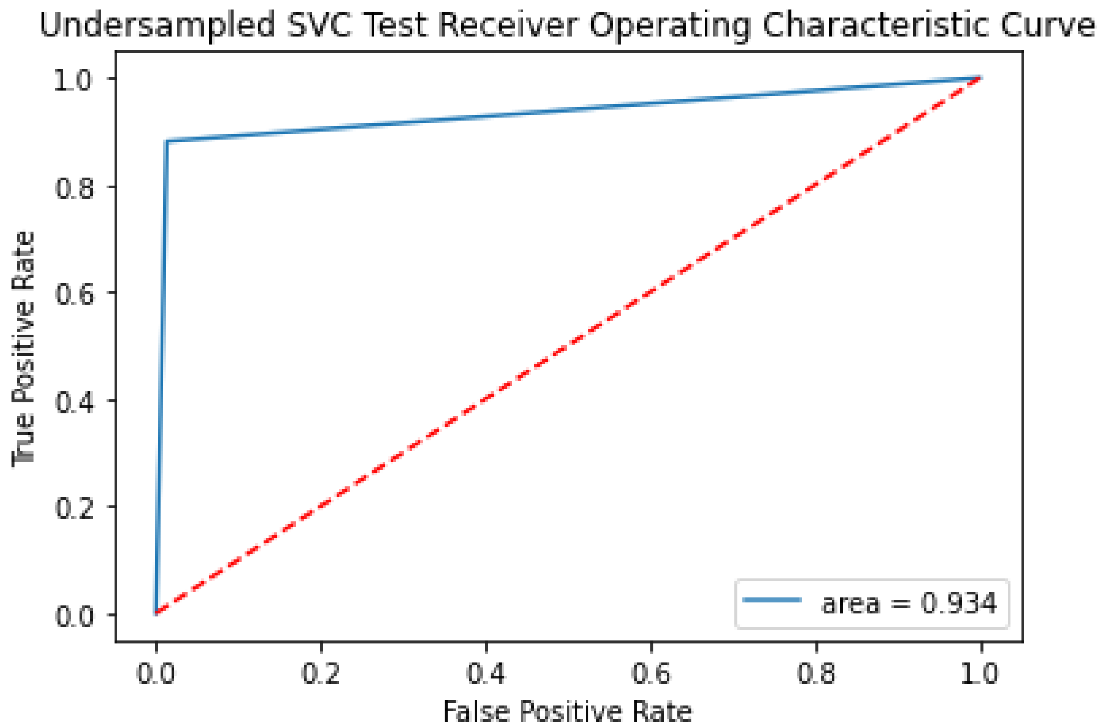




roc auc score train 0.9476840603185621



roc auc score test 0.9341669571279192




```
Test accuracy score 0.985604438046417

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.10      0.87      0.17        98

    accuracy                           0.99     56962
   macro avg       0.55      0.93      0.58     56962
weighted avg       1.00      0.99      0.99     56962


Completed for Undersampled SVC
Saving model as Undersampled SVC.pkl
```

SVC with unsersampled data performed better than others.

Logistic Regression

Logistic Regression with oversampled data

```
lr_ovr = LogisticRegression(class_weight= 'balanced', solver=
'liblinear')
lr_params = {"C":np.logspace(-3,3,7), "penalty":["l1","l2", "none"]}
```

```
buildModel(lr_ovr, lr_params, x_ovr_train, y_ovr_train, x_ovr_test,
y_ovr_test, test_X, test_y, 'Oversampled LR')
```

```
Building model Oversampled LR.......

/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/
_validation.py:372: FitFailedWarning:
35 fits failed out of a total of 105.
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:
--------------------------------------------------------------------------
----------
35 fits failed with the following error:
Traceback (most recent call last):
  File
"/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_valid
ation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File
"/usr/local/lib/python3.7/dist-packages/sklearn/linear_model/_logistic
.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File
"/usr/local/lib/python3.7/dist-packages/sklearn/linear_model/_logistic
.py", line 464, in _check_solver
    raise ValueError("penalty='none' is not supported for the
liblinear solver")
ValueError: penalty='none' is not supported for the liblinear solver

  warnings.warn(some_fits_failed_message, FitFailedWarning)
/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_search
.py:972: UserWarning: One or more of the test scores are non-finite:
[0.94924394 0.94961435        nan 0.95194658 0.95191346        nan
 0.9516181  0.9516457         nan 0.95182911 0.9518374         nan
 0.95162638 0.9520594         nan 0.95157945 0.95206216        nan
 0.95183463 0.95206216        nan]
  category=UserWarning,


Best score  0.9520621575772905
Best param  {'C': 1000.0, 'penalty': 'l2'}
Best model  LogisticRegression(C=1000.0, class_weight='balanced',
solver='liblinear')

Model performance Oversampled LR
```

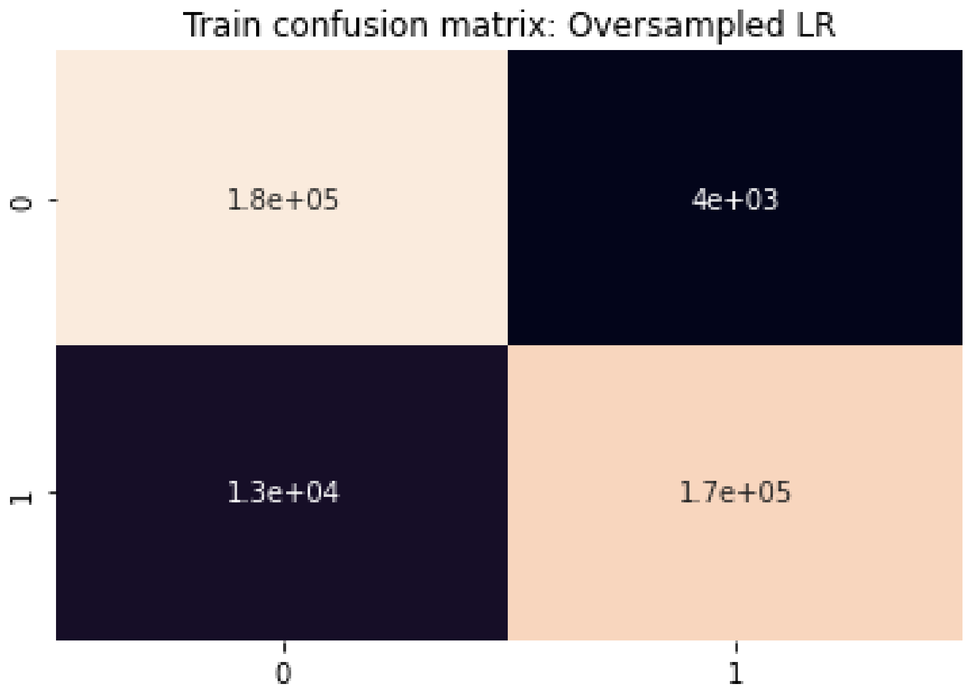
accuracy score train 0.9516704876369257
accuracy score test 0.9521907943496201

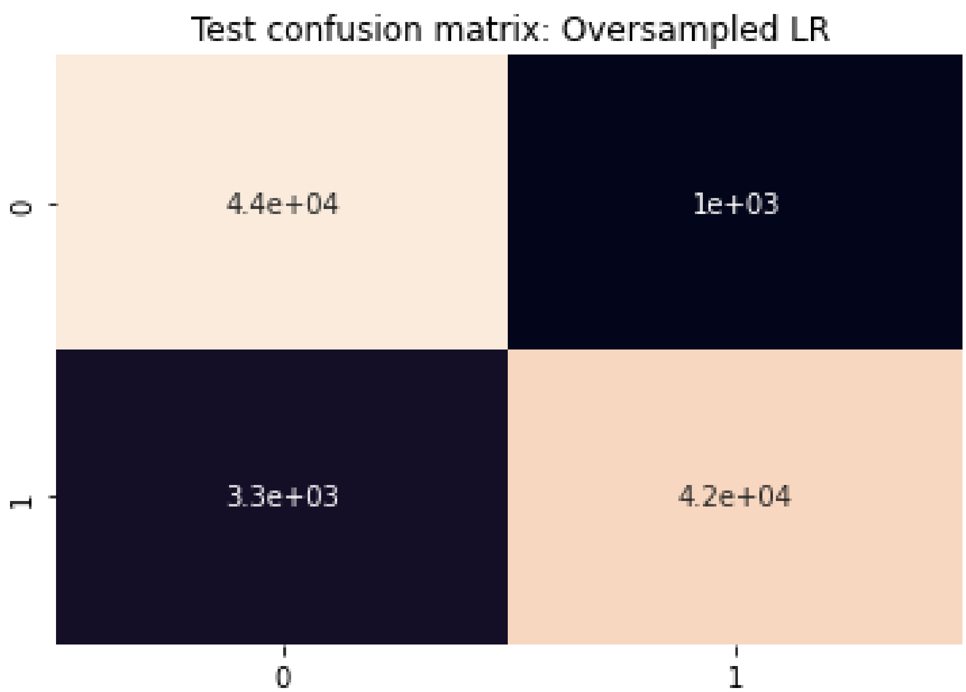
Train classification report: Oversampled LR

	precision	recall	f1-score	support
0	0.93	0.98	0.95	180800
1	0.98	0.93	0.95	180801
accuracy			0.95	361601
macro avg	0.95	0.95	0.95	361601
weighted avg	0.95	0.95	0.95	361601

Test classification report: Oversampled LR

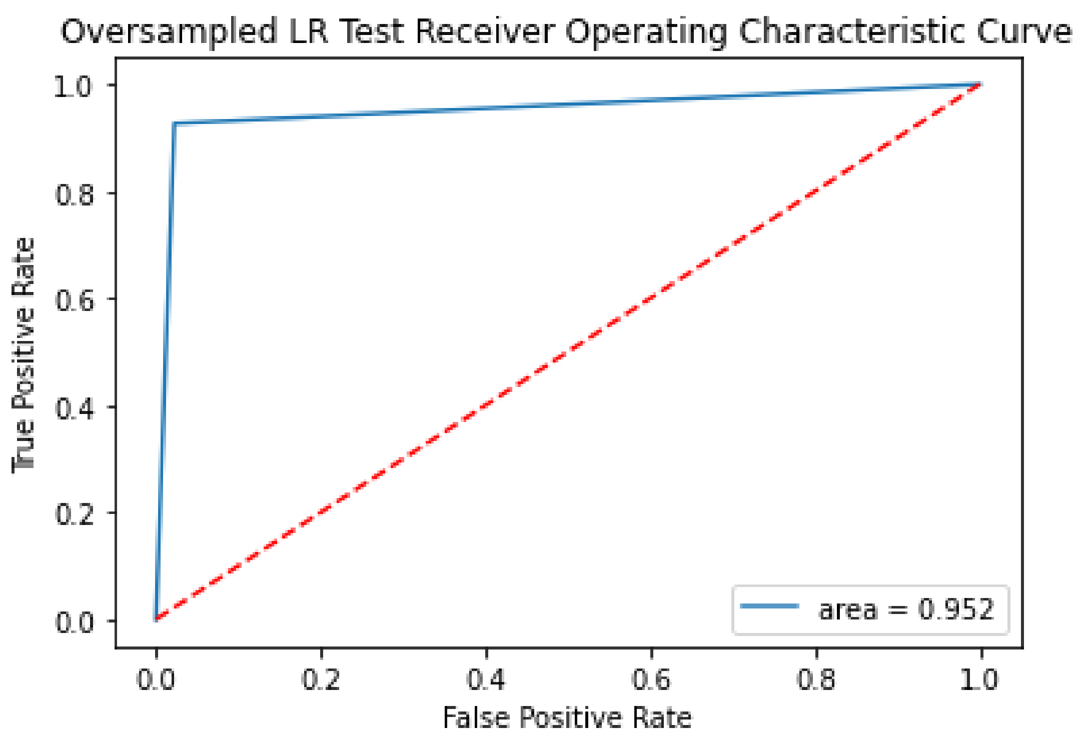
	precision	recall	f1-score	support
0	0.93	0.98	0.95	45201
1	0.98	0.93	0.95	45200
accuracy			0.95	90401
macro avg	0.95	0.95	0.95	90401
weighted avg	0.95	0.95	0.95	90401






```
roc auc score train 0.9516705599089704
```

roc auc score test 0.9521905119277454



Test accuracy score 0.9770373231276992

```
Classification report

              precision    recall  f1-score   support

           0       1.00      0.98      0.99     56864
           1       0.06      0.88      0.12        98

    accuracy                           0.98     56962
   macro avg       0.53      0.93      0.55     56962
weighted avg       1.00      0.98      0.99     56962


Completed for Oversampled LR
Saving model as Oversampled LR.pkl
```

Oversampled logistic regression gave better performance than naive bayes, but not svc.

Logistic Regression with undersampled data

```
lr_udr = LogisticRegression(class_weight= 'balanced', solver=
'liblinear')
lr_params = {"C":np.logspace(-3,3,7), "penalty":["l1","l2", "none"]}

buildModel(lr_udr, lr_params, x_udr_train, y_udr_train, x_udr_test,
y_udr_test, test_X, test_y, 'Undersampled LR')
```

```
Building model Undersampled LR.......

/usr/local/lib/python3.7/dist-packages/sklearn/svm/_base.py:1208:
ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  ConvergenceWarning,
/usr/local/lib/python3.7/dist-packages/sklearn/svm/_base.py:1208:
ConvergenceWarning: Liblinear failed to converge, increase the number
of iterations.
  ConvergenceWarning,


Best score  0.9471951318150978
Best param  {'C': 0.1, 'penalty': 'l2'}
Best model  LogisticRegression(C=0.1, class_weight='balanced',
solver='liblinear')

Model performance Undersampled LR

accuracy score train 0.9579646017699115
accuracy score test 0.9515418502202643

Train classification report: Undersampled LR
```

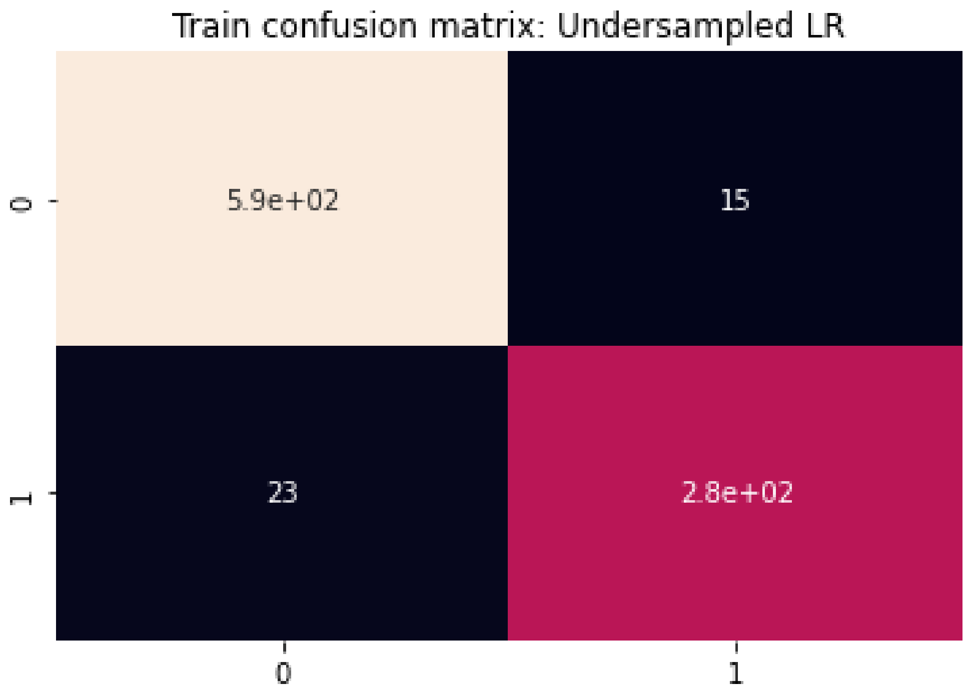
```
              precision    recall  f1-score   support

           0       0.96      0.98      0.97       603
           1       0.95      0.92      0.94       301

    accuracy                           0.96       904
   macro avg       0.96      0.95      0.95       904
weighted avg       0.96      0.96      0.96       904
```

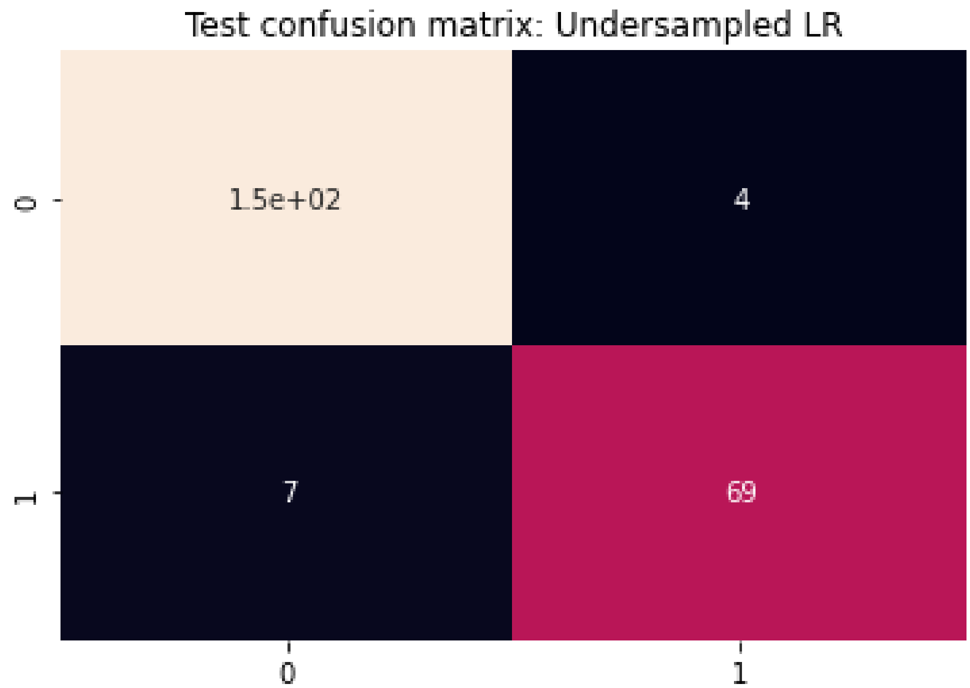
Test classification report: Undersampled LR

```
              precision    recall  f1-score   support

           0       0.95      0.97      0.96       151
           1       0.95      0.91      0.93        76

    accuracy                           0.95       227
   macro avg       0.95      0.94      0.95       227
weighted avg       0.95      0.95      0.95       227
```

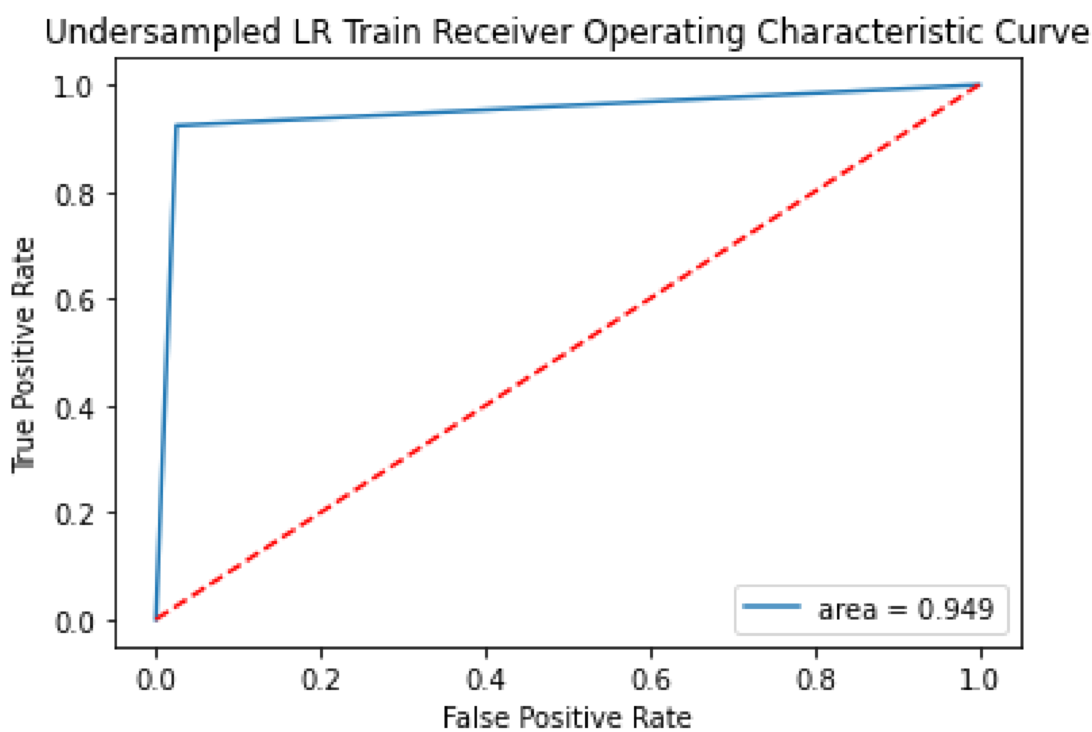
```
/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/
_validation.py:372: FitFailedWarning:
35 fits failed out of a total of 105.
The score on these train-test partitions for these parameters will be
set to nan.
If these failures are not expected, you can try to debug them by
setting error_score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------
----------
35 fits failed with the following error:
Traceback (most recent call last):
  File
"/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_valid
ation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File
"/usr/local/lib/python3.7/dist-packages/sklearn/linear_model/_logistic
.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File
"/usr/local/lib/python3.7/dist-packages/sklearn/linear_model/_logistic
.py", line 464, in _check_solver
    raise ValueError("penalty='none' is not supported for the
```

```
liblinear solver")
ValueError: penalty='none' is not supported for the liblinear solver

  warnings.warn(some_fits_failed_message, FitFailedWarning)
/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_search
.py:972: UserWarning: One or more of the test scores are non-finite:
[0.61243345 0.90812638        nan 0.89353767 0.9436896         nan
 0.94279731 0.94719513        nan 0.94123003 0.9450495         nan
 0.94023415 0.94270683        nan 0.94023415 0.93892794        nan
 0.94017528 0.94144928        nan]
  category=UserWarning,
```

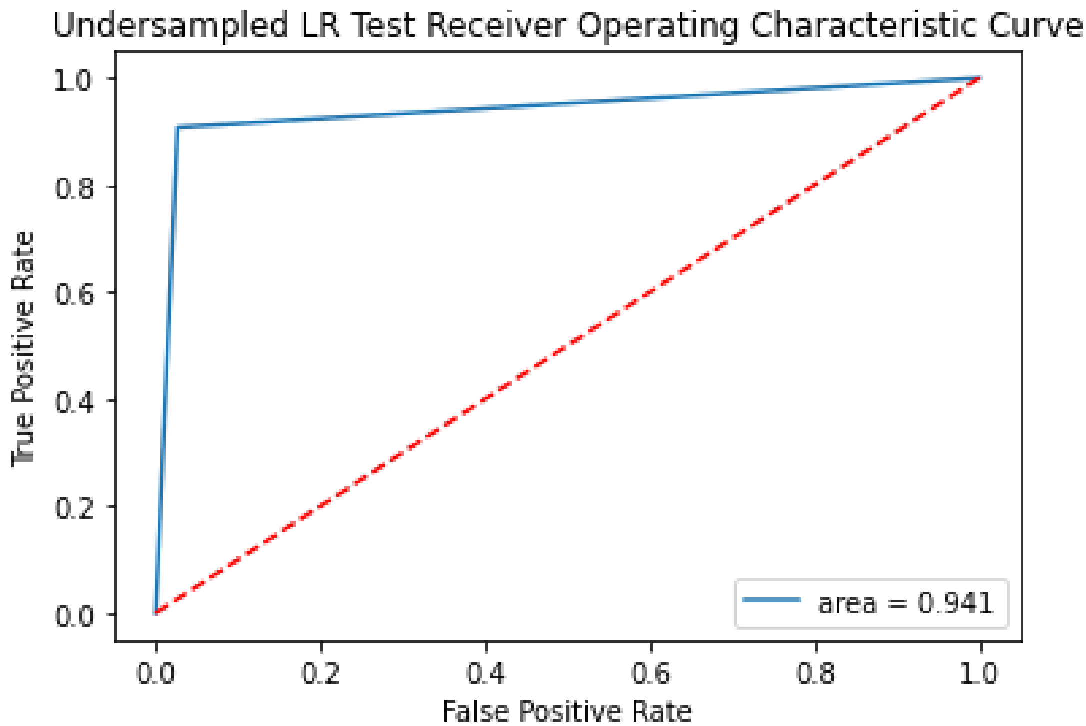




roc auc score train 0.9493562089882812



roc auc score test 0.9407023353084699




```
Test accuracy score 0.9765808784803904

Classification report

              precision    recall  f1-score   support

           0       1.00      0.98      0.99     56864
           1       0.06      0.87      0.11        98

    accuracy                           0.98     56962
   macro avg       0.53      0.92      0.55     56962
weighted avg       1.00      0.98      0.99     56962


Completed for Undersampled LR
Saving model as Undersampled LR.pkl
```

Undersampled logistic regression same similar performance as oversampled data.

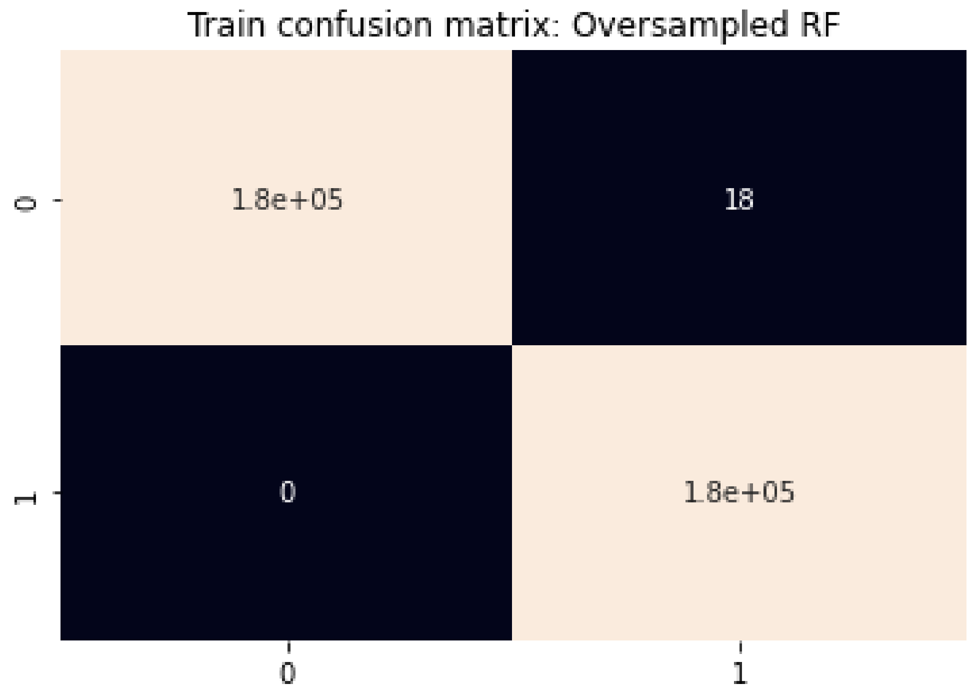
RandomForest Classifier

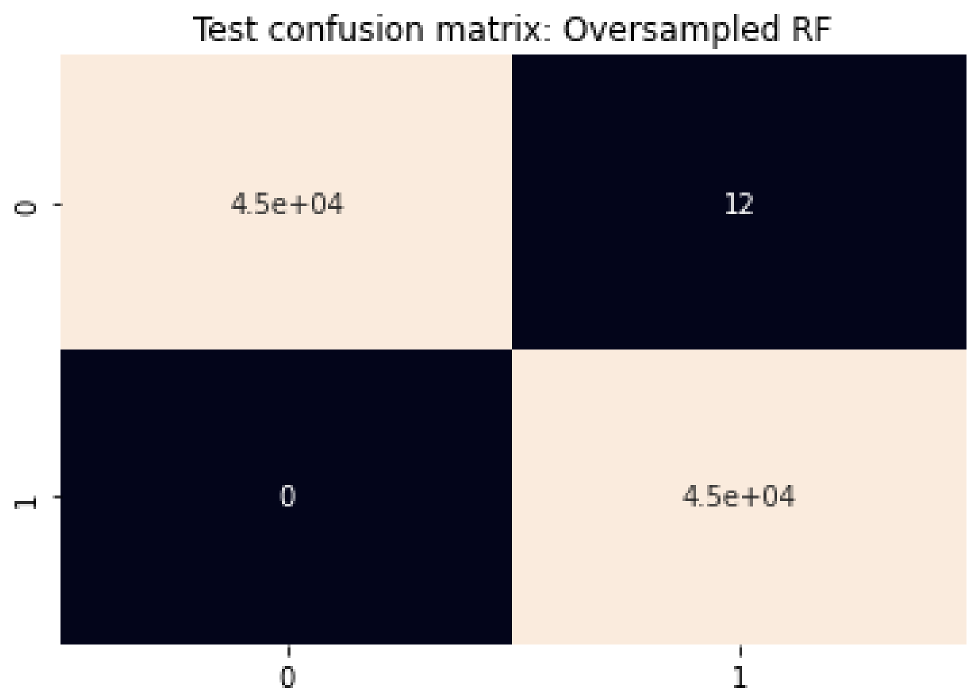
RandomForest Classifier with oversampled data

```
rf_ovr = RandomForestClassifier(class_weight='balanced')
rf_params = {'n_estimators': [100, 150], 'max_depth': [10, 15],
'min_samples_split': [2, 4]}
```

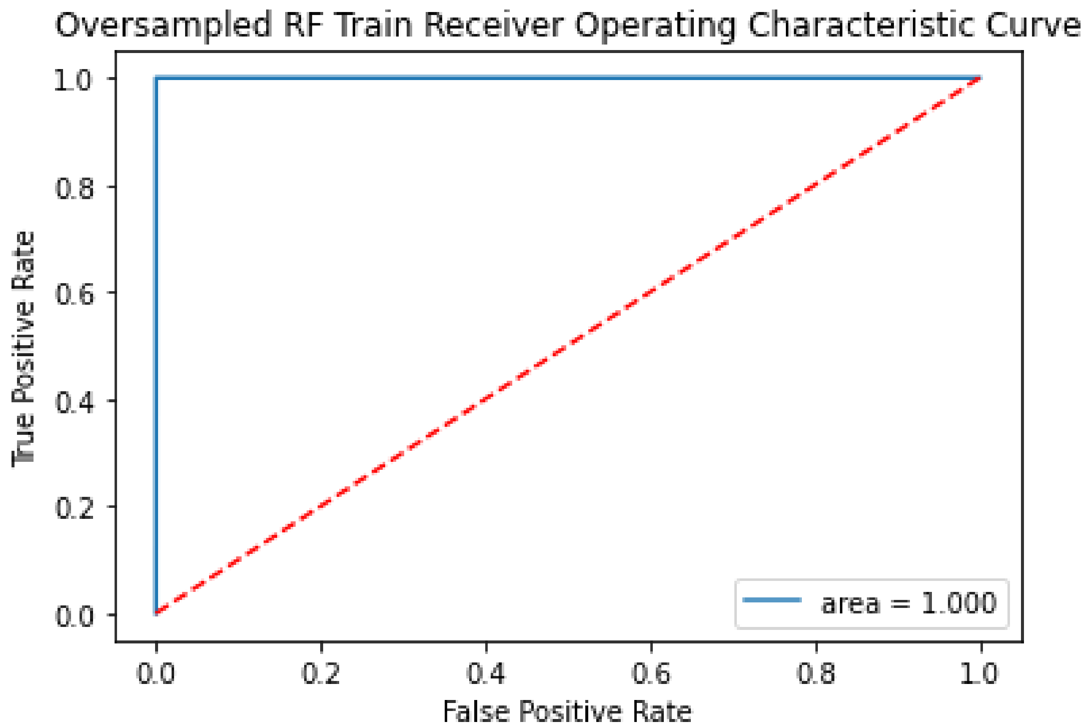
```
buildModel(rf_ovr, rf_params, x_ovr_train, y_ovr_train, x_ovr_test,
y_ovr_test, test_X, test_y, 'Oversampled RF')
```

```
Building model Oversampled RF.......

Best score  0.9999225664854812
Best param  {'max_depth': 15, 'min_samples_split': 2, 'n_estimators':
100}
Best model  RandomForestClassifier(class_weight='balanced',
max_depth=15)

Model performance Oversampled RF

accuracy score train 0.9999502213766002
accuracy score test 0.9998672581055519

Train classification report: Oversampled RF

              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       1.00      1.00      1.00    180801

    accuracy                           1.00    361601
   macro avg       1.00      1.00      1.00    361601
weighted avg       1.00      1.00      1.00    361601


Test classification report: Oversampled RF

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       1.00      1.00      1.00     45200

    accuracy                           1.00     90401
   macro avg       1.00      1.00      1.00     90401
weighted avg       1.00      1.00      1.00     90401
```

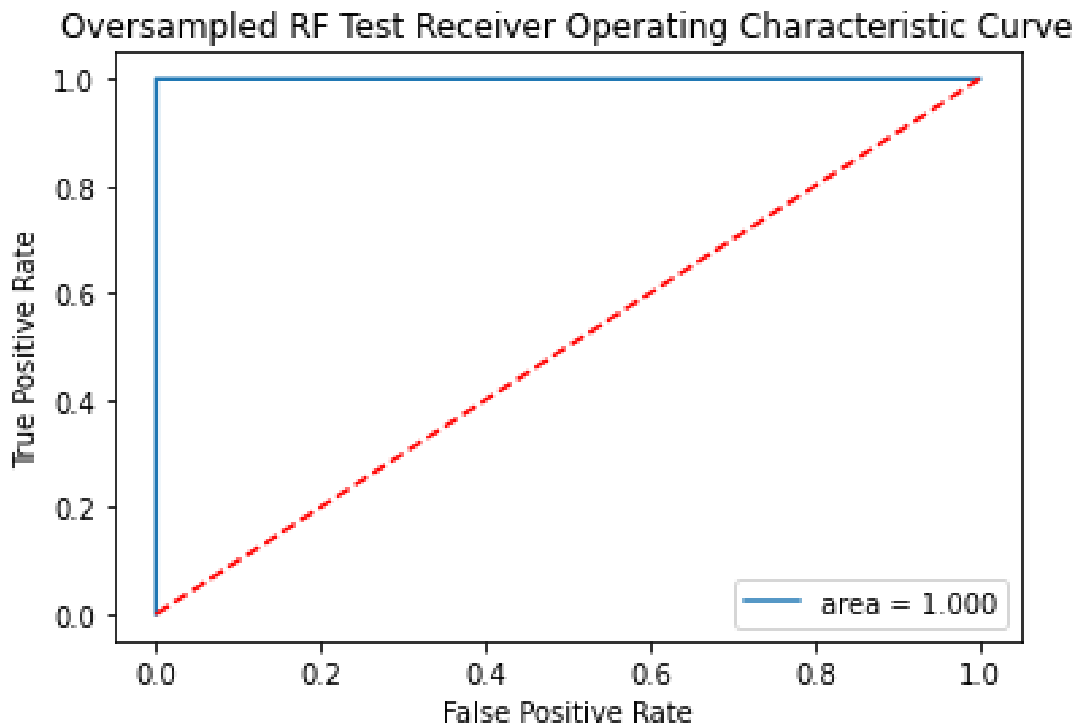





```
roc auc score train 0.9999502212389381
```



roc auc score test 0.9998672595739032



Test accuracy score 0.9994557775359011

```
Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.89      0.79      0.83        98

    accuracy                           1.00     56962
   macro avg       0.94      0.89      0.92     56962
weighted avg       1.00      1.00      1.00     56962


Completed for Oversampled RF
Saving model as Oversampled RF.pkl
```

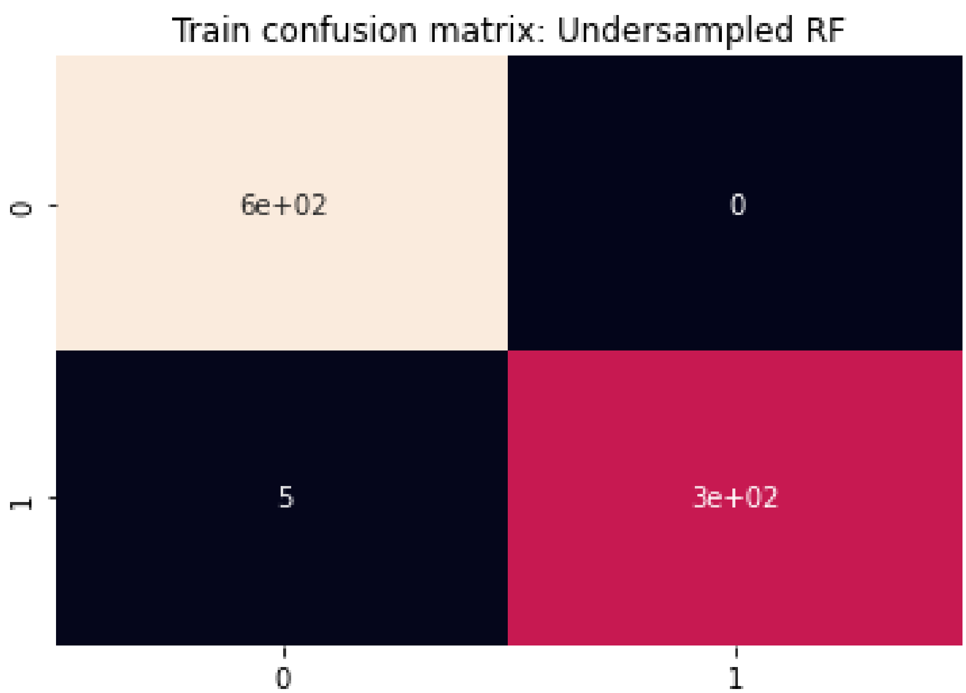
RandomForest classifier with oversampled data gave the performance among all the models with significant difference.

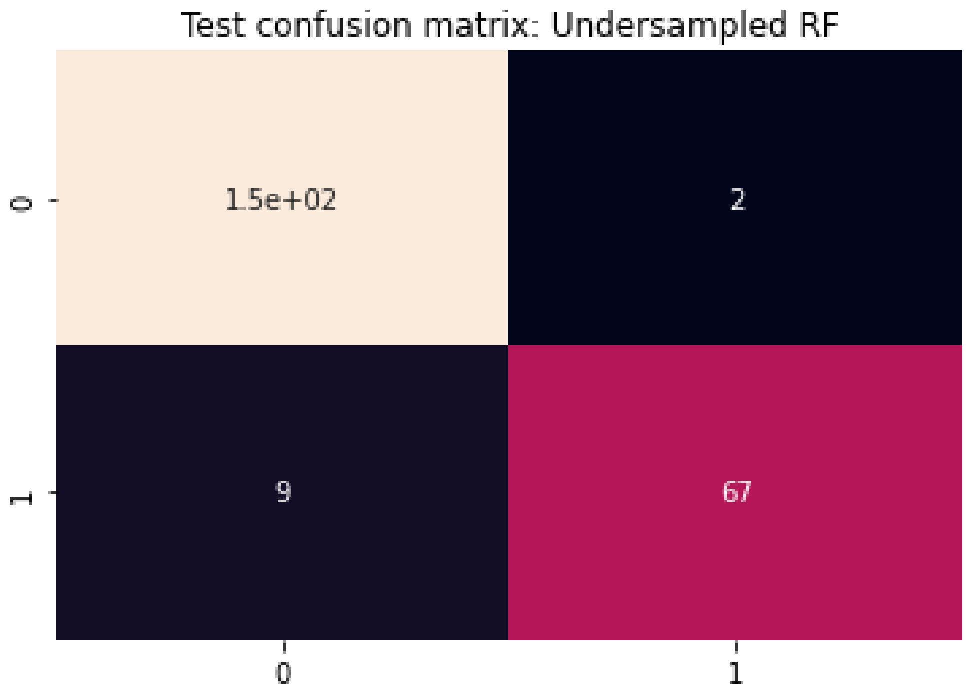
RandomForest Classifier with undersampled data

```
rf_udr = RandomForestClassifier(class_weight='balanced')
rf_params = {'n_estimators': [100, 150], 'max_depth': [10, 15],
'min_samples_split': [2, 4]}

buildModel(rf_udr, rf_params, x_udr_train, y_udr_train, x_udr_test,
y_udr_test, test_X, test_y, 'Undersampled RF')
```

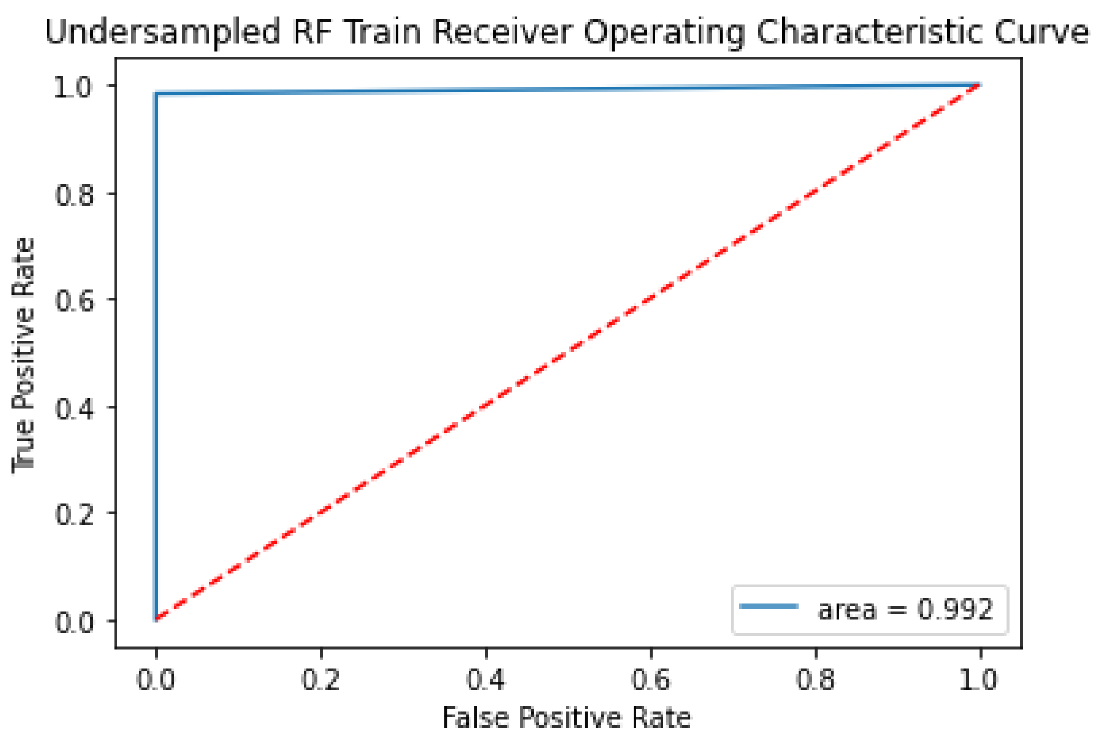
```
Building model Undersampled RF.......

Best score  0.9500027939245086
Best param  {'max_depth': 10, 'min_samples_split': 4, 'n_estimators':
100}
Best model  RandomForestClassifier(class_weight='balanced',
max_depth=10,
                       min_samples_split=4)

Model performance Undersampled RF

accuracy score train 0.9944690265486725
accuracy score test 0.9515418502202643

Train classification report: Undersampled RF

              precision    recall  f1-score   support

           0       0.99      1.00      1.00       603
           1       1.00      0.98      0.99       301

    accuracy                           0.99       904
```

```
   macro avg       1.00      0.99      0.99       904
weighted avg       0.99      0.99      0.99       904


Test classification report: Undersampled RF

              precision    recall  f1-score   support

           0       0.94      0.99      0.96       151
           1       0.97      0.88      0.92        76

    accuracy                           0.95       227
   macro avg       0.96      0.93      0.94       227
weighted avg       0.95      0.95      0.95       227
```

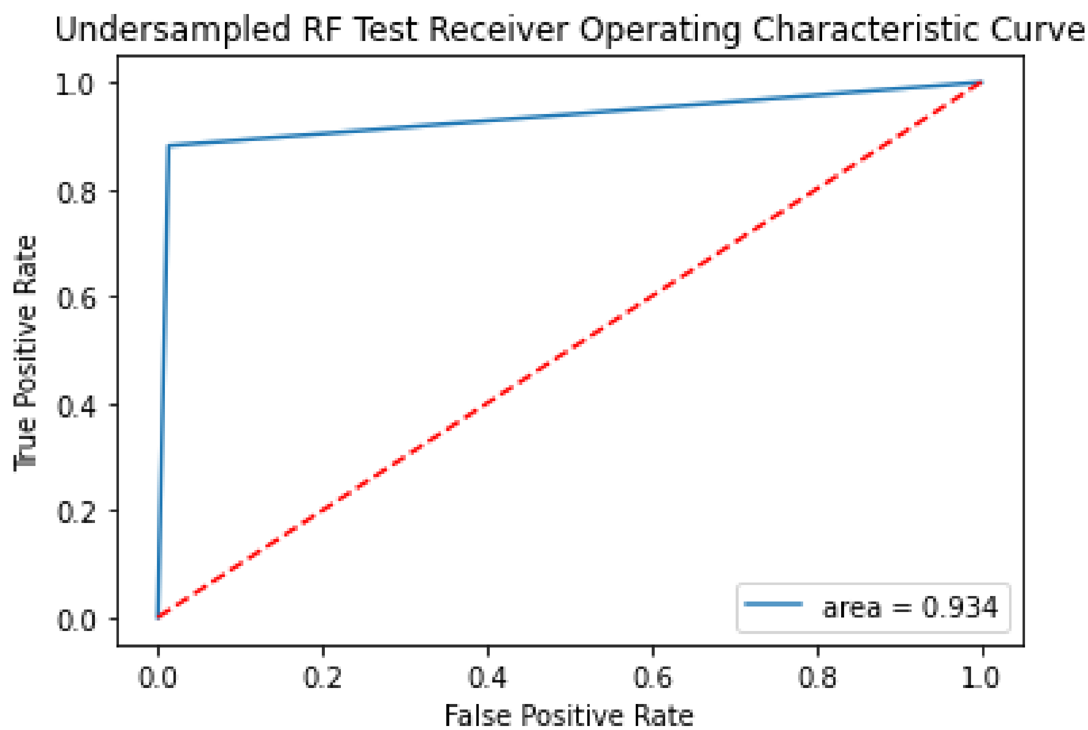





```
roc auc score train 0.9916943521594684
```




```
roc auc score test 0.9341669571279192
```




```
Test accuracy score 0.9913275517011341

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      1.00     56864
           1       0.15      0.86      0.25        98

    accuracy                           0.99     56962
   macro avg       0.57      0.92      0.62     56962
weighted avg       1.00      0.99      0.99     56962


Completed for Undersampled RF
Saving model as Undersampled RF.pkl
```

Random forest with undersampled data gave better performance than the other models. but its less as compared to the same with oversampled data. Thats why its always good to try an ensamble technique.

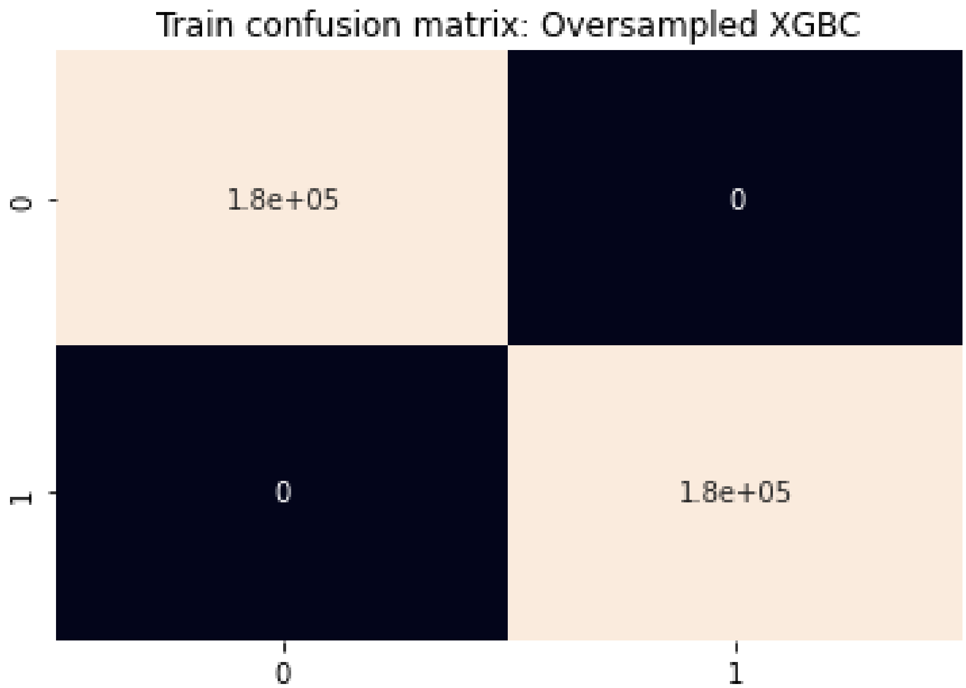
XGBoost Classifier

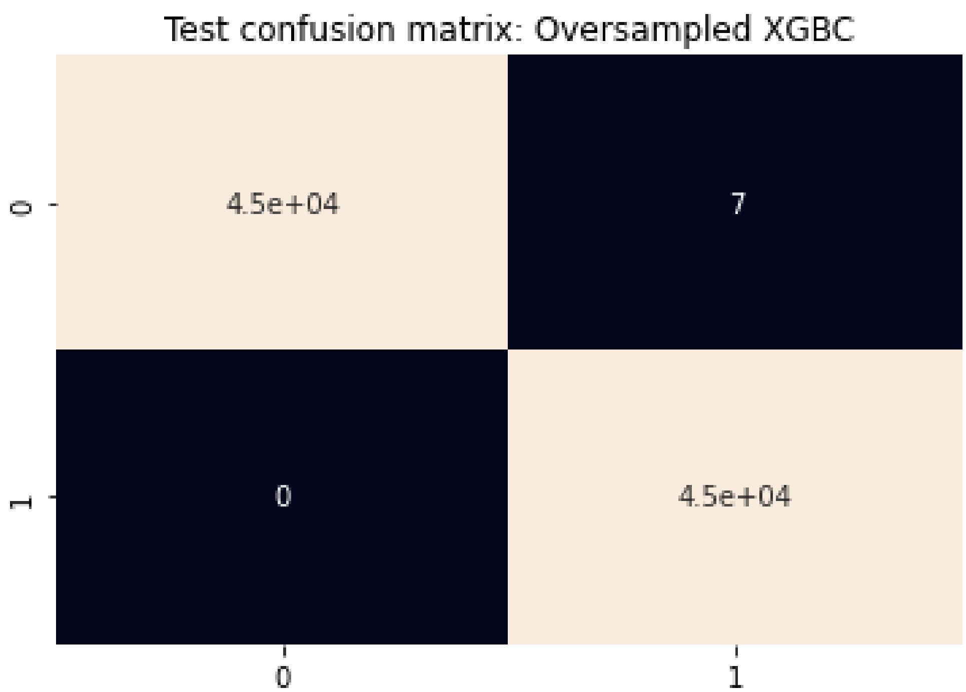
XGBClassifier with oversampled data

```
xgbc_ovr = XGBClassifier(objective='binary:logistic')
xgbc_params = {
```

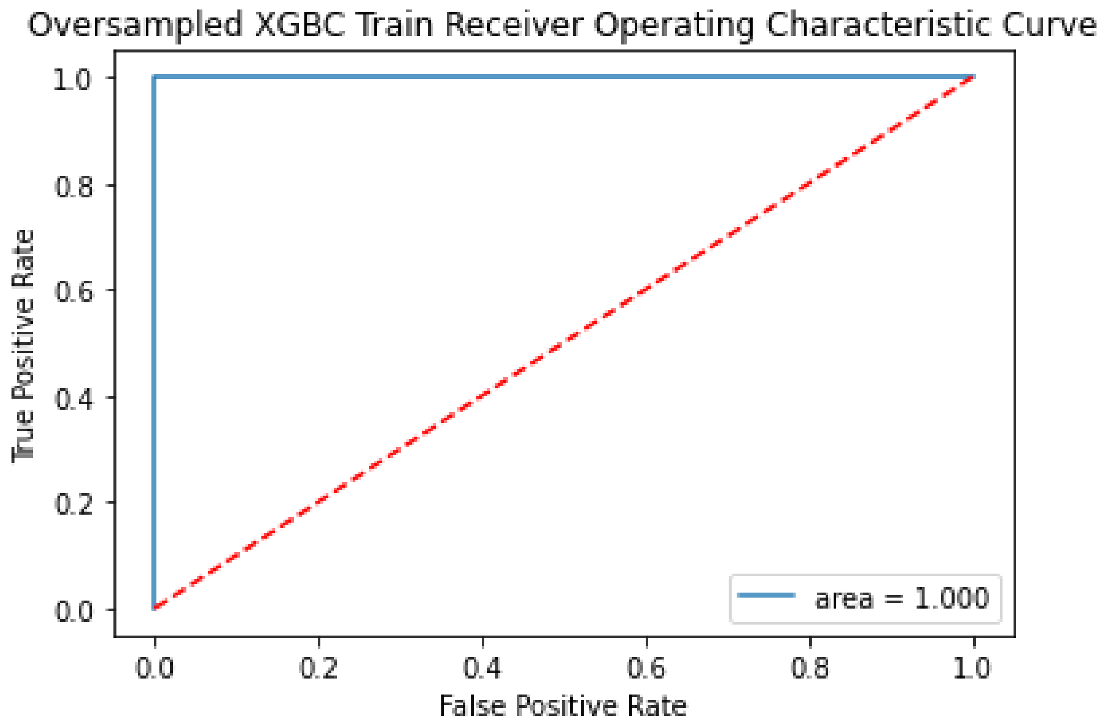
```
"gamma": [0.05, 0.1], "max_depth": [10, 15],
"n_estimators": [120, 150]
}

buildModel(xgbc_ovr, xgbc_params, x_ovr_train, y_ovr_train,
x_ovr_test, y_ovr_test, test_X, test_y, 'Oversampled XGBC')
```

```
Building model Oversampled XGBC.......

Best score  0.9999087390899989
Best param  {'gamma': 0.05, 'max_depth': 10, 'n_estimators': 150}
Best model  XGBClassifier(gamma=0.05, max_depth=10, n_estimators=150)

Model performance Oversampled XGBC

accuracy score train 1.0
accuracy score test 0.9999225672282386

Train classification report: Oversampled XGBC

              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       1.00      1.00      1.00    180801

    accuracy                           1.00    361601
   macro avg       1.00      1.00      1.00    361601
weighted avg       1.00      1.00      1.00    361601


Test classification report: Oversampled XGBC

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       1.00      1.00      1.00     45200

    accuracy                           1.00     90401
   macro avg       1.00      1.00      1.00     90401
weighted avg       1.00      1.00      1.00     90401
```

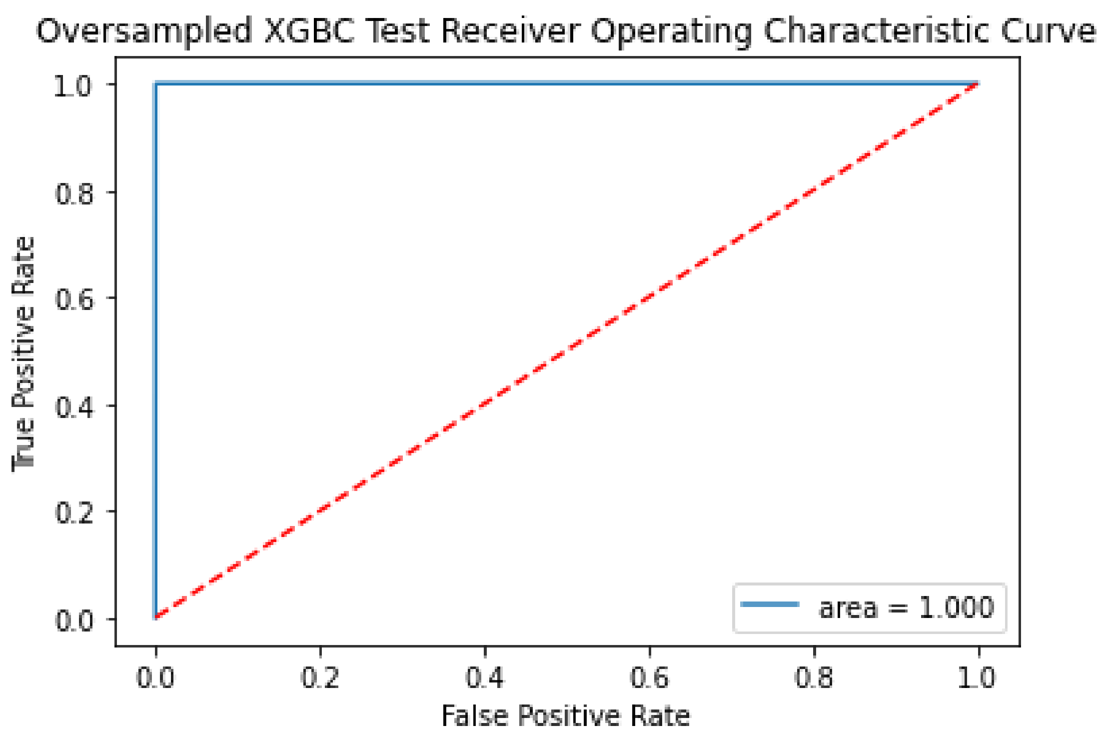





```
roc auc score train 1.0
```




```
roc auc score test 0.9999225680847769
```




```
Test accuracy score 0.999403110845827
```

```
Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.86      0.79      0.82        98

    accuracy                           1.00     56962
   macro avg       0.93      0.89      0.91     56962
weighted avg       1.00      1.00      1.00     56962


Completed for Oversampled XGBC
Saving model as Oversampled XGBC.pkl
```

XGBClassifier with oversampled data performed so well that its similar to random forest.

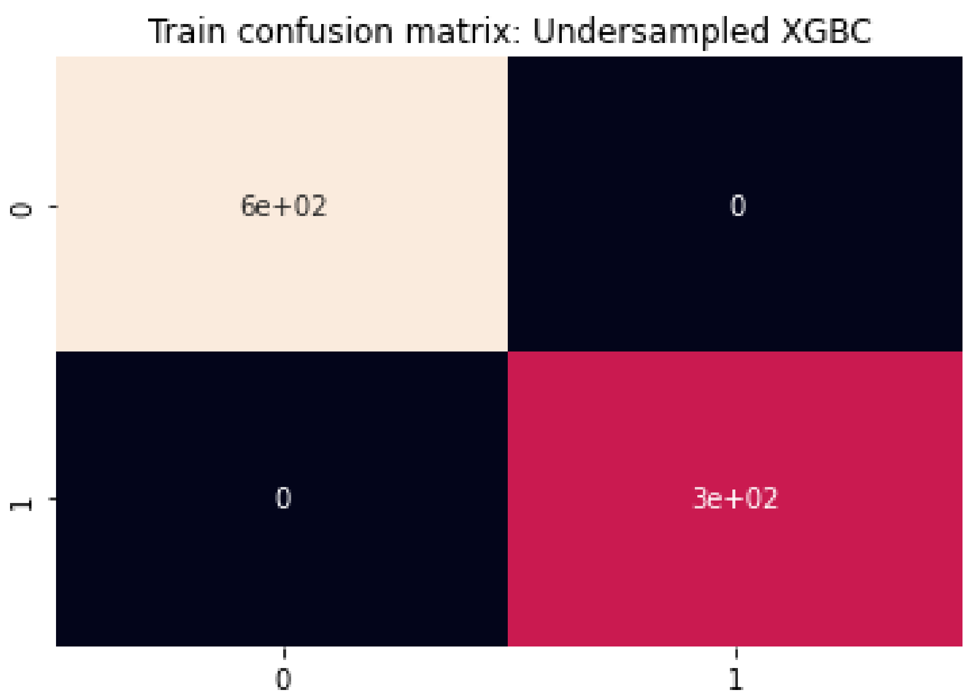
With all there performances, we can see how ensable techniques with proper data can give significant better performance than the other models.

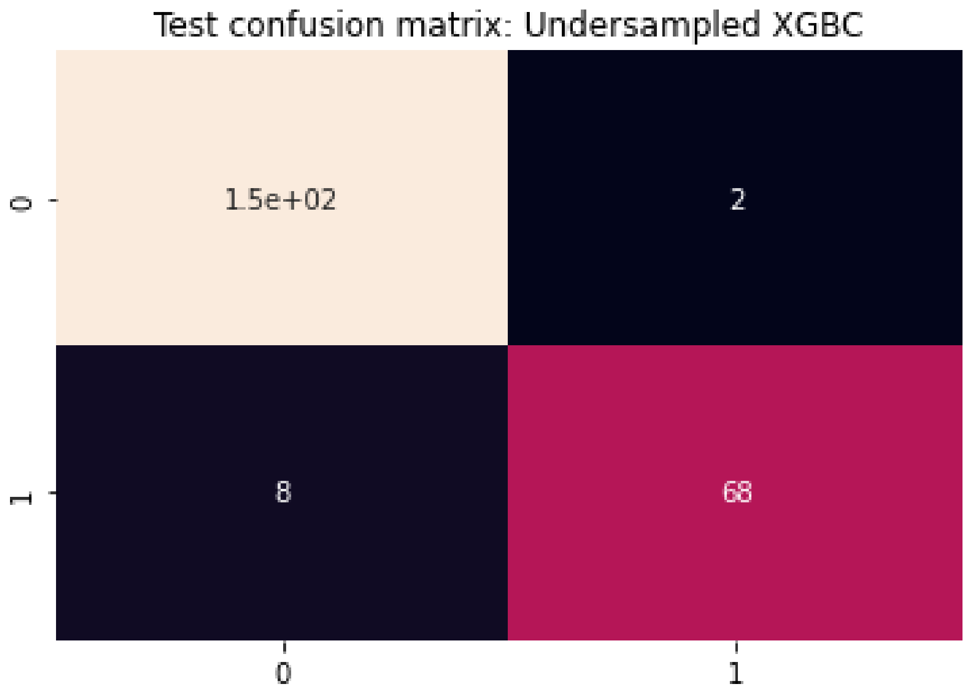
XGBClassifier with undersampled data

```
xgbc_udr = XGBClassifier(objective='binary:logistic')
xgbc_params = {
"gamma": [0.01, 0.05, 0.1], "max_depth": [5, 10, 15],
"n_estimators": [100, 120, 150]
}

buildModel(xgbc_udr, xgbc_params, x_udr_train, y_udr_train,
x_udr_test, y_udr_test, test_X, test_y, 'Undersampled XGBC')
```

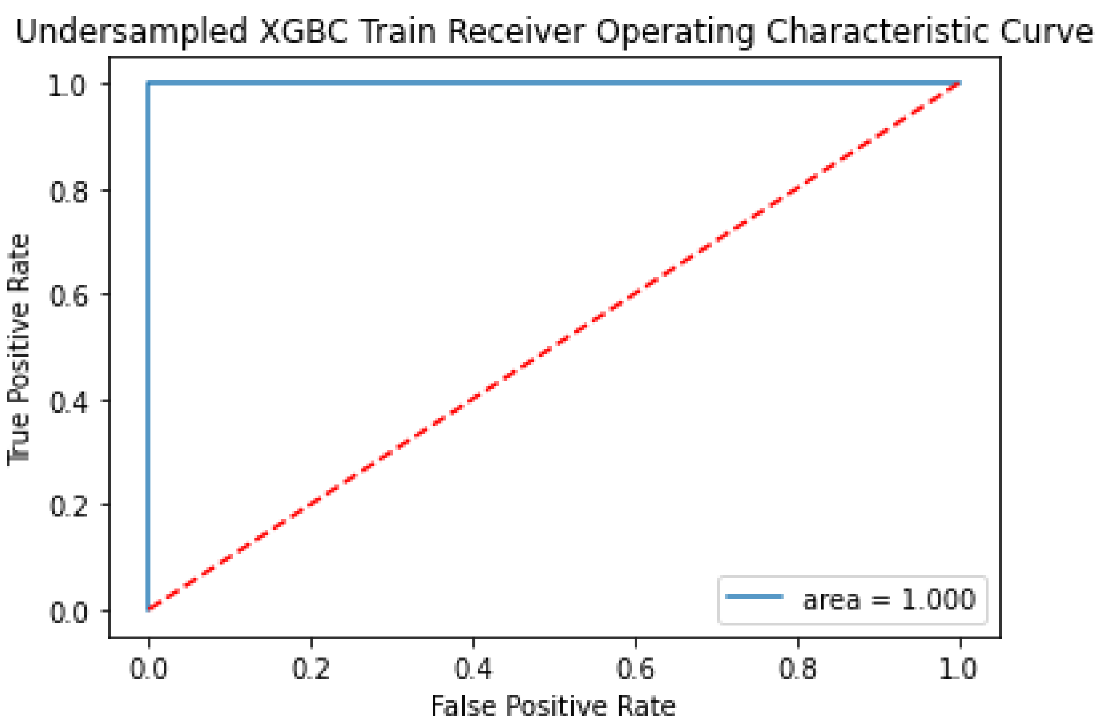
```
Building model Undersampled XGBC.......

Best score  0.9517150786855014
Best param  {'gamma': 0.01, 'max_depth': 10, 'n_estimators': 150}
Best model  XGBClassifier(gamma=0.01, max_depth=10, n_estimators=150)

Model performance Undersampled XGBC

accuracy score train 1.0
accuracy score test 0.9559471365638766

Train classification report: Undersampled XGBC

              precision    recall  f1-score   support

           0       1.00      1.00      1.00       603
           1       1.00      1.00      1.00       301
```

```
    accuracy                           1.00       904
   macro avg       1.00      1.00      1.00       904
weighted avg       1.00      1.00      1.00       904


Test classification report: Undersampled XGBC

              precision    recall  f1-score   support

           0       0.95      0.99      0.97       151
           1       0.97      0.89      0.93        76

    accuracy                           0.96       227
   macro avg       0.96      0.94      0.95       227
weighted avg       0.96      0.96      0.96       227
```

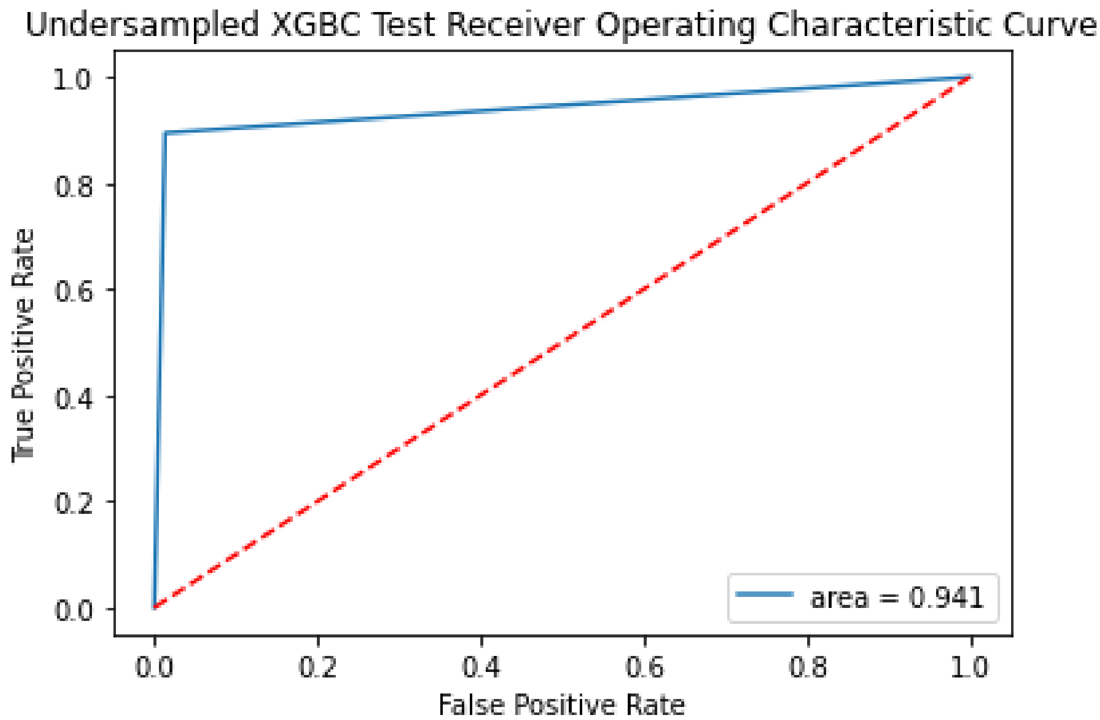




roc auc score train 1.0



roc auc score test 0.9407459044963403




```
Test accuracy score 0.9878515501562445

Classification report
              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.11      0.86      0.20        98

    accuracy                           0.99     56962
   macro avg       0.55      0.92      0.59     56962
weighted avg       1.00      0.99      0.99     56962


Completed for Undersampled XGBC
Saving model as Undersampled XGBC.pkl
```

XGBClassifier with undersampled data performed better than other models, but its less than random forest classifier and its oversampled version.

For models like Logistic regression, random forest and xgboost, performed better wwith the oversampled data.

SVC model gave better performance with undersampled data, where as naive bayes gave almost similar performance.

So we have random forest with oversampled data gave the highest performance in terms of f1-score (0.92) on test data.

SVC with undersampled data gave the lowest performance.

Other models with different combination of data, gave moderate performance.

So we can consider Random forest with oversampled data as our final ML model.

Final ML Model (Random Forest with Oversampled data)

Lets upload the random forest model from the pickle file and try to get top 10 important features from it.

```
train_udr_df = pd.read_pickle('finance_udr_train.pkl')
```

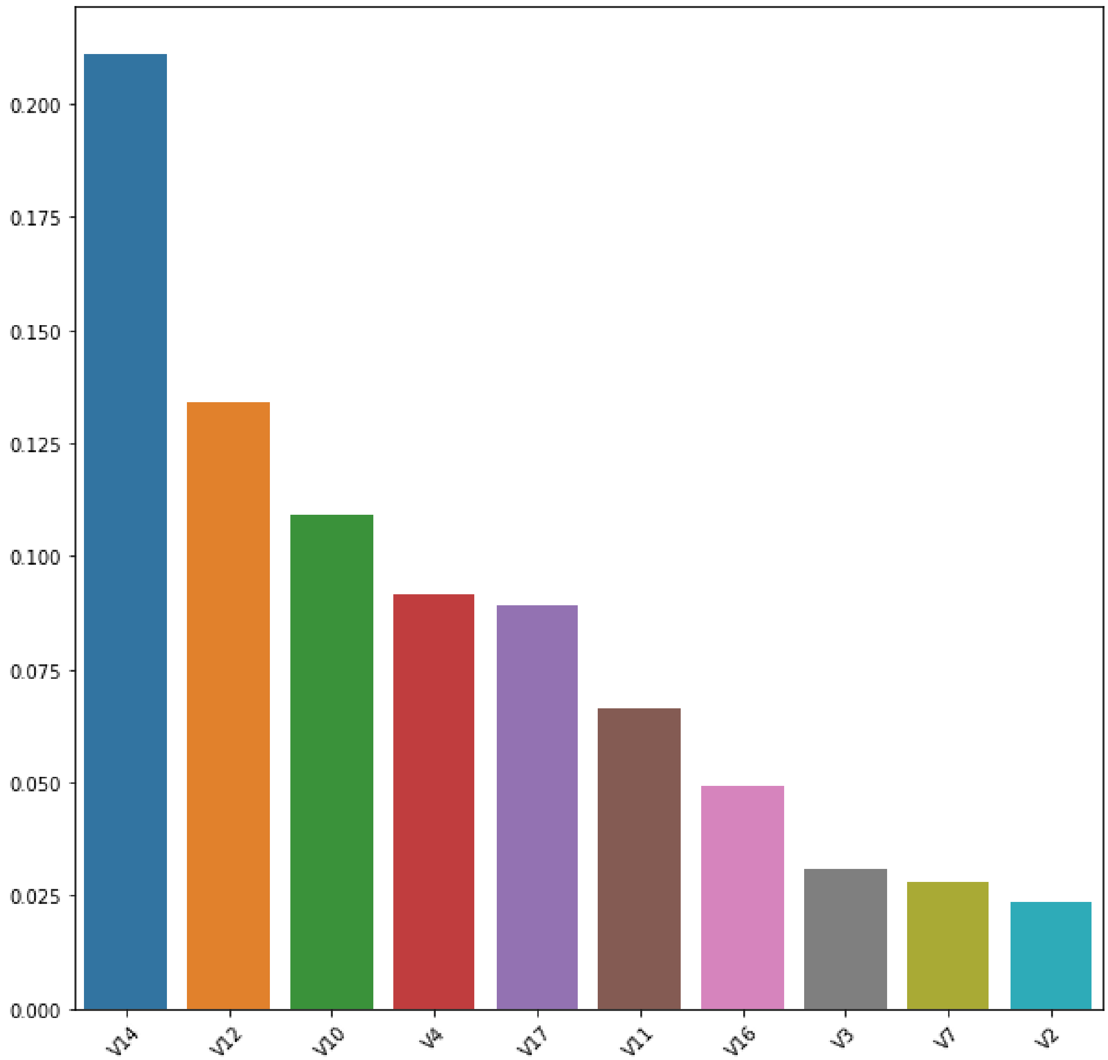
```
rf_ovr = pickle.load(open('Oversampled RF.pkl', 'rb'))
```

```
train_udr_df.columns
```

```
Index(['Time', 'V1', 'V2', 'V3', 'V4', 'V5', 'V6', 'V7', 'V8', 'V9',
'V10',
       'V11', 'V12', 'V13', 'V14', 'V15', 'V16', 'V17', 'V18', 'V19',
'V20',
       'V21', 'V22', 'V23', 'V24', 'V25', 'V26', 'V27', 'V28',
'Amount',
       'Class'],
      dtype='object')
```

```
feature_names = train_udr_df.columns[:-1]
importances = rf_ovr.feature_importances_
important_features = np.argsort(importances)[::-1][:10]
names = feature_names[important_features]
values = importances[important_features]
plt.figure(figsize=(10,10))
sns.barplot(names, values)
plt.xticks(rotation=45)
plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/seaborn/_decorators.py:43:
FutureWarning: Pass the following variables as keyword args: x, y.
From version 0.12, the only valid positional argument will be `data`,
and passing other arguments without an explicit keyword will result in
an error or misinterpretation.
  FutureWarning
```



Out of all the PCA transformed features, above are the most important features as per random forest model.

Unfortunately, we dont see amount and time here. So its possible that time and amount dont have close relationship with the class labels.

Project Task: Week 2

Applying ANN

For this binary classification problem, we can try out different ANN models where we can experiment with the number of layers, number of neurons, activation function, kernel initializers, regularizers, batch size, number of epochs, optimizers etc.

So, we can randomly experiment by selecting different combination and can build 6 models and finally we can pick the best model.

```
def buildANN(num_layer, num_neuron, activation_fn, initializer,
regularizers, optimizerName, batch_size, epochs, name, dropOut= None):
  input = Input(x_train.shape[-1],)
  x = input
  nu_num = num_neuron
  for i in range(num_layer):
    x = Dense(units = nu_num, activation = activation_fn,
              kernel_initializer = initializer, kernel_regularizer =
regularizers)(x)
    nu_num //= 2
  if dropOut is not None:
    x = Dropout(dropOut)(x)
    x = BatchNormalization()(x)

  x = Dense(units = 10, activation = activation_fn,
              kernel_initializer = initializer, kernel_regularizer =
regularizers)(x)
  output = Dense(2, activation = 'softmax')(x)

  model = Model(input, output)
  print(model.summary())
  model.compile(loss='categorical_crossentropy', optimizer=
optimizerName, metrics=[F1Score(num_classes= 2, average= 'macro')])
  callback = EarlyStopping(monitor='val_loss', patience=3)
  model.fit(x_train, y_train,
                validation_data=(x_test, y_test), batch_size=
batch_size, epochs=epochs, callbacks=[callback])

  y_train_pred = model.predict(x_train)
  y_test_pred = model.predict(x_test)
  y_train_label = np.argmax(y_train, axis= 1)
  y_train_pred = np.argmax(y_train_pred, axis= 1)
  y_test_label = np.argmax(y_test, axis= 1)
  y_test_pred = np.argmax(y_test_pred, axis= 1)

  getPerformance(y_train_label, y_train_pred, y_test_label,
y_test_pred, name)

  test_y_pred = model.predict(test_X)
  test_y_label = np.argmax(test_y, axis= 1)
  test_y_pred = np.argmax(test_y_pred, axis= 1)

  print('\nTest accuracy score {} \
n'.format(accuracy_score(test_y_label, test_y_pred)))
  print('Classification report\n')
  print(classification_report(test_y_label, test_y_pred))
  print('\nCompleted and saved for model ' + name)
  model.save(name)
```

Oversampled data

```
finance_ovr_train = pd.read_pickle('finance_ovr_train.pkl')
finance_test = pd.read_pickle('finance_test.pkl')

train_ovr_X = finance_ovr_train.drop(['Class'], axis=1)
train_ovr_y = finance_ovr_train[['Class']]

test_X = finance_test.drop(['Class'], axis=1)
test_y = finance_test[['Class']]

x_train, x_test, y_train, y_test = train_test_split(train_ovr_X,
train_ovr_y,

stratify= train_ovr_y,

test_size= 0.2, random_state= 0)

y_train = to_categorical(y_train)
y_test = to_categorical(y_test)
test_y = to_categorical(test_y)

print(x_train.shape)
print(y_train.shape)
print(x_test.shape)
print(y_test.shape)
print(test_X.shape)
print(test_y.shape)
```

```
(361601, 30)
(361601, 2)
(90401, 30)
(90401, 2)
(56962, 30)
(56962, 2)
```

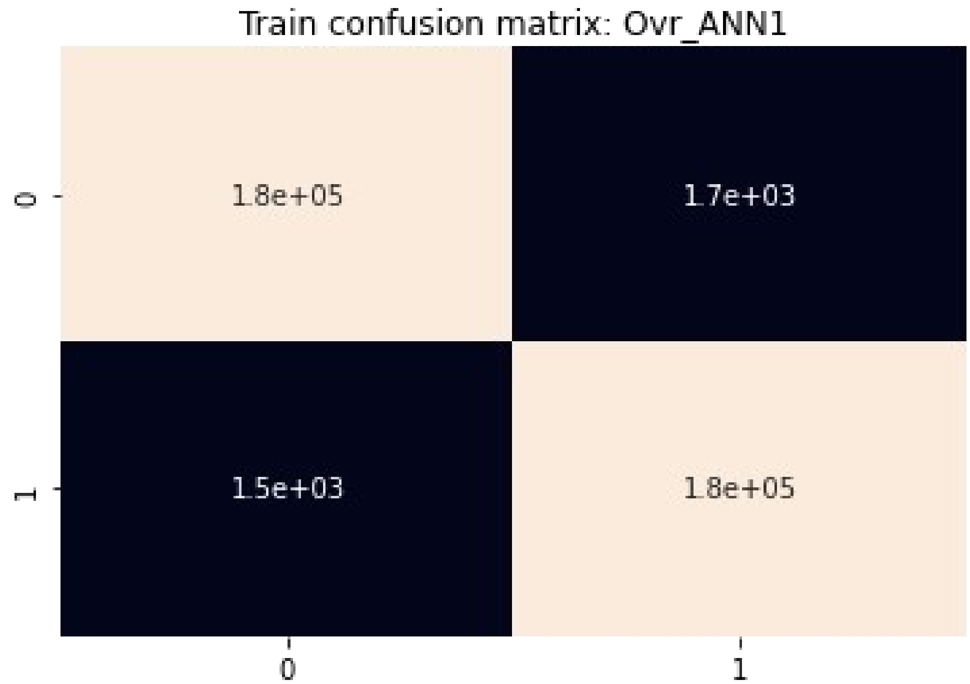
ANN with oversampled data

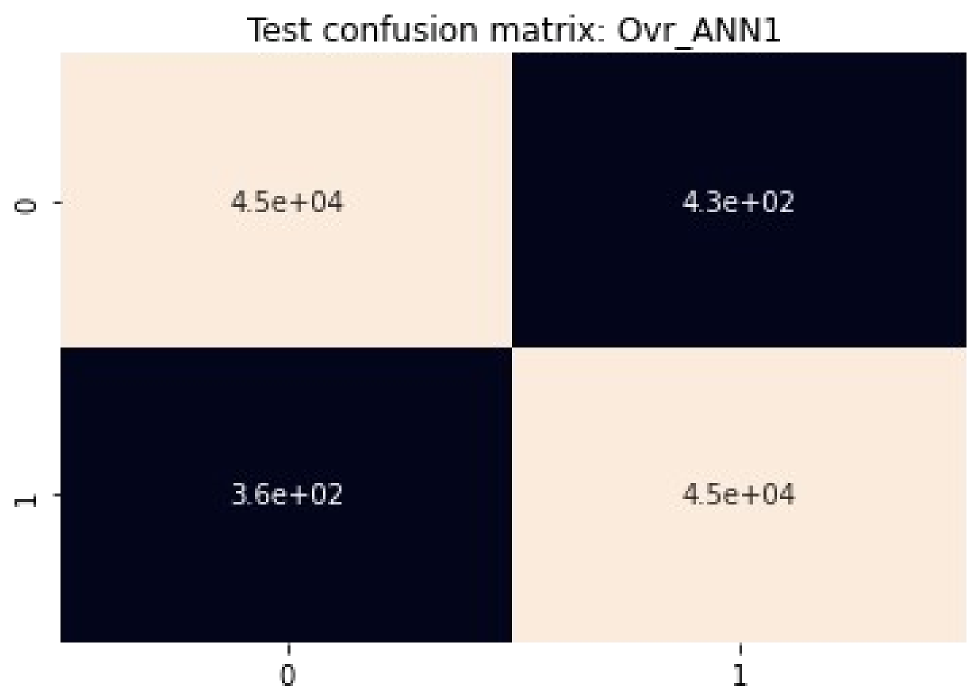
```
buildANN(1, 32, 'relu', 'he_normal', 'l2', 'sgd', 30, 5, 'Ovr_ANN1')
```

```
Model: "model_22"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_30 (InputLayer)       [(None, 30)]              0

 dense_130 (Dense)           (None, 32)                992

 dense_131 (Dense)           (None, 10)                330

 dense_132 (Dense)           (None, 2)                 22

=================================================================
```

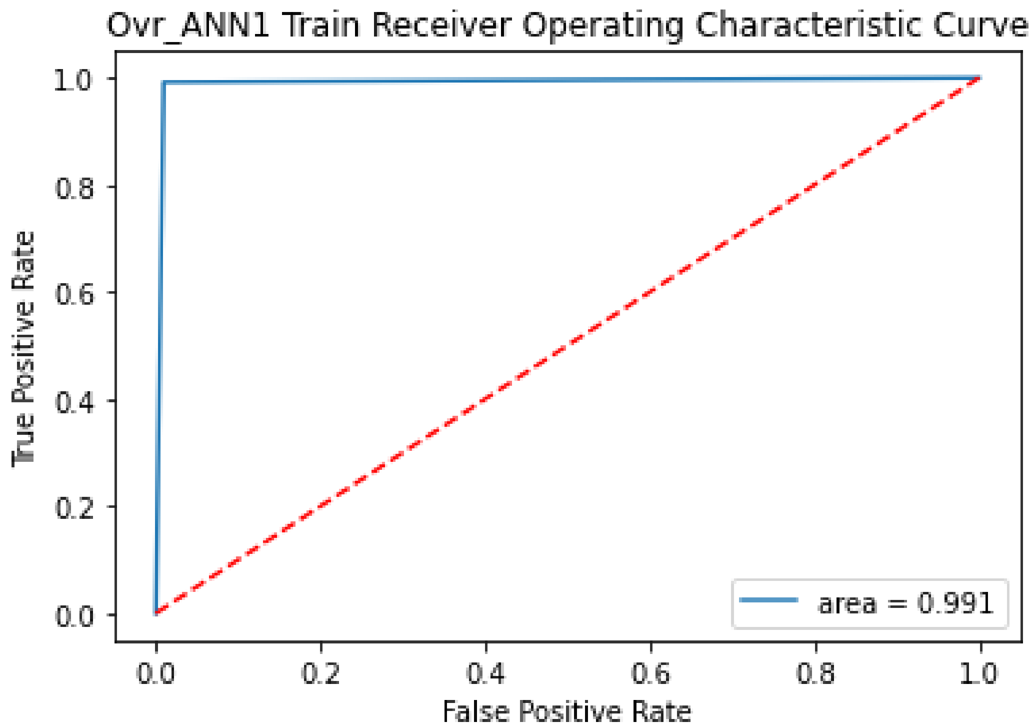
```
Total params: 1,344
Trainable params: 1,344
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/5
12054/12054 [==============================] - 26s 2ms/step - loss: 
0.3099 - f1_score: 0.9580 - val_loss: 0.1203 - val_f1_score: 0.9738
Epoch 2/5
12054/12054 [==============================] - 25s 2ms/step - loss: 
0.1037 - f1_score: 0.9789 - val_loss: 0.0953 - val_f1_score: 0.9853
Epoch 3/5
12054/12054 [==============================] - 25s 2ms/step - loss: 
0.0884 - f1_score: 0.9857 - val_loss: 0.0848 - val_f1_score: 0.9870
Epoch 4/5
12054/12054 [==============================] - 26s 2ms/step - loss: 
0.0812 - f1_score: 0.9890 - val_loss: 0.0804 - val_f1_score: 0.9870
Epoch 5/5
12054/12054 [==============================] - 27s 2ms/step - loss: 
0.0770 - f1_score: 0.9905 - val_loss: 0.0759 - val_f1_score: 0.9913
11301/11301 [==============================] - 16s 1ms/step
2826/2826 [==============================] - 4s 1ms/step

Model performance Ovr_ANN1

accuracy score train 0.9911919491373088
accuracy score test 0.9912832822645767

Train classification report: Ovr_ANN1

              precision    recall  f1-score   support

           0       0.99      0.99      0.99    180800
           1       0.99      0.99      0.99    180801

    accuracy                           0.99    361601
   macro avg       0.99      0.99      0.99    361601
weighted avg       0.99      0.99      0.99    361601


Test classification report: Ovr_ANN1

              precision    recall  f1-score   support

           0       0.99      0.99      0.99     45201
           1       0.99      0.99      0.99     45200

    accuracy                           0.99     90401
   macro avg       0.99      0.99      0.99     90401
```

```
weighted avg       0.99      0.99      0.99     90401
```

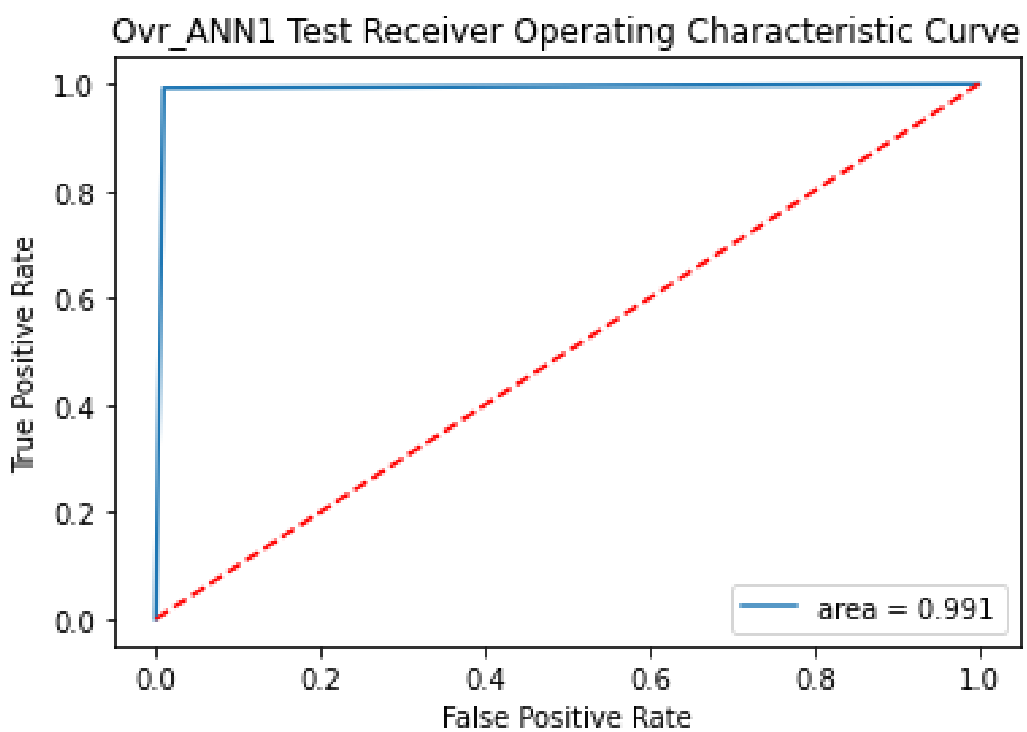





```
roc auc score train 0.9911919473093994
```




```
roc auc score test 0.9912832918078991
```



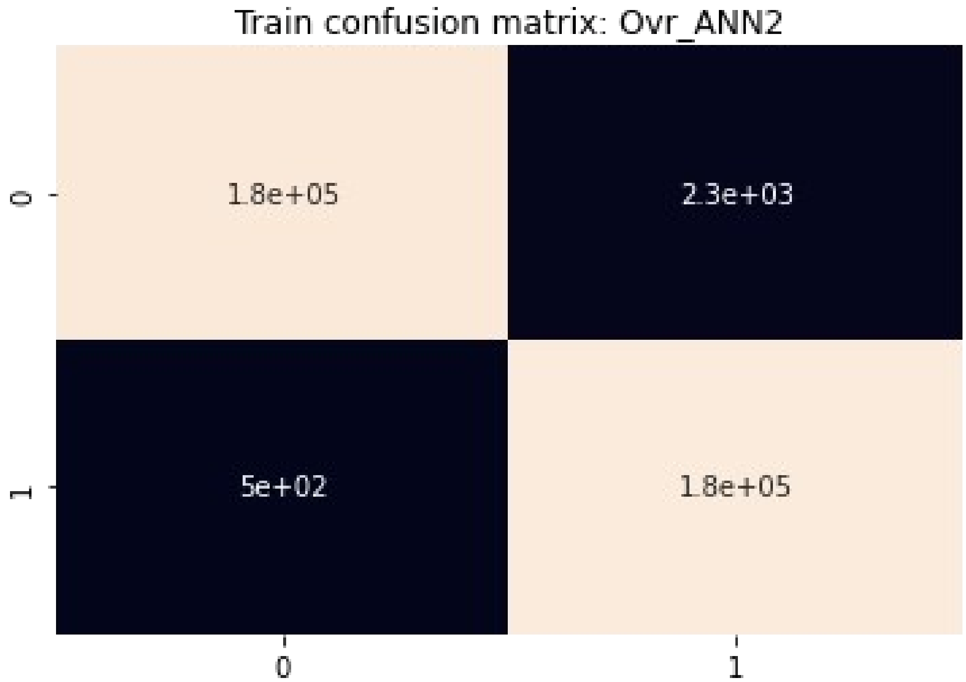

```
1781/1781 [==============================] - 2s 1ms/step
```

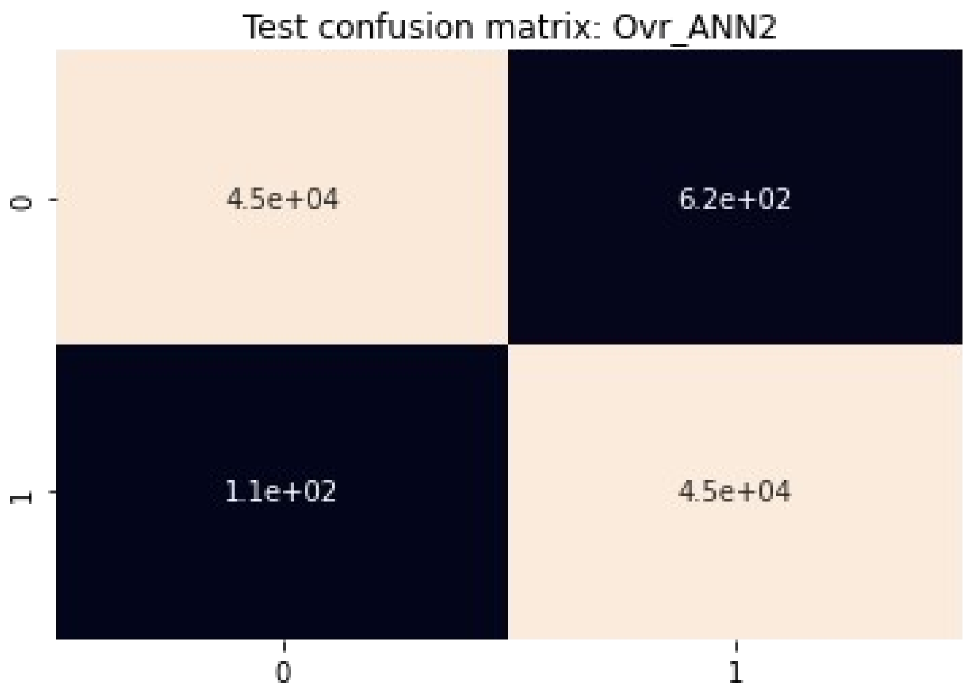
```
Test accuracy score 0.9896773287454794

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.13      0.89      0.23        98

    accuracy                           0.99     56962
   macro avg       0.57      0.94      0.61     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Ovr_ANN1
```

```
buildANN(2, 32, 'relu', 'he_normal', 'l2', 'sgd', 30, 5, 'Ovr_ANN2')
```

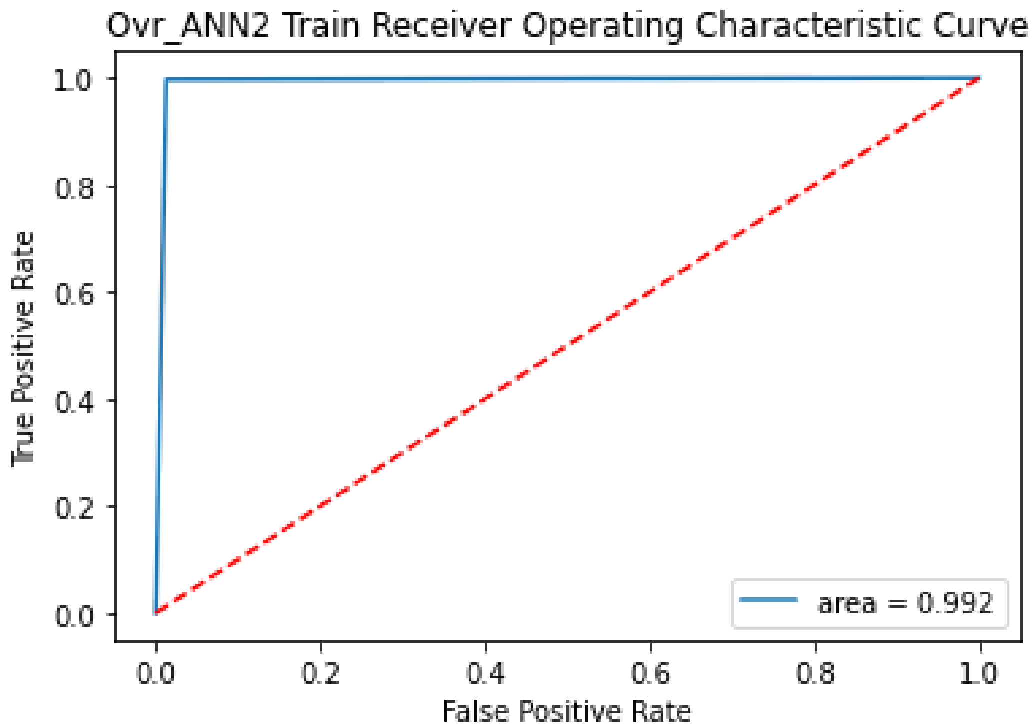
```
Model: "model_23"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_31 (InputLayer)       [(None, 30)]              0

 dense_133 (Dense)           (None, 32)                992

 dense_134 (Dense)           (None, 16)                528

 dense_135 (Dense)           (None, 10)                170

 dense_136 (Dense)           (None, 2)                 22

=================================================================
Total params: 1,712
Trainable params: 1,712
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/5
12054/12054 [==============================] - 29s 2ms/step - loss:
0.3813 - f1_score: 0.9644 - val_loss: 0.1275 - val_f1_score: 0.9821
Epoch 2/5
12054/12054 [==============================] - 27s 2ms/step - loss:
0.1084 - f1_score: 0.9864 - val_loss: 0.0989 - val_f1_score: 0.9910
Epoch 3/5
12054/12054 [==============================] - 27s 2ms/step - loss:
0.0940 - f1_score: 0.9906 - val_loss: 0.0919 - val_f1_score: 0.9917
Epoch 4/5
12054/12054 [==============================] - 27s 2ms/step - loss:
0.0881 - f1_score: 0.9919 - val_loss: 0.0873 - val_f1_score: 0.9914
```

```
Epoch 5/5
12054/12054 [==============================] - 26s 2ms/step - loss:
0.0842 - f1_score: 0.9926 - val_loss: 0.0847 - val_f1_score: 0.9920
11301/11301 [==============================] - 16s 1ms/step
2826/2826 [==============================] - 4s 1ms/step

Model performance Ovr_ANN2

accuracy score train 0.9921958180425386
accuracy score test 0.9919801772104291

Train classification report: Ovr_ANN2

              precision    recall  f1-score   support

           0       1.00      0.99      0.99    180800
           1       0.99      1.00      0.99    180801

    accuracy                           0.99    361601
   macro avg       0.99      0.99      0.99    361601
weighted avg       0.99      0.99      0.99    361601


Test classification report: Ovr_ANN2

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     45201
           1       0.99      1.00      0.99     45200

    accuracy                           0.99     90401
   macro avg       0.99      0.99      0.99     90401
weighted avg       0.99      0.99      0.99     90401
```

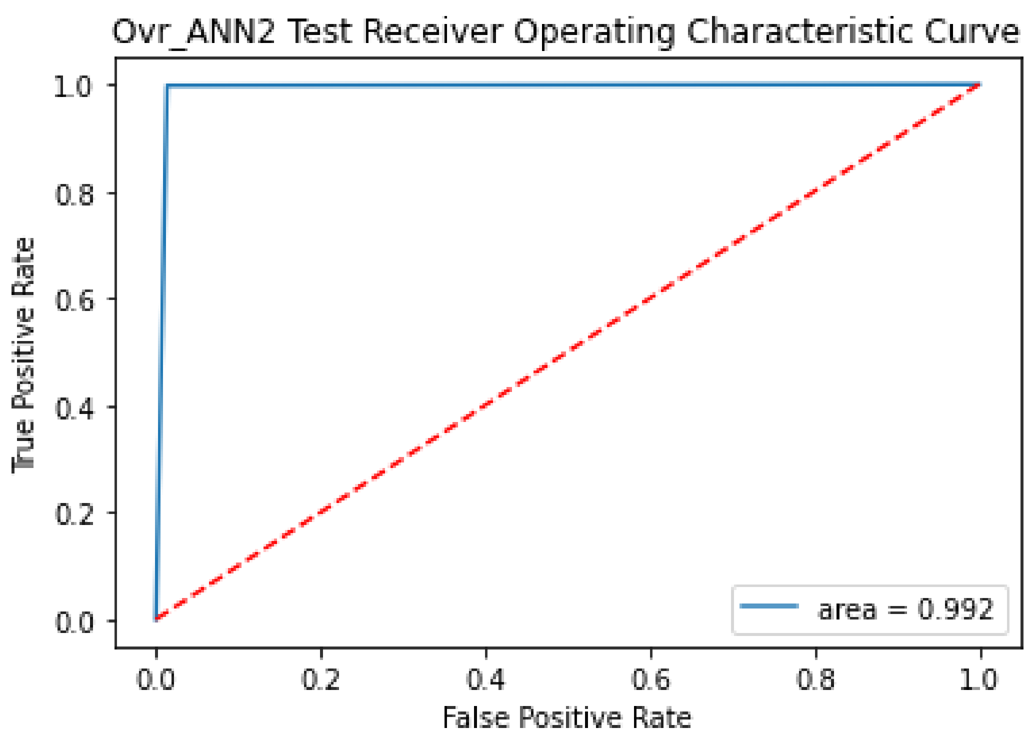





```
roc auc score train 0.9921958041386431
```




```
roc auc score test 0.9919802399821603
```



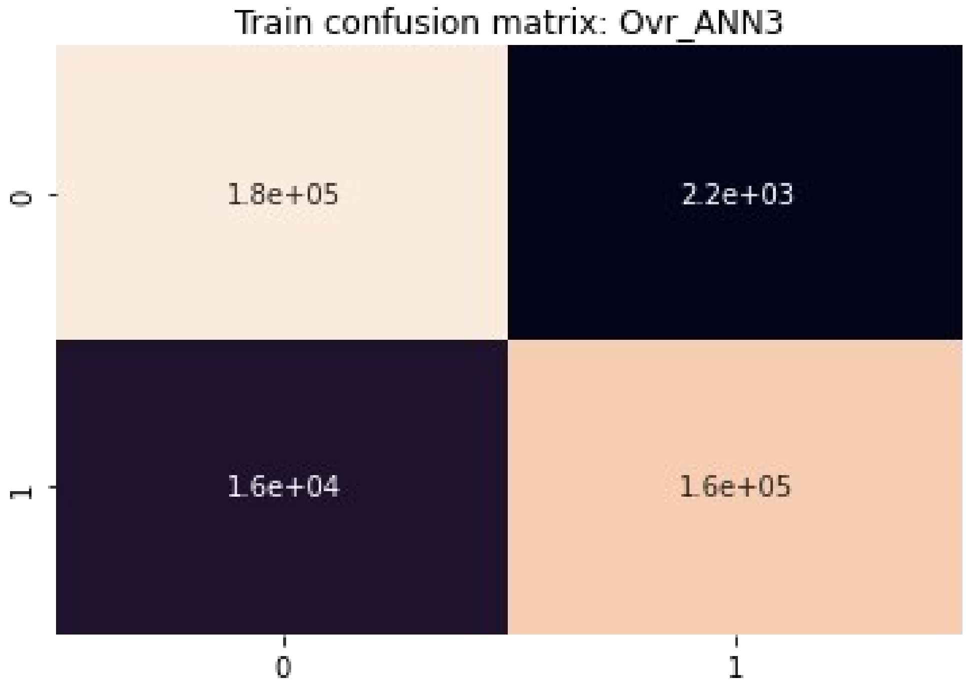

```
1781/1781 [==============================] - 3s 1ms/step
```

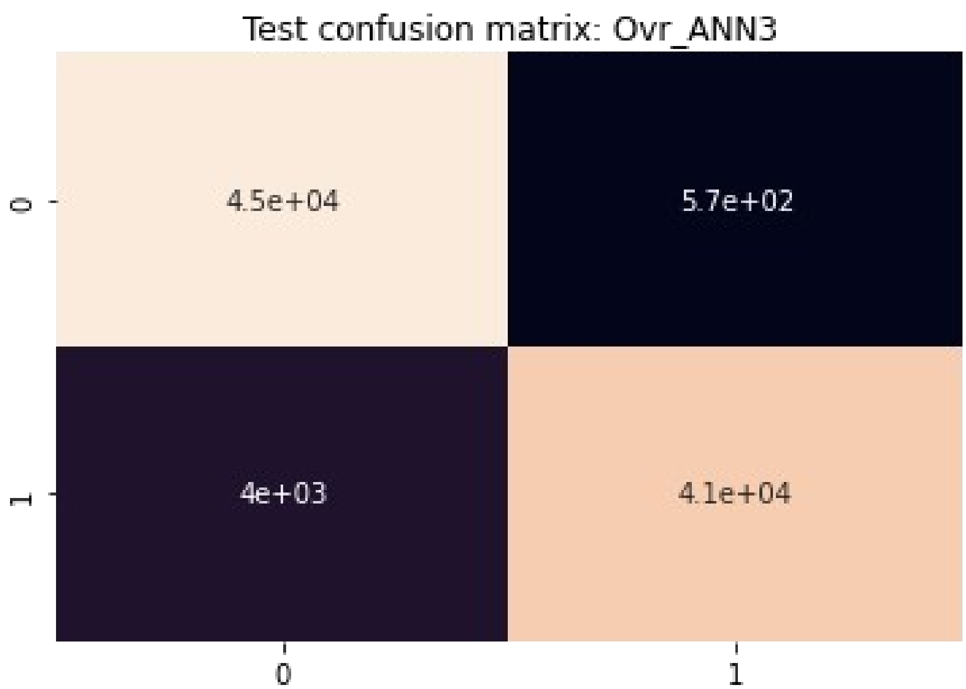
```
Test accuracy score 0.9861311049471577

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.10      0.91      0.18        98

    accuracy                           0.99     56962
   macro avg       0.55      0.95      0.59     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Ovr_ANN2
```

```
buildANN(2, 128, 'relu', 'he_normal', 'l1', 'sgd', 30, 10, 'Ovr_ANN3')
```

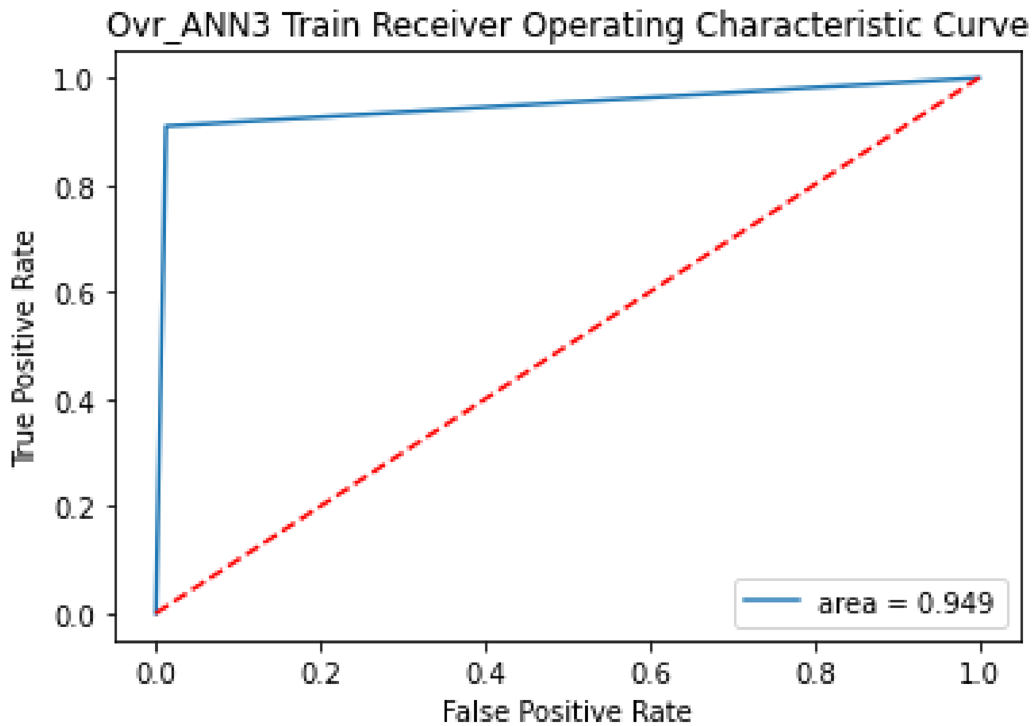
```
Model: "model_24"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_32 (InputLayer)       [(None, 30)]              0

 dense_137 (Dense)           (None, 128)               3968

 dense_138 (Dense)           (None, 64)                8256

 dense_139 (Dense)           (None, 10)                650

 dense_140 (Dense)           (None, 2)                 22

=================================================================
Total params: 12,896
Trainable params: 12,896
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
12054/12054 [==============================] - 30s 2ms/step - loss:
1.9296 - f1_score: 0.9461 - val_loss: 0.1912 - val_f1_score: 0.9496
Epoch 2/10
12054/12054 [==============================] - 29s 2ms/step - loss:
0.1863 - f1_score: 0.9490 - val_loss: 0.1811 - val_f1_score: 0.9483
Epoch 3/10
12054/12054 [==============================] - 28s 2ms/step - loss:
0.1783 - f1_score: 0.9491 - val_loss: 0.1767 - val_f1_score: 0.9507
Epoch 4/10
12054/12054 [==============================] - 28s 2ms/step - loss:
0.1775 - f1_score: 0.9486 - val_loss: 0.1764 - val_f1_score: 0.9483
```

```
Epoch 5/10
12054/12054 [==============================] - 28s 2ms/step - loss:
0.1767 - f1_score: 0.9489 - val_loss: 0.1760 - val_f1_score: 0.9480
Epoch 6/10
12054/12054 [==============================] - 29s 2ms/step - loss:
0.1763 - f1_score: 0.9489 - val_loss: 0.2042 - val_f1_score: 0.9394
Epoch 7/10
12054/12054 [==============================] - 28s 2ms/step - loss:
0.1760 - f1_score: 0.9487 - val_loss: 0.1826 - val_f1_score: 0.9445
Epoch 8/10
12054/12054 [==============================] - 29s 2ms/step - loss:
0.1756 - f1_score: 0.9486 - val_loss: 0.1837 - val_f1_score: 0.9489
11301/11301 [==============================] - 16s 1ms/step
2826/2826 [==============================] - 4s 1ms/step

Model performance Ovr_ANN3

accuracy score train 0.9486865357120141
accuracy score test 0.948927556111105

Train classification report: Ovr_ANN3

              precision    recall  f1-score   support

           0       0.92      0.99      0.95    180800
           1       0.99      0.91      0.95    180801

    accuracy                           0.95    361601
   macro avg       0.95      0.95      0.95    361601
weighted avg       0.95      0.95      0.95    361601


Test classification report: Ovr_ANN3

              precision    recall  f1-score   support

           0       0.92      0.99      0.95     45201
           1       0.99      0.91      0.95     45200

    accuracy                           0.95     90401
   macro avg       0.95      0.95      0.95     90401
weighted avg       0.95      0.95      0.95     90401
```

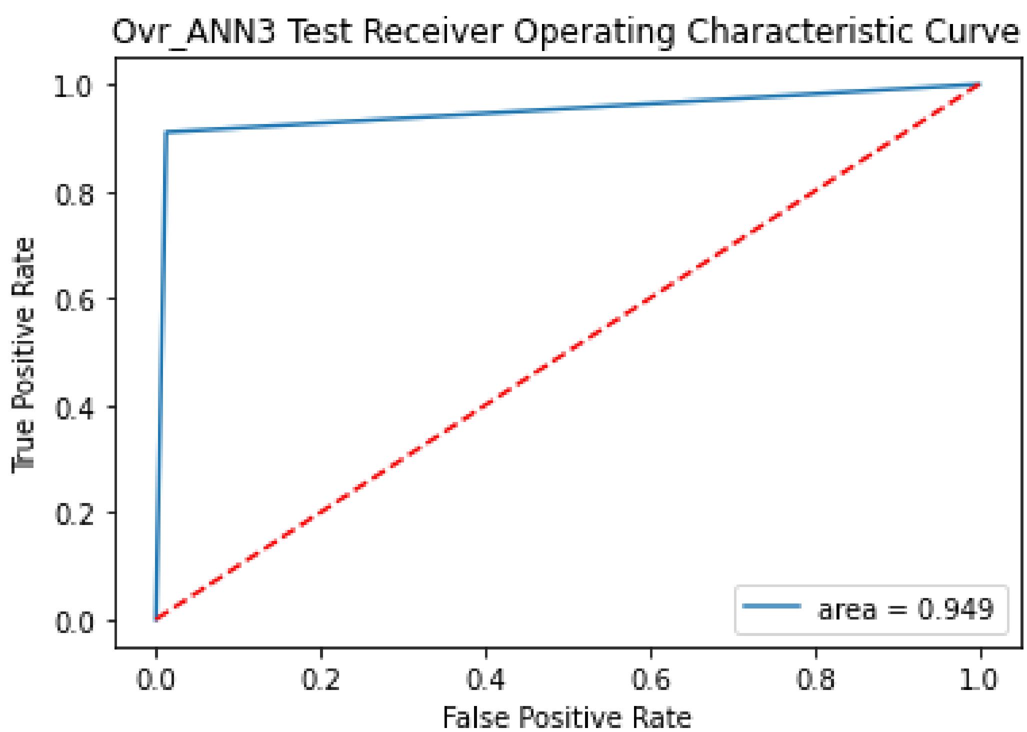





```
roc auc score train 0.9486866432789769
```




```
roc auc score test 0.9489271311348152
```



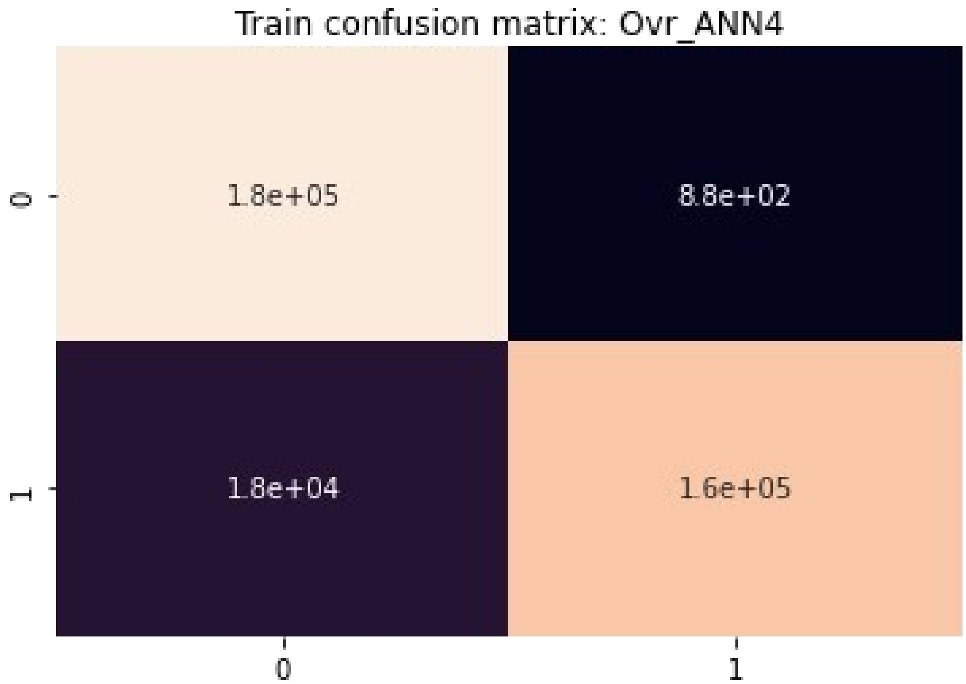

```
1781/1781 [==============================] - 3s 1ms/step
```

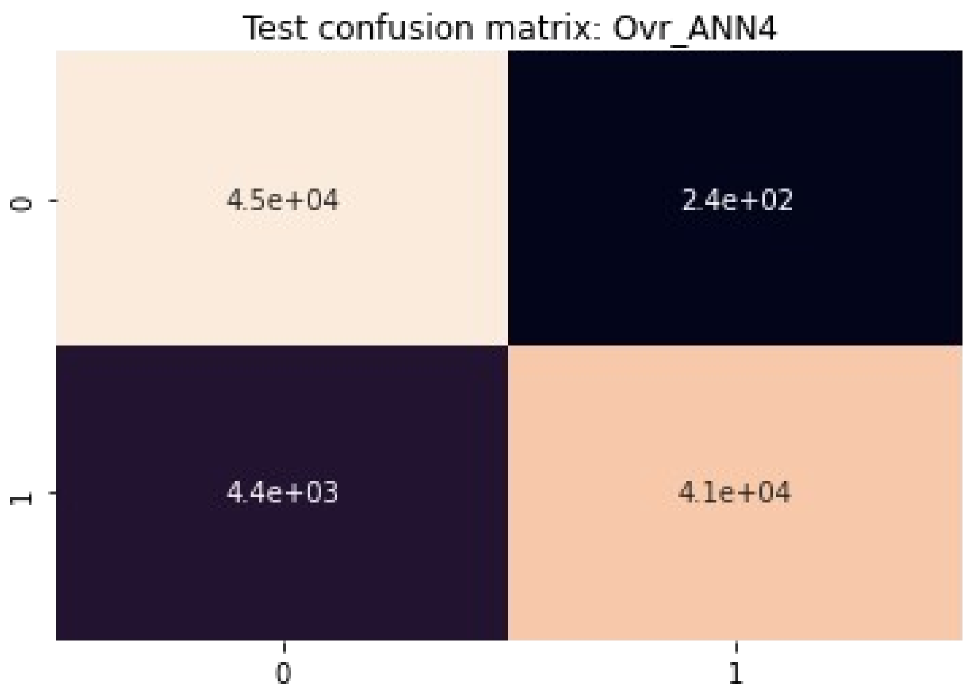
```
Test accuracy score 0.9870088831150592

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.10      0.87      0.19        98

    accuracy                           0.99     56962
   macro avg       0.55      0.93      0.59     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Ovr_ANN3
```

```
buildANN(3, 128, 'relu', 'he_normal', 'l1', 'sgd', 30, 10, 'Ovr_ANN4',
0.2)
```

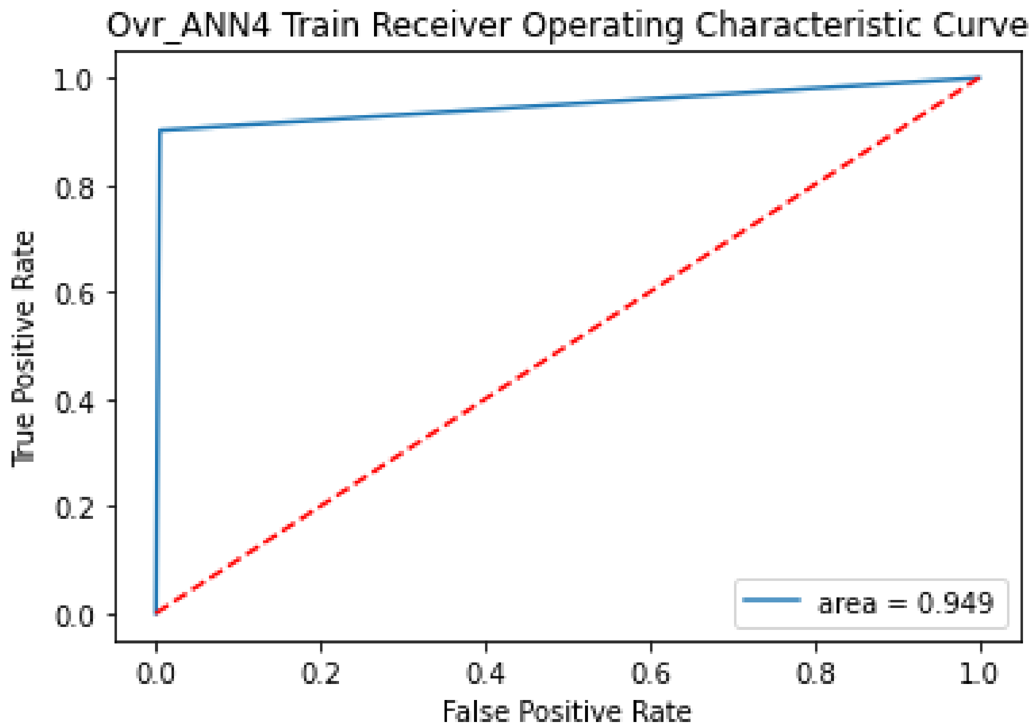
```
Model: "model_25"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_33 (InputLayer)       [(None, 30)]              0

 dense_141 (Dense)           (None, 128)               3968

 dense_142 (Dense)           (None, 64)                8256

 dense_143 (Dense)           (None, 32)                2080

 dropout_9 (Dropout)         (None, 32)                0

 batch_normalization_9 (Batc  (None, 32)               128
 hNormalization)

 dense_144 (Dense)           (None, 10)                330

 dense_145 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,784
Trainable params: 14,720
Non-trainable params: 64
_________________________________________________________________
None
Epoch 1/10
12054/12054 [==============================] - 33s 3ms/step - loss:
2.2359 - f1_score: 0.9478 - val_loss: 0.2221 - val_f1_score: 0.9484
Epoch 2/10
```

```
12054/12054 [==============================] - 32s 3ms/step - loss:
0.2220 - f1_score: 0.9552 - val_loss: 0.2121 - val_f1_score: 0.9524
Epoch 3/10
12054/12054 [==============================] - 32s 3ms/step - loss:
0.2183 - f1_score: 0.9551 - val_loss: 0.2086 - val_f1_score: 0.9531
Epoch 4/10
12054/12054 [==============================] - 32s 3ms/step - loss:
0.2173 - f1_score: 0.9536 - val_loss: 0.1895 - val_f1_score: 0.9632
Epoch 5/10
12054/12054 [==============================] - 32s 3ms/step - loss:
0.2141 - f1_score: 0.9538 - val_loss: 0.2417 - val_f1_score: 0.9373
Epoch 6/10
12054/12054 [==============================] - 32s 3ms/step - loss:
0.2150 - f1_score: 0.9535 - val_loss: 0.2896 - val_f1_score: 0.9372
Epoch 7/10
12054/12054 [==============================] - 32s 3ms/step - loss:
0.2166 - f1_score: 0.9525 - val_loss: 0.2202 - val_f1_score: 0.9485
11301/11301 [==============================] - 18s 2ms/step
2826/2826 [==============================] - 5s 2ms/step

Model performance Ovr_ANN4

accuracy score train 0.948603571339681
accuracy score test 0.9485735777259101

Train classification report: Ovr_ANN4

              precision    recall  f1-score   support

           0       0.91      1.00      0.95    180800
           1       0.99      0.90      0.95    180801

    accuracy                           0.95    361601
   macro avg       0.95      0.95      0.95    361601
weighted avg       0.95      0.95      0.95    361601


Test classification report: Ovr_ANN4

              precision    recall  f1-score   support

           0       0.91      0.99      0.95     45201
           1       0.99      0.90      0.95     45200

    accuracy                           0.95     90401
   macro avg       0.95      0.95      0.95     90401
weighted avg       0.95      0.95      0.95     90401
```

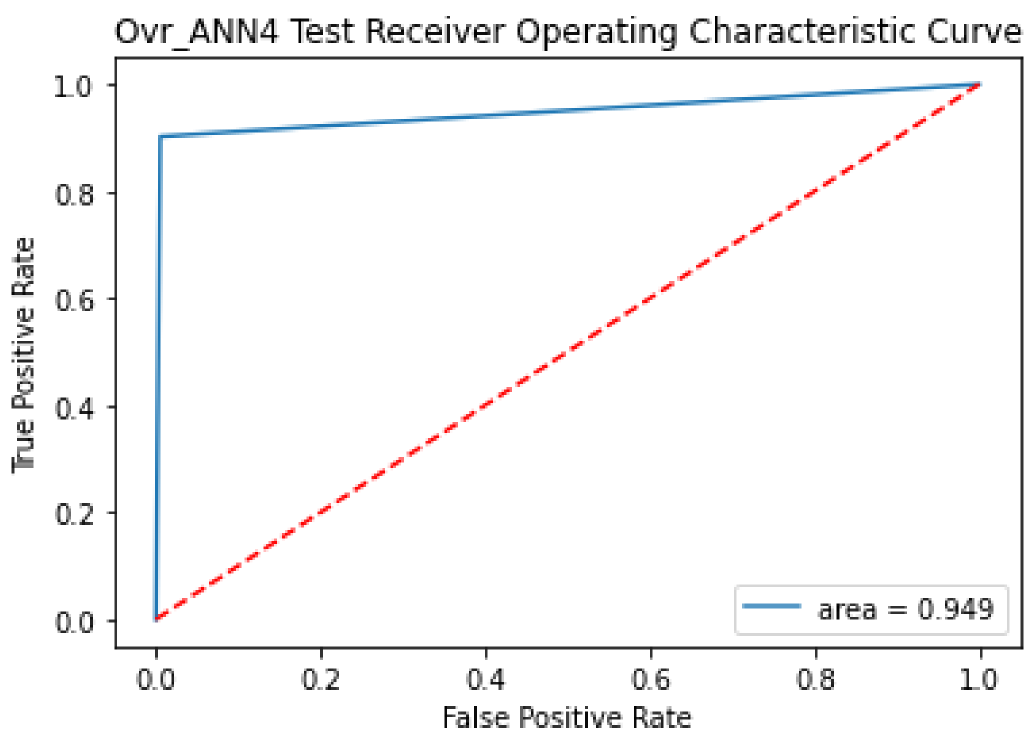





```
roc auc score train 0.9486037000147769
```




```
roc auc score test 0.9485730683184431
```




```
1781/1781 [==============================] - 3s 2ms/step
```

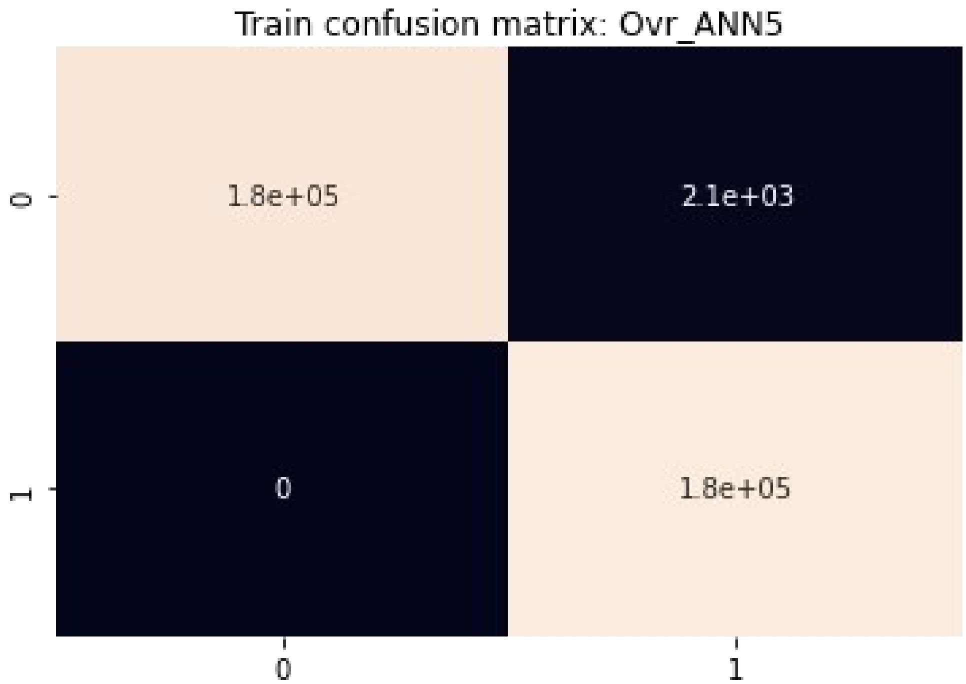
```
Test accuracy score 0.9945928864857273

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      1.00     56864
           1       0.22      0.86      0.35        98

    accuracy                           0.99     56962
   macro avg       0.61      0.93      0.68     56962
weighted avg       1.00      0.99      1.00     56962


Completed and saved for model Ovr_ANN4
```

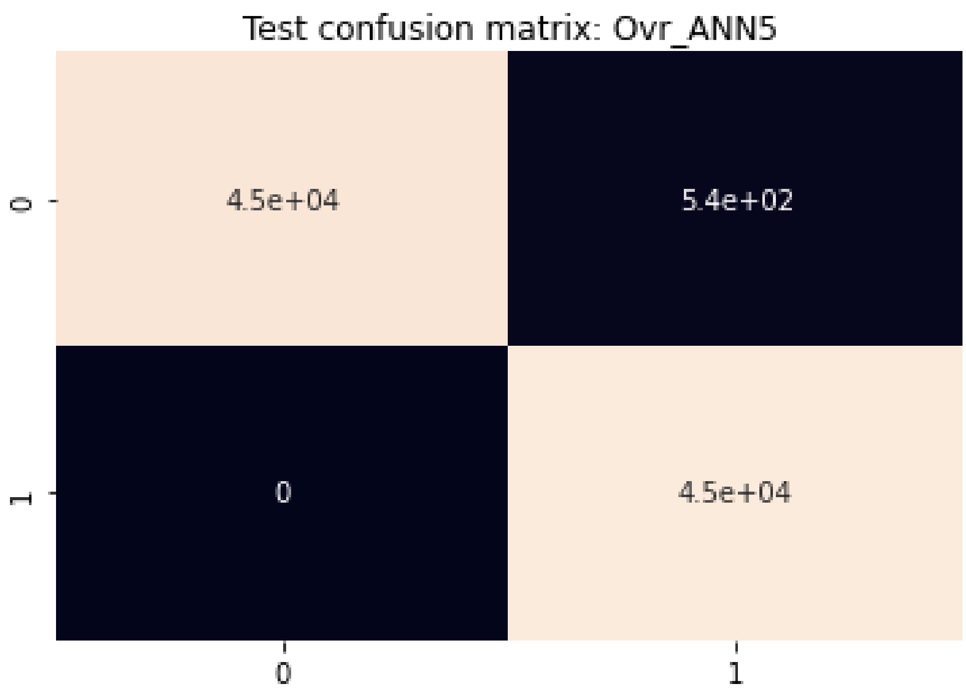
```
buildANN(3, 128, 'relu', 'he_normal', 'l2', 'rmsprop', 30, 10,
'Ovr_ANN5')
```

```
Model: "model_26"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_34 (InputLayer)       [(None, 30)]              0

 dense_146 (Dense)           (None, 128)               3968

 dense_147 (Dense)           (None, 64)                8256

 dense_148 (Dense)           (None, 32)                2080

 dense_149 (Dense)           (None, 10)                330

 dense_150 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,656
Trainable params: 14,656
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
12054/12054 [==============================] - 33s 3ms/step - loss:
0.1897 - f1_score: 0.9829 - val_loss: 0.0841 - val_f1_score: 0.9927
Epoch 2/10
12054/12054 [==============================] - 31s 3ms/step - loss:
0.0816 - f1_score: 0.9903 - val_loss: 0.0749 - val_f1_score: 0.9931
Epoch 3/10
12054/12054 [==============================] - 31s 3ms/step - loss:
0.0746 - f1_score: 0.9913 - val_loss: 0.0927 - val_f1_score: 0.9720
```

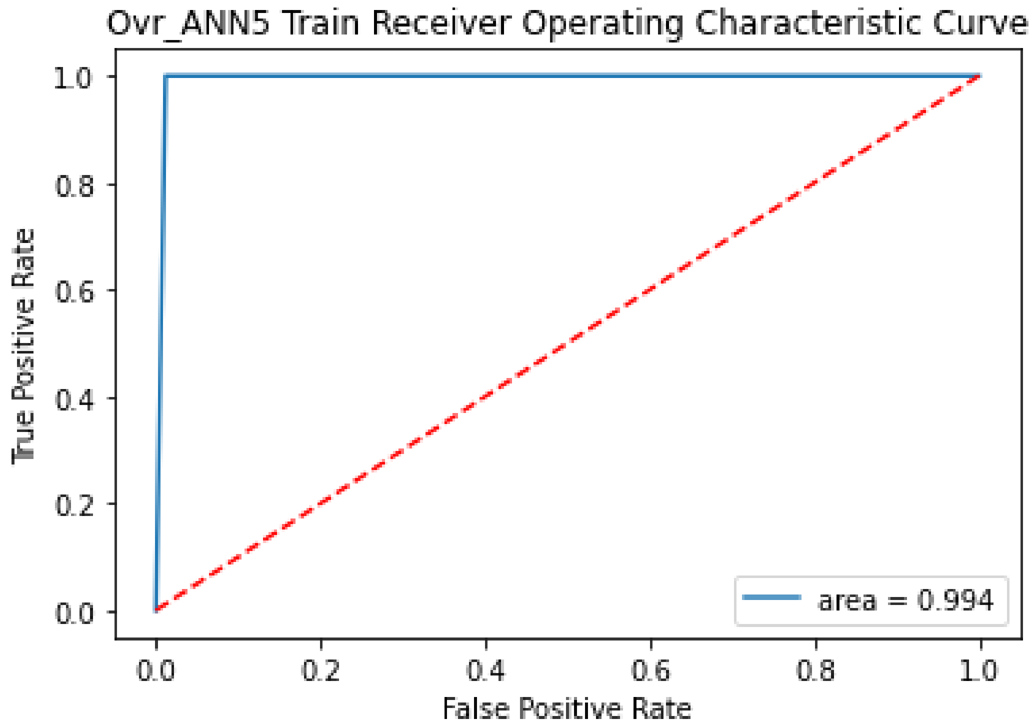
```
Epoch 4/10
12054/12054 [==============================] - 31s 3ms/step - loss:
0.0705 - f1_score: 0.9919 - val_loss: 0.0656 - val_f1_score: 0.9944
Epoch 5/10
12054/12054 [==============================] - 31s 3ms/step - loss:
0.0676 - f1_score: 0.9923 - val_loss: 0.0710 - val_f1_score: 0.9918
Epoch 6/10
12054/12054 [==============================] - 32s 3ms/step - loss:
0.0663 - f1_score: 0.9922 - val_loss: 0.0801 - val_f1_score: 0.9799
Epoch 7/10
12054/12054 [==============================] - 31s 3ms/step - loss:
0.0648 - f1_score: 0.9923 - val_loss: 0.0598 - val_f1_score: 0.9971
Epoch 8/10
12054/12054 [==============================] - 32s 3ms/step - loss:
0.0635 - f1_score: 0.9926 - val_loss: 0.0663 - val_f1_score: 0.9928
Epoch 9/10
12054/12054 [==============================] - 32s 3ms/step - loss:
0.0623 - f1_score: 0.9928 - val_loss: 0.0694 - val_f1_score: 0.9890
Epoch 10/10
12054/12054 [==============================] - 31s 3ms/step - loss:
0.0615 - f1_score: 0.9930 - val_loss: 0.0613 - val_f1_score: 0.9940
11301/11301 [==============================] - 17s 1ms/step
2826/2826 [==============================] - 4s 1ms/step

Model performance Ovr_ANN5

accuracy score train 0.9940569854618765
accuracy score test 0.9940044911007622

Train classification report: Ovr_ANN5

              precision    recall  f1-score   support

           0       1.00      0.99      0.99    180800
           1       0.99      1.00      0.99    180801

    accuracy                           0.99    361601
   macro avg       0.99      0.99      0.99    361601
weighted avg       0.99      0.99      0.99    361601


Test classification report: Ovr_ANN5

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     45201
           1       0.99      1.00      0.99     45200

    accuracy                           0.99     90401
```

macro avg	0.99	0.99	0.99	90401
weighted avg	0.99	0.99	0.99	90401

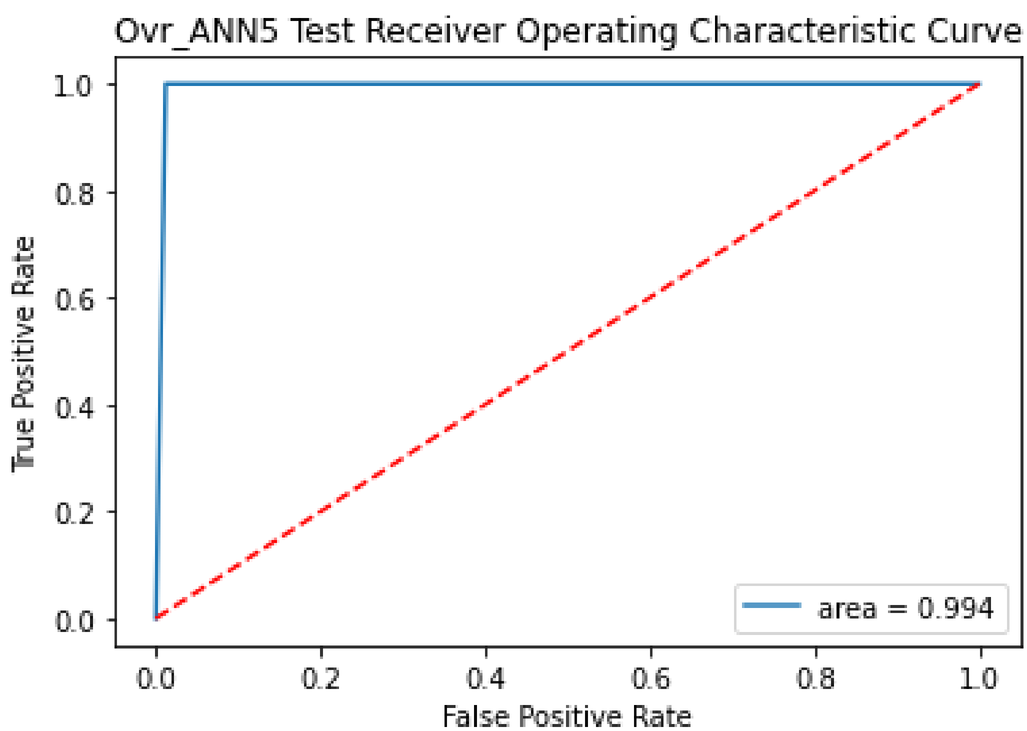




```
roc auc score train 0.9940569690265486
```




```
roc auc score test 0.994004557421296
```



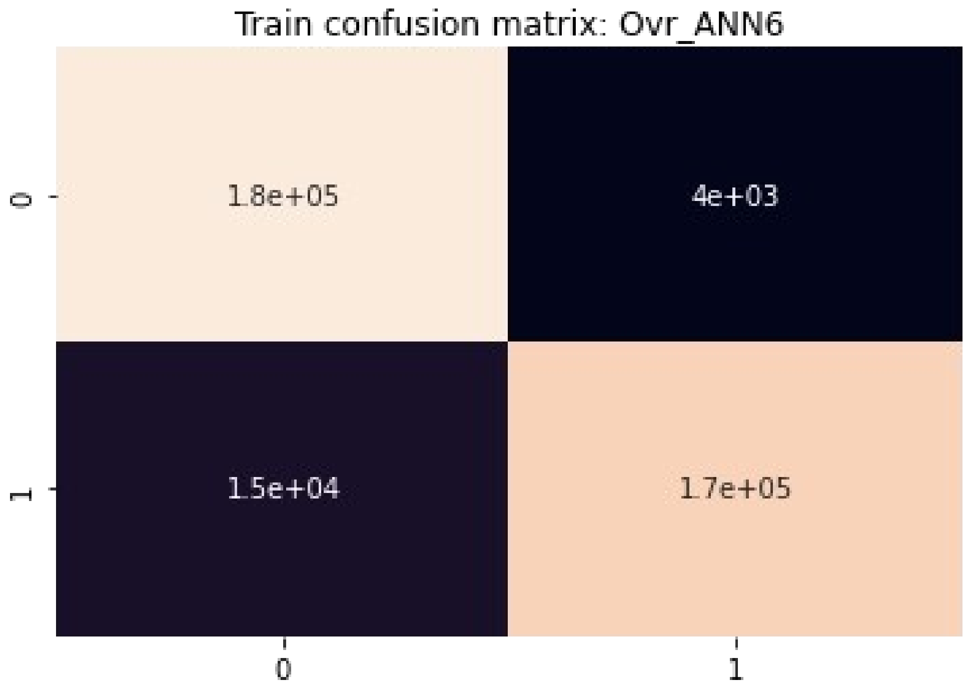
```
1781/1781 [==============================] - 3s 2ms/step

Test accuracy score 0.9876057722692321

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.11      0.87      0.19        98

    accuracy                           0.99     56962
   macro avg       0.55      0.93      0.59     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Ovr_ANN5
```

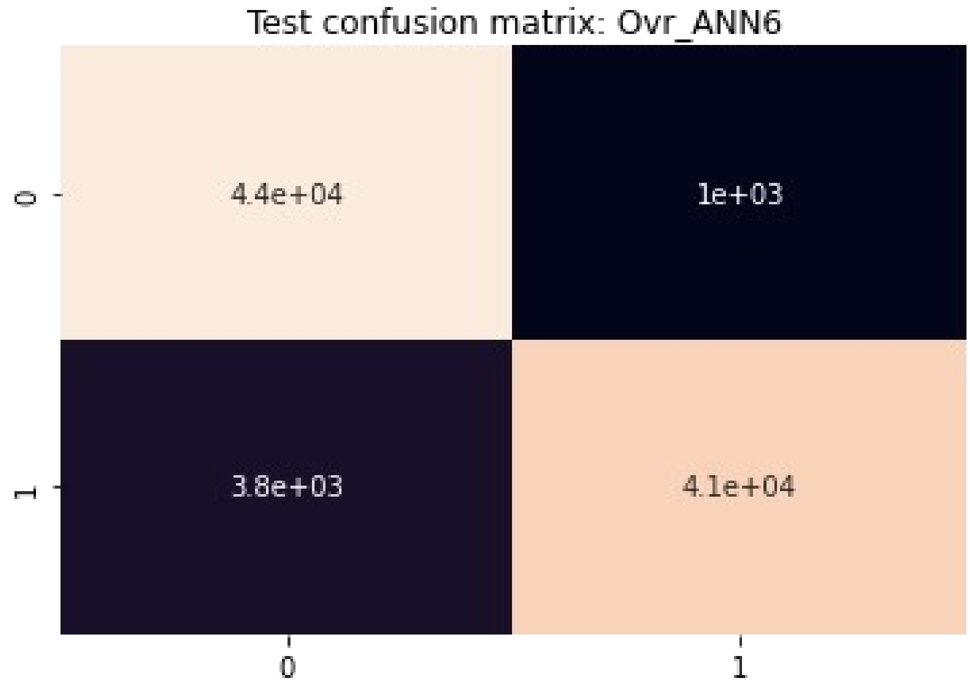
```
buildANN(3, 128, 'relu', 'he_uniform', 'l1', 'adadelta', 30, 10,
'Ovr_ANN6', 0.2)
```

```
Model: "model_27"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_35 (InputLayer)       [(None, 30)]              0

 dense_151 (Dense)           (None, 128)               3968

 dense_152 (Dense)           (None, 64)                8256

 dense_153 (Dense)           (None, 32)                2080

 dropout_10 (Dropout)        (None, 32)                0

 batch_normalization_10 (Bat  (None, 32)               128
 chNormalization)

 dense_154 (Dense)           (None, 10)                330

 dense_155 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,784
Trainable params: 14,720
Non-trainable params: 64
_________________________________________________________________
None
Epoch 1/10
12054/12054 [==============================] - 35s 3ms/step - loss:
```

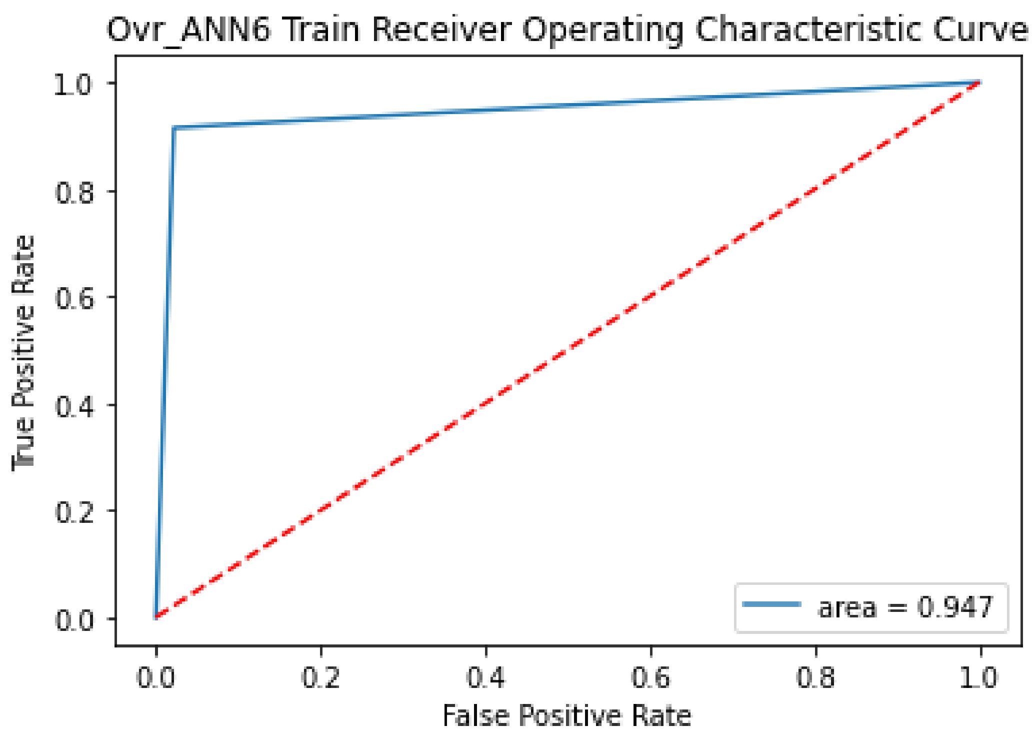
```
21.4032 - f1_score: 0.6867 - val_loss: 20.7938 - val_f1_score: 0.8490
Epoch 2/10
12054/12054 [==============================] - 35s 3ms/step - loss:
20.2433 - f1_score: 0.8410 - val_loss: 19.6695 - val_f1_score: 0.8955
Epoch 3/10
12054/12054 [==============================] - 34s 3ms/step - loss:
19.1308 - f1_score: 0.8831 - val_loss: 18.5701 - val_f1_score: 0.9126
Epoch 4/10
12054/12054 [==============================] - 34s 3ms/step - loss:
18.0212 - f1_score: 0.9036 - val_loss: 17.4477 - val_f1_score: 0.9273
Epoch 5/10
12054/12054 [==============================] - 35s 3ms/step - loss:
16.9231 - f1_score: 0.9163 - val_loss: 16.3920 - val_f1_score: 0.9330
Epoch 6/10
12054/12054 [==============================] - 35s 3ms/step - loss:
15.9089 - f1_score: 0.9250 - val_loss: 15.4093 - val_f1_score: 0.9349
Epoch 7/10
12054/12054 [==============================] - 35s 3ms/step - loss:
14.9457 - f1_score: 0.9303 - val_loss: 14.4624 - val_f1_score: 0.9415
Epoch 8/10
12054/12054 [==============================] - 35s 3ms/step - loss:
14.0237 - f1_score: 0.9341 - val_loss: 13.5619 - val_f1_score: 0.9444
Epoch 9/10
12054/12054 [==============================] - 35s 3ms/step - loss:
13.1404 - f1_score: 0.9373 - val_loss: 12.6942 - val_f1_score: 0.9452
Epoch 10/10
12054/12054 [==============================] - 35s 3ms/step - loss:
12.3093 - f1_score: 0.9389 - val_loss: 11.8949 - val_f1_score: 0.9470
11301/11301 [==============================] - 18s 2ms/step
2826/2826 [==============================] - 4s 2ms/step

Model performance Ovr_ANN6

accuracy score train 0.946601364487377
accuracy score test 0.9470359841152199

Train classification report: Ovr_ANN6

              precision    recall  f1-score   support

           0       0.92      0.98      0.95    180800
           1       0.98      0.92      0.94    180801

    accuracy                           0.95    361601
   macro avg       0.95      0.95      0.95    361601
weighted avg       0.95      0.95      0.95    361601


Test classification report: Ovr_ANN6
```

	precision	recall	f1-score	support
0	0.92	0.98	0.95	45201
1	0.98	0.92	0.95	45200
accuracy			0.95	90401
macro avg	0.95	0.95	0.95	90401
weighted avg	0.95	0.95	0.95	90401

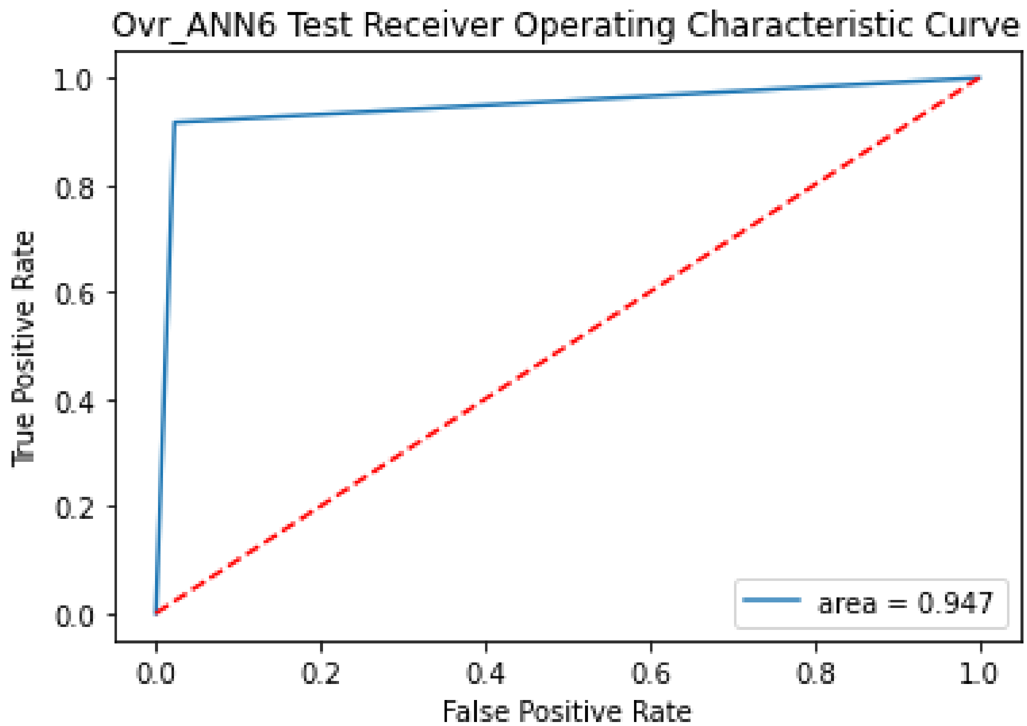




roc auc score train 0.9466014517262733



roc auc score test 0.9470356493209388




```
1781/1781 [==============================] - 3s 2ms/step

Test accuracy score 0.9779853235490327

Classification report

              precision    recall  f1-score   support

           0       1.00      0.98      0.99     56864
           1       0.06      0.87      0.12        98

    accuracy                           0.98     56962
   macro avg       0.53      0.92      0.55     56962
weighted avg       1.00      0.98      0.99     56962


Completed and saved for model Ovr_ANN6
```

```
buildANN(4, 128, 'tanh', 'he_uniform', 'l2', 'adagrad', 20, 10,
'Ovr_ANN7')
```

```
Model: "model_28"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_36 (InputLayer)       [(None, 30)]              0
```

```
 dense_156 (Dense)           (None, 128)               3968

 dense_157 (Dense)           (None, 64)                8256

 dense_158 (Dense)           (None, 32)                2080

 dense_159 (Dense)           (None, 16)                528

 dense_160 (Dense)           (None, 10)                170

 dense_161 (Dense)           (None, 2)                 22

=================================================================
Total params: 15,024
Trainable params: 15,024
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
18081/18081 [==============================] - 51s 3ms/step - loss:
3.0693 - f1_score: 0.9534 - val_loss: 1.9878 - val_f1_score: 0.9627
Epoch 2/10
18081/18081 [==============================] - 50s 3ms/step - loss:
1.5443 - f1_score: 0.9620 - val_loss: 1.2180 - val_f1_score: 0.9625
Epoch 3/10
18081/18081 [==============================] - 45s 2ms/step - loss:
1.0217 - f1_score: 0.9615 - val_loss: 0.8654 - val_f1_score: 0.9620
Epoch 4/10
18081/18081 [==============================] - 49s 3ms/step - loss:
0.7582 - f1_score: 0.9615 - val_loss: 0.6698 - val_f1_score: 0.9614
Epoch 5/10
18081/18081 [==============================] - 49s 3ms/step - loss:
0.6040 - f1_score: 0.9611 - val_loss: 0.5487 - val_f1_score: 0.9618
Epoch 6/10
18081/18081 [==============================] - 49s 3ms/step - loss:
0.5049 - f1_score: 0.9603 - val_loss: 0.4679 - val_f1_score: 0.9607
Epoch 7/10
18081/18081 [==============================] - 47s 3ms/step - loss:
0.4372 - f1_score: 0.9596 - val_loss: 0.4113 - val_f1_score: 0.9601
Epoch 8/10
18081/18081 [==============================] - 49s 3ms/step - loss:
0.3887 - f1_score: 0.9587 - val_loss: 0.3697 - val_f1_score: 0.9589
Epoch 9/10
18081/18081 [==============================] - 45s 3ms/step - loss:
0.3526 - f1_score: 0.9577 - val_loss: 0.3384 - val_f1_score: 0.9603
Epoch 10/10
18081/18081 [==============================] - 49s 3ms/step - loss:
0.3250 - f1_score: 0.9576 - val_loss: 0.3141 - val_f1_score: 0.9577
11301/11301 [==============================] - 17s 2ms/step
2826/2826 [==============================] - 4s 2ms/step
```

Model performance Ovr_ANN7

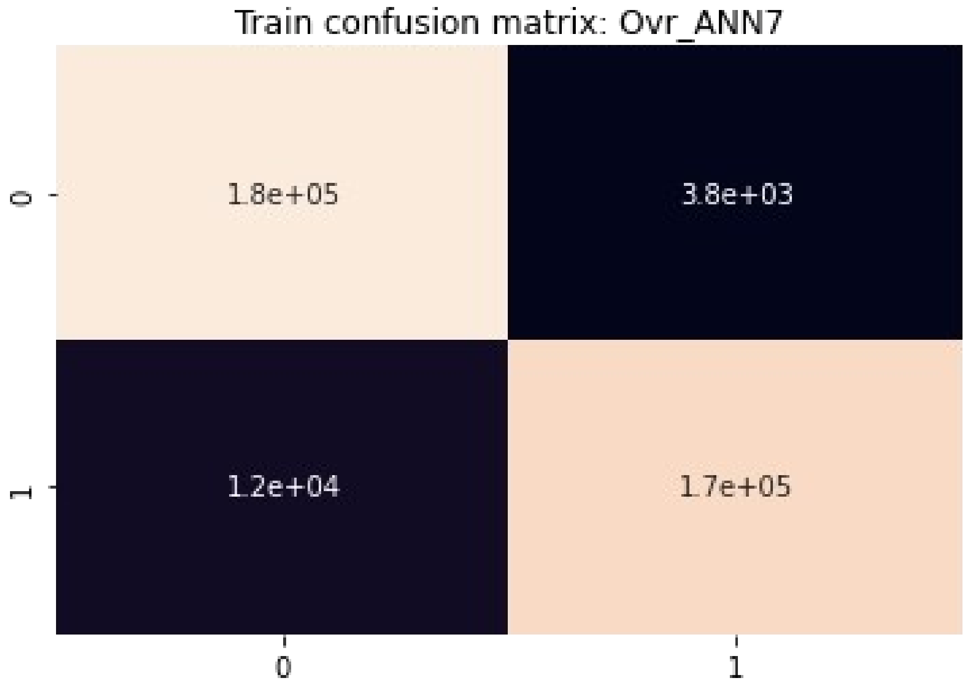
accuracy score train 0.9574973520537831
accuracy score test 0.9576885211446776

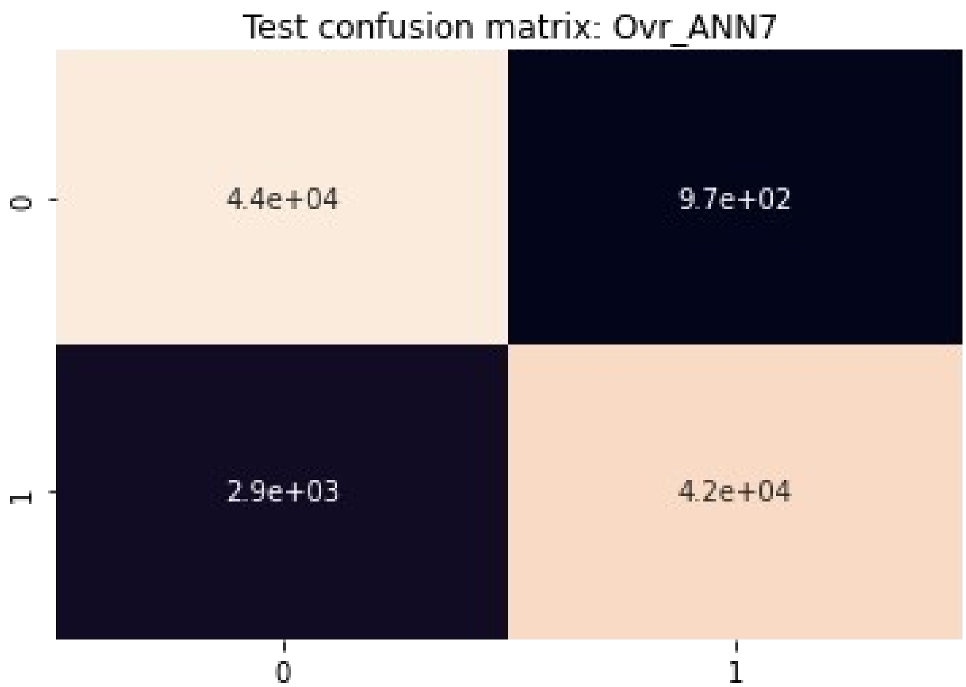
Train classification report: Ovr_ANN7

	precision	recall	f1-score	support
0	0.94	0.98	0.96	180800
1	0.98	0.94	0.96	180801
accuracy			0.96	361601
macro avg	0.96	0.96	0.96	361601
weighted avg	0.96	0.96	0.96	361601

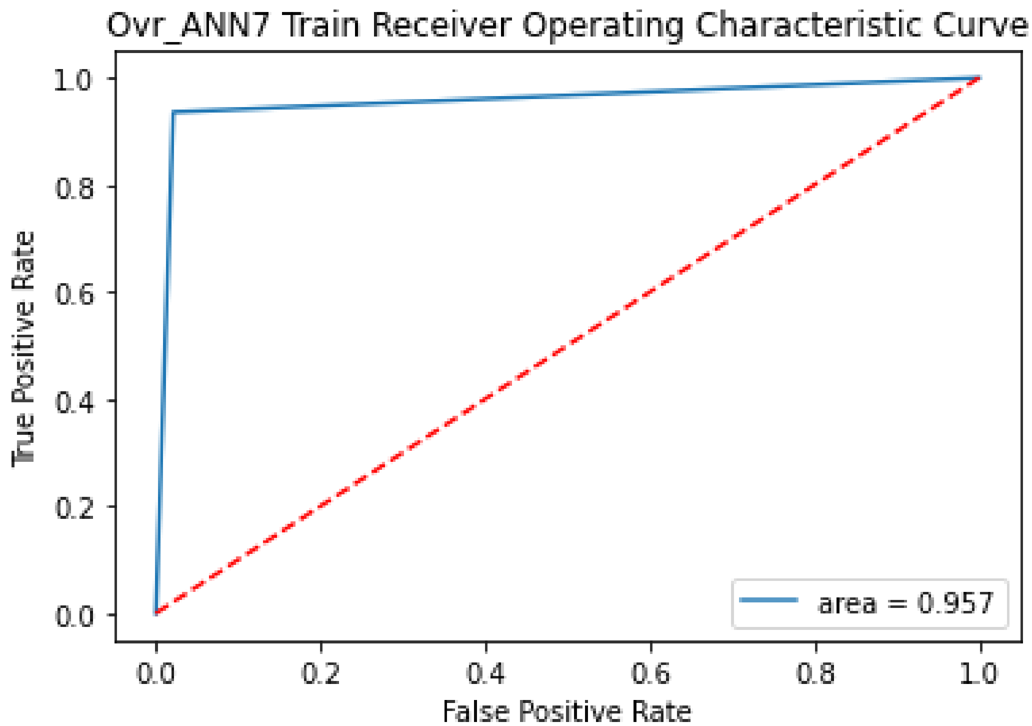
Test classification report: Ovr_ANN7

	precision	recall	f1-score	support
0	0.94	0.98	0.96	45201
1	0.98	0.94	0.96	45200
accuracy			0.96	90401
macro avg	0.96	0.96	0.96	90401
weighted avg	0.96	0.96	0.96	90401

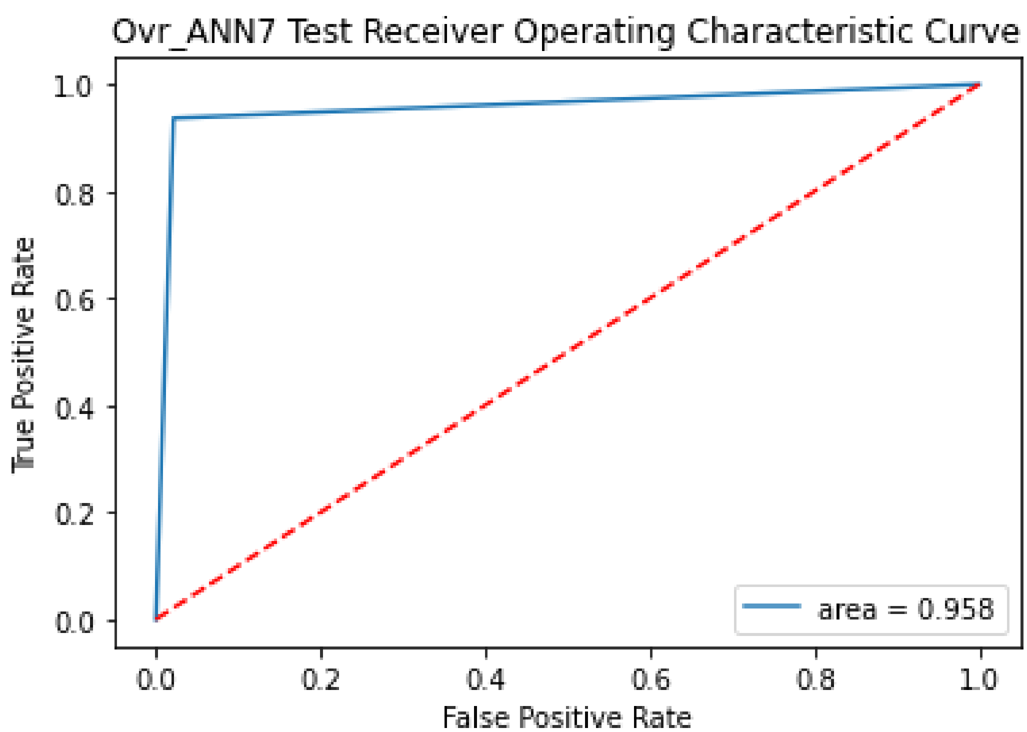





```
roc auc score train 0.9574974113015419
```




```
roc auc score test 0.9576882895045199
```




```
1781/1781 [==============================] - 3s 2ms/step
```

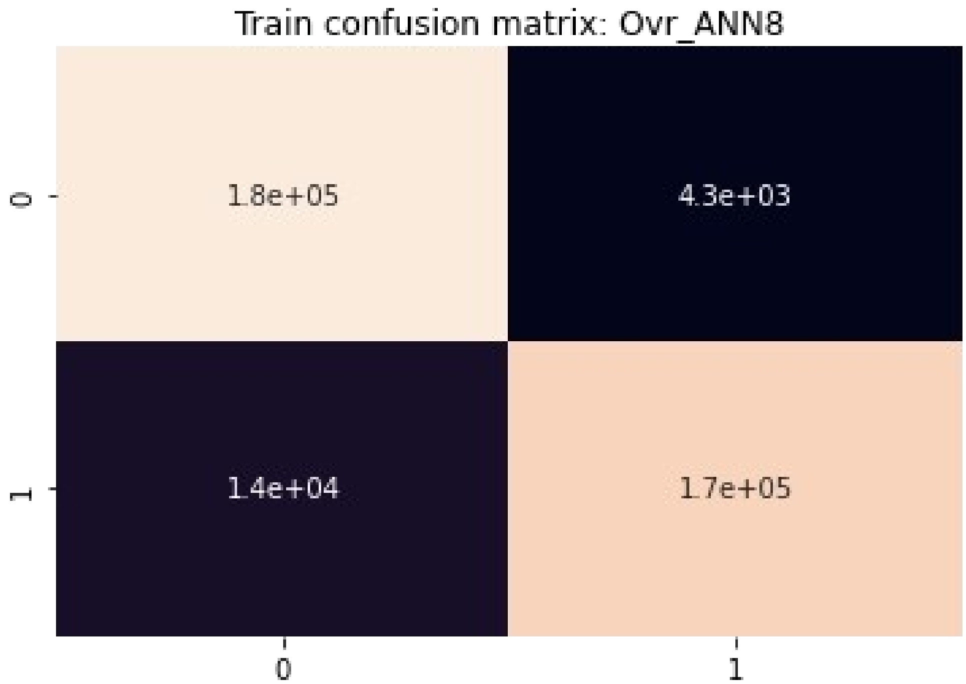
```
Test accuracy score 0.9782486569994031

Classification report

              precision    recall  f1-score   support

           0       1.00      0.98      0.99     56864
           1       0.07      0.89      0.12        98

    accuracy                           0.98     56962
   macro avg       0.53      0.93      0.56     56962
weighted avg       1.00      0.98      0.99     56962


Completed and saved for model Ovr_ANN7
```

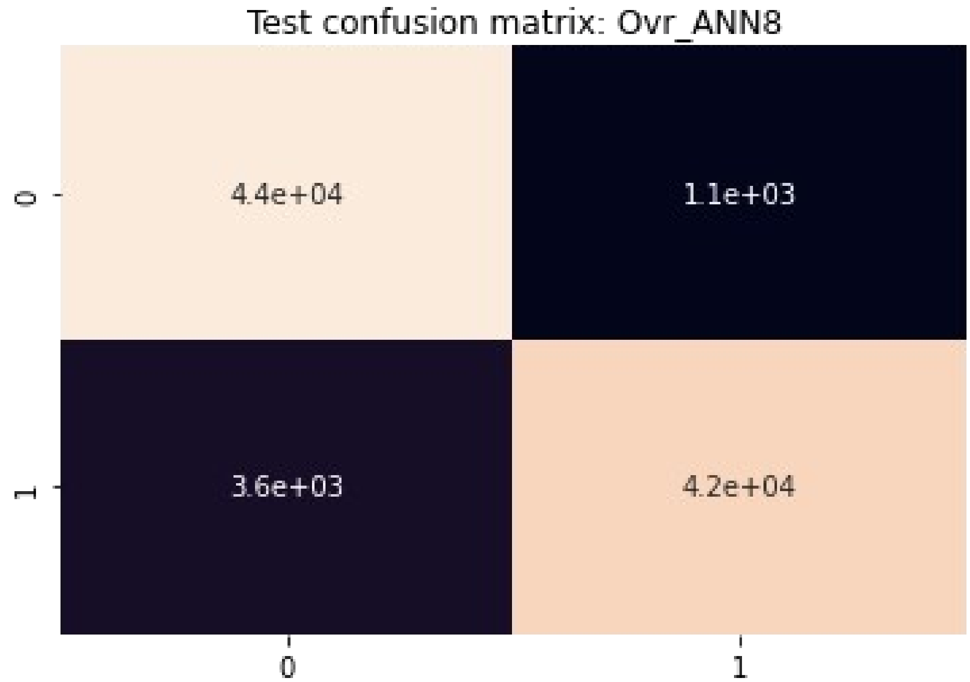
```
buildANN(4, 128, 'relu', 'he_normal', 'l1', 'adam', 40, 10,
'Ovr_ANN8')
```

```
Model: "model_29"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_37 (InputLayer)       [(None, 30)]              0

 dense_162 (Dense)           (None, 128)               3968

 dense_163 (Dense)           (None, 64)                8256

 dense_164 (Dense)           (None, 32)                2080

 dense_165 (Dense)           (None, 16)                528

 dense_166 (Dense)           (None, 10)                170

 dense_167 (Dense)           (None, 2)                 22

=================================================================
Total params: 15,024
Trainable params: 15,024
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
9041/9041 [==============================] - 33s 4ms/step - loss:
0.6429 - f1_score: 0.9459 - val_loss: 0.2139 - val_f1_score: 0.9493
Epoch 2/10
9041/9041 [==============================] - 28s 3ms/step - loss:
0.2104 - f1_score: 0.9498 - val_loss: 0.2090 - val_f1_score: 0.9525
Epoch 3/10
```

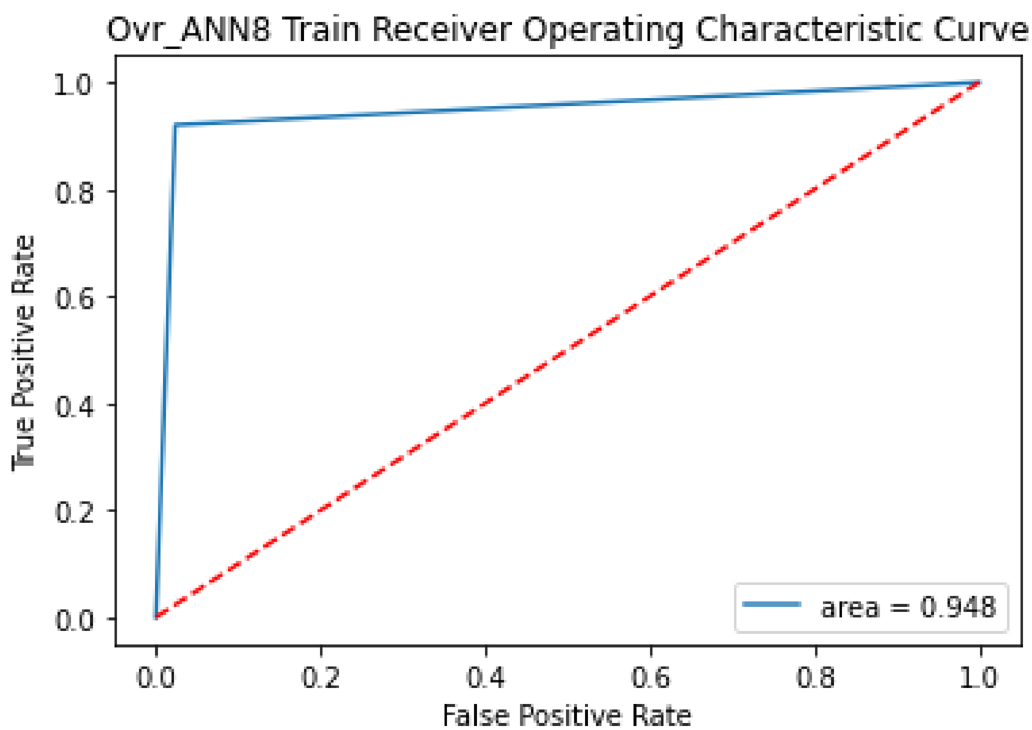
```
9041/9041 [==============================] - 30s 3ms/step - loss: 
0.2054 - f1_score: 0.9500 - val_loss: 0.2001 - val_f1_score: 0.9521
Epoch 4/10
9041/9041 [==============================] - 29s 3ms/step - loss: 
0.1990 - f1_score: 0.9500 - val_loss: 0.1992 - val_f1_score: 0.9497
Epoch 5/10
9041/9041 [==============================] - 30s 3ms/step - loss: 
0.1974 - f1_score: 0.9503 - val_loss: 0.1987 - val_f1_score: 0.9481
Epoch 6/10
9041/9041 [==============================] - 30s 3ms/step - loss: 
0.1964 - f1_score: 0.9503 - val_loss: 0.1966 - val_f1_score: 0.9489
Epoch 7/10
9041/9041 [==============================] - 30s 3ms/step - loss: 
0.1957 - f1_score: 0.9504 - val_loss: 0.1951 - val_f1_score: 0.9496
Epoch 8/10
9041/9041 [==============================] - 28s 3ms/step - loss: 
0.1950 - f1_score: 0.9502 - val_loss: 0.1951 - val_f1_score: 0.9491
Epoch 9/10
9041/9041 [==============================] - 28s 3ms/step - loss: 
0.1944 - f1_score: 0.9502 - val_loss: 0.1954 - val_f1_score: 0.9527
Epoch 10/10
9041/9041 [==============================] - 28s 3ms/step - loss: 
0.1938 - f1_score: 0.9502 - val_loss: 0.1938 - val_f1_score: 0.9487
11301/11301 [==============================] - 17s 2ms/step
2826/2826 [==============================] - 4s 2ms/step

Model performance Ovr_ANN8

accuracy score train 0.9483380853482153
accuracy score test 0.9487616287430449

Train classification report: Ovr_ANN8

              precision    recall  f1-score   support

           0       0.92      0.98      0.95    180800
           1       0.97      0.92      0.95    180801

    accuracy                           0.95    361601
   macro avg       0.95      0.95      0.95    361601
weighted avg       0.95      0.95      0.95    361601


Test classification report: Ovr_ANN8

              precision    recall  f1-score   support

           0       0.93      0.98      0.95     45201
           1       0.98      0.92      0.95     45200
```

accuracy			0.95	90401
macro avg	0.95	0.95	0.95	90401
weighted avg	0.95	0.95	0.95	90401

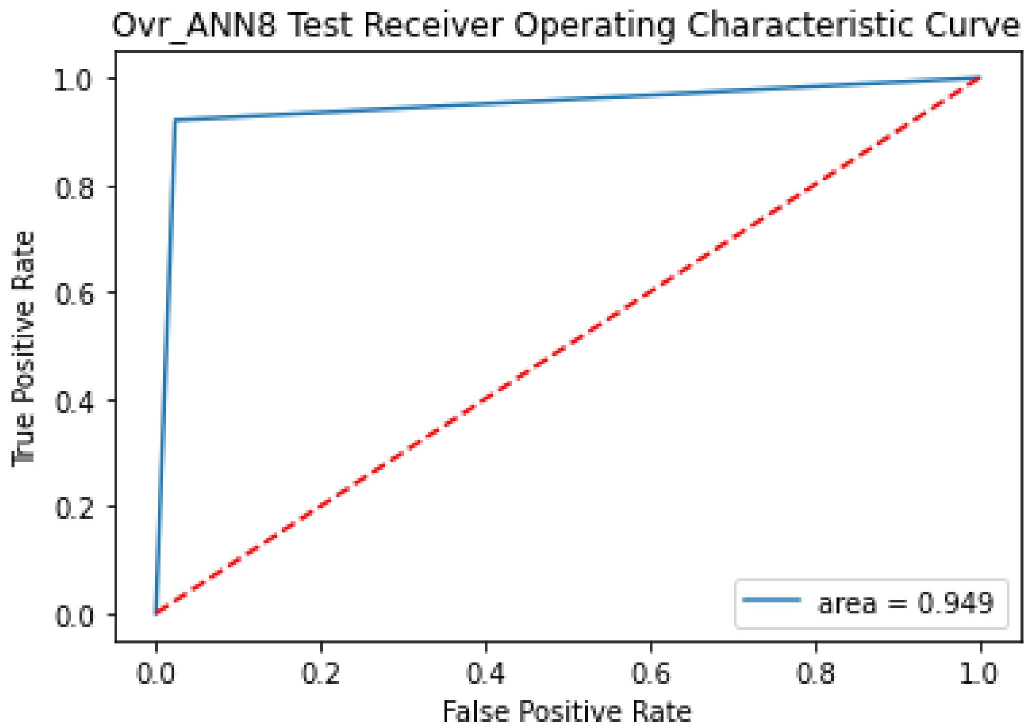




roc auc score train 0.9483381629049158



roc auc score test 0.948761322582142




```
1781/1781 [==============================] - 3s 1ms/step

Test accuracy score 0.9761771005231558

Classification report

              precision    recall  f1-score   support

           0       1.00      0.98      0.99     56864
           1       0.06      0.88      0.11        98

    accuracy                           0.98     56962
   macro avg       0.53      0.93      0.55     56962
weighted avg       1.00      0.98      0.99     56962


Completed and saved for model Ovr_ANN8
```

```
buildANN(4, 256, 'relu', 'he_normal', 'l2', 'adam', 30, 10,
'Ovr_ANN9')
```

```
Model: "model_30"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_38 (InputLayer)       [(None, 30)]              0
```

```
 dense_168 (Dense)           (None, 256)               7936

 dense_169 (Dense)           (None, 128)               32896

 dense_170 (Dense)           (None, 64)                8256

 dense_171 (Dense)           (None, 32)                2080

 dense_172 (Dense)           (None, 10)                330

 dense_173 (Dense)           (None, 2)                 22

=================================================================
Total params: 51,520
Trainable params: 51,520
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
12054/12054 [==============================] - 44s 4ms/step - loss:
0.2647 - f1_score: 0.9812 - val_loss: 0.1043 - val_f1_score: 0.9915
Epoch 2/10
12054/12054 [==============================] - 43s 4ms/step - loss:
0.0972 - f1_score: 0.9916 - val_loss: 0.1099 - val_f1_score: 0.9858
Epoch 3/10
12054/12054 [==============================] - 42s 3ms/step - loss:
0.0887 - f1_score: 0.9928 - val_loss: 0.0858 - val_f1_score: 0.9938
Epoch 4/10
12054/12054 [==============================] - 42s 3ms/step - loss:
0.0839 - f1_score: 0.9934 - val_loss: 0.0834 - val_f1_score: 0.9932
Epoch 5/10
12054/12054 [==============================] - 42s 4ms/step - loss:
0.0808 - f1_score: 0.9938 - val_loss: 0.0893 - val_f1_score: 0.9928
Epoch 6/10
12054/12054 [==============================] - 43s 4ms/step - loss:
0.0790 - f1_score: 0.9937 - val_loss: 0.0794 - val_f1_score: 0.9942
Epoch 7/10
12054/12054 [==============================] - 44s 4ms/step - loss:
0.0770 - f1_score: 0.9940 - val_loss: 0.0756 - val_f1_score: 0.9959
Epoch 8/10
12054/12054 [==============================] - 43s 4ms/step - loss:
0.0757 - f1_score: 0.9940 - val_loss: 0.0799 - val_f1_score: 0.9923
Epoch 9/10
12054/12054 [==============================] - 42s 3ms/step - loss:
0.0748 - f1_score: 0.9940 - val_loss: 0.0739 - val_f1_score: 0.9973
Epoch 10/10
12054/12054 [==============================] - 42s 4ms/step - loss:
0.0739 - f1_score: 0.9942 - val_loss: 0.0708 - val_f1_score: 0.9946
11301/11301 [==============================] - 19s 2ms/step
2826/2826 [==============================] - 5s 2ms/step
```

Model performance Ovr_ANN9

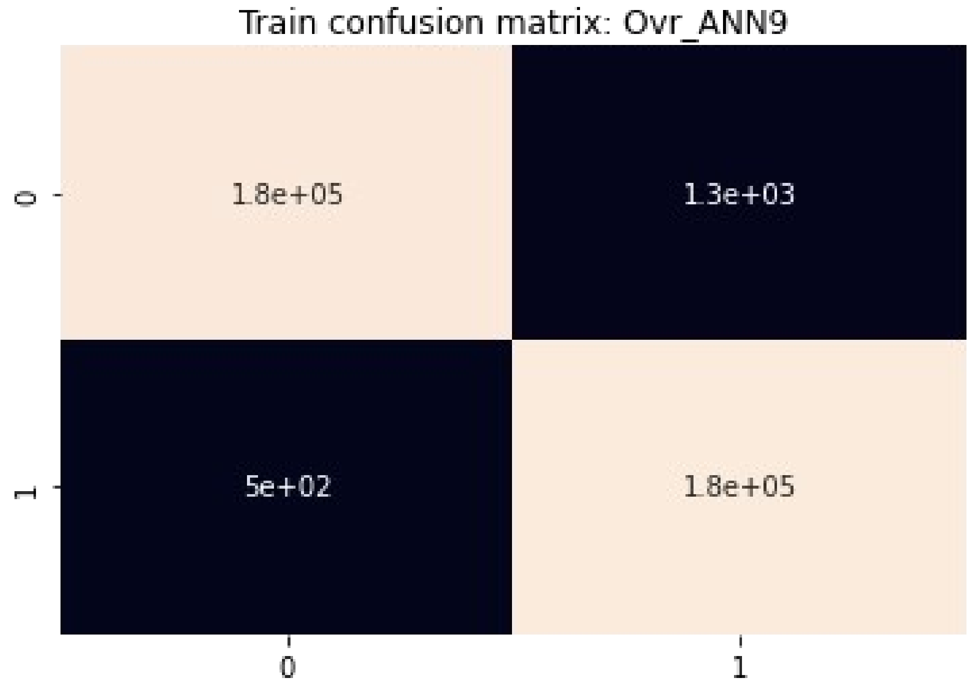
accuracy score train 0.9951299913440504
accuracy score test 0.9945797059767038

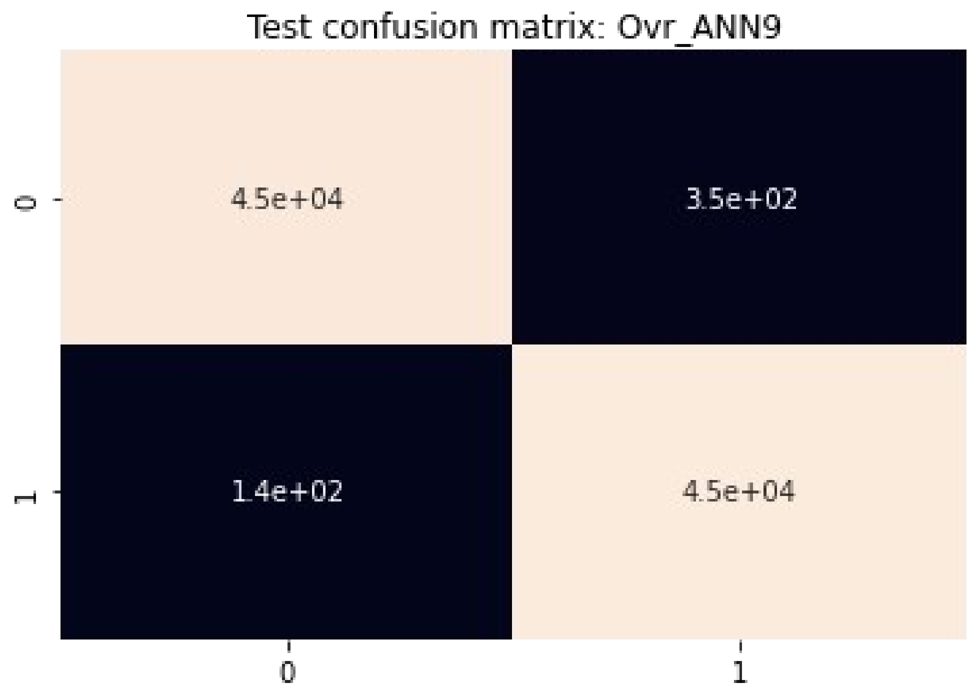
Train classification report: Ovr_ANN9

	precision	recall	f1-score	support
0	1.00	0.99	1.00	180800
1	0.99	1.00	1.00	180801
accuracy			1.00	361601
macro avg	1.00	1.00	1.00	361601
weighted avg	1.00	1.00	1.00	361601

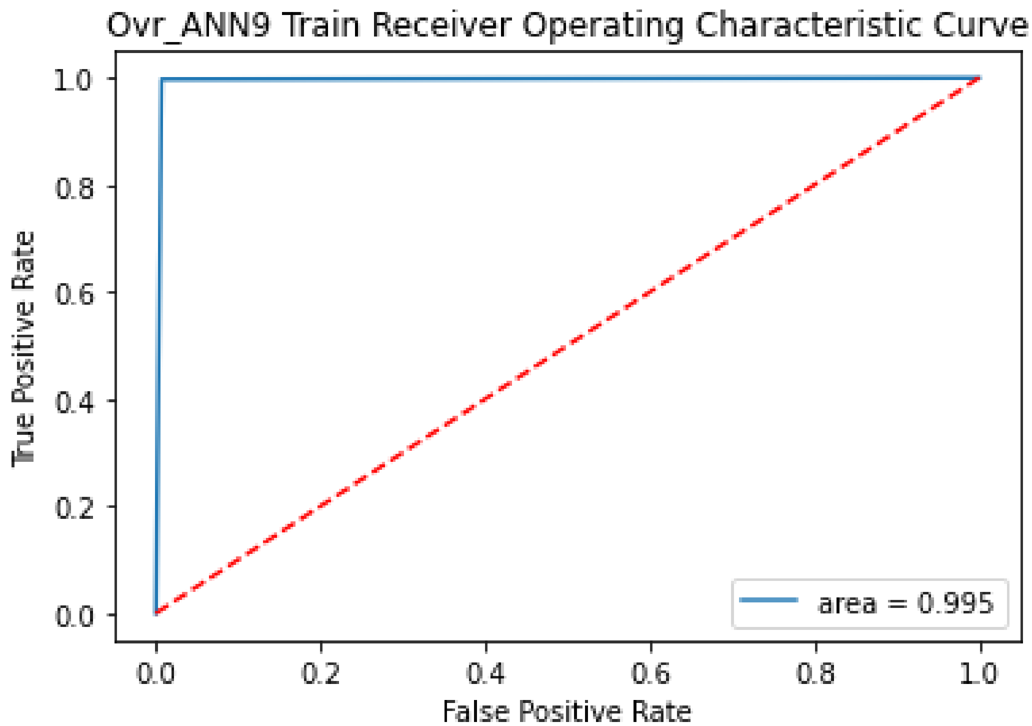
Test classification report: Ovr_ANN9

	precision	recall	f1-score	support
0	1.00	0.99	0.99	45201
1	0.99	1.00	0.99	45200
accuracy			0.99	90401
macro avg	0.99	0.99	0.99	90401
weighted avg	0.99	0.99	0.99	90401

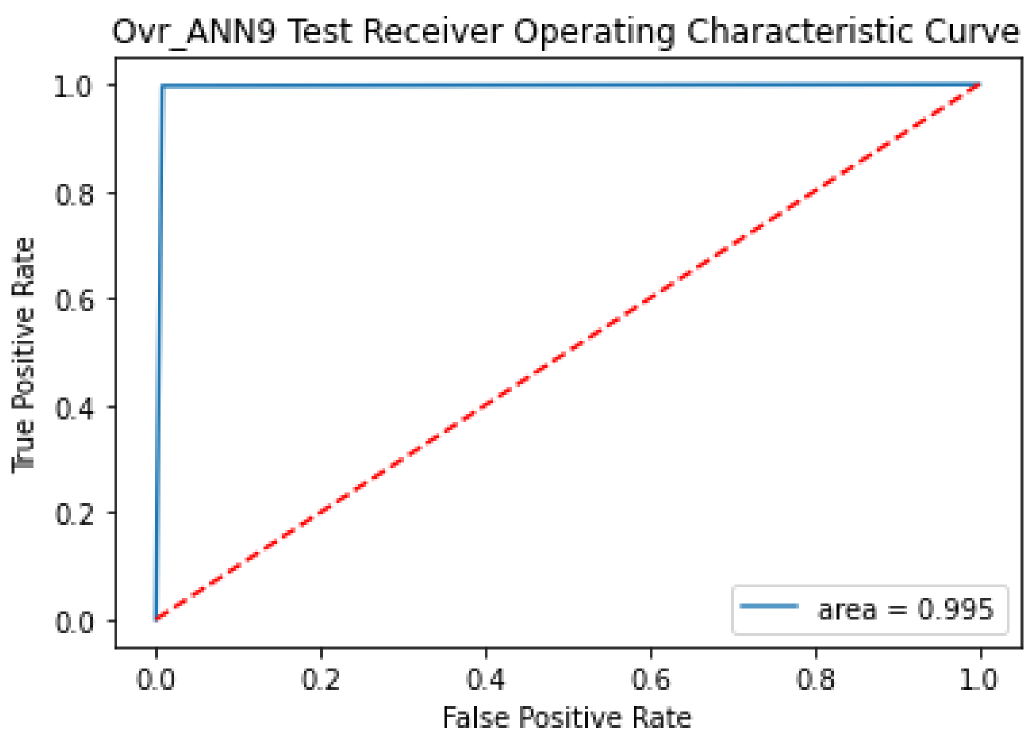





```
roc auc score train 0.9951299854780935
```




```
roc auc score test 0.9945797324066564
```




```
1781/1781 [==============================] - 3s 2ms/step
```

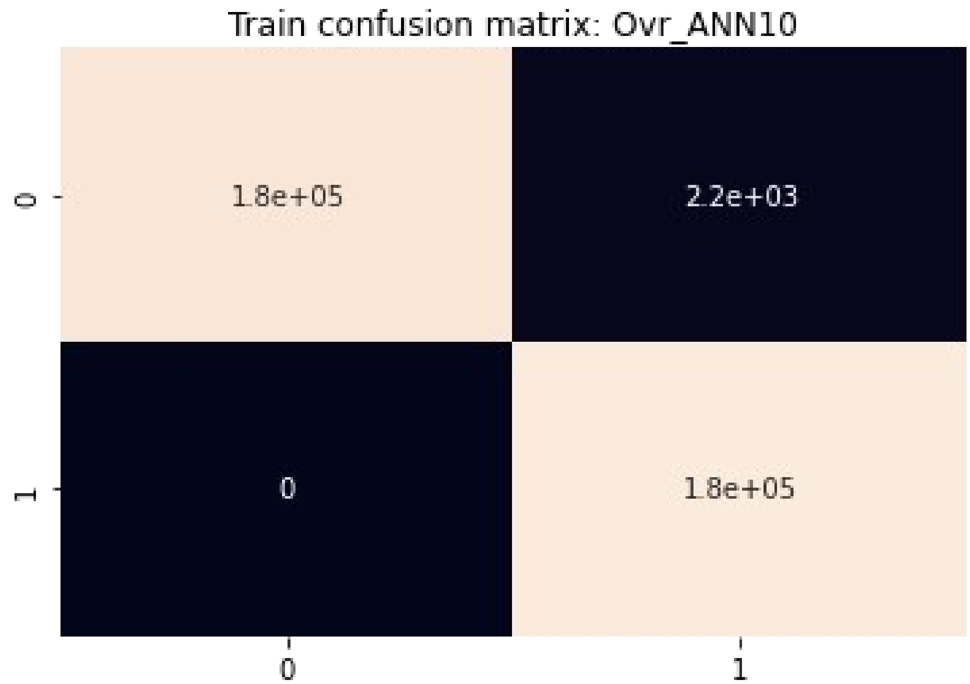
```
Test accuracy score 0.9923106632491837

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      1.00     56864
           1       0.17      0.88      0.28        98

    accuracy                           0.99     56962
   macro avg       0.58      0.94      0.64     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Ovr_ANN9
```

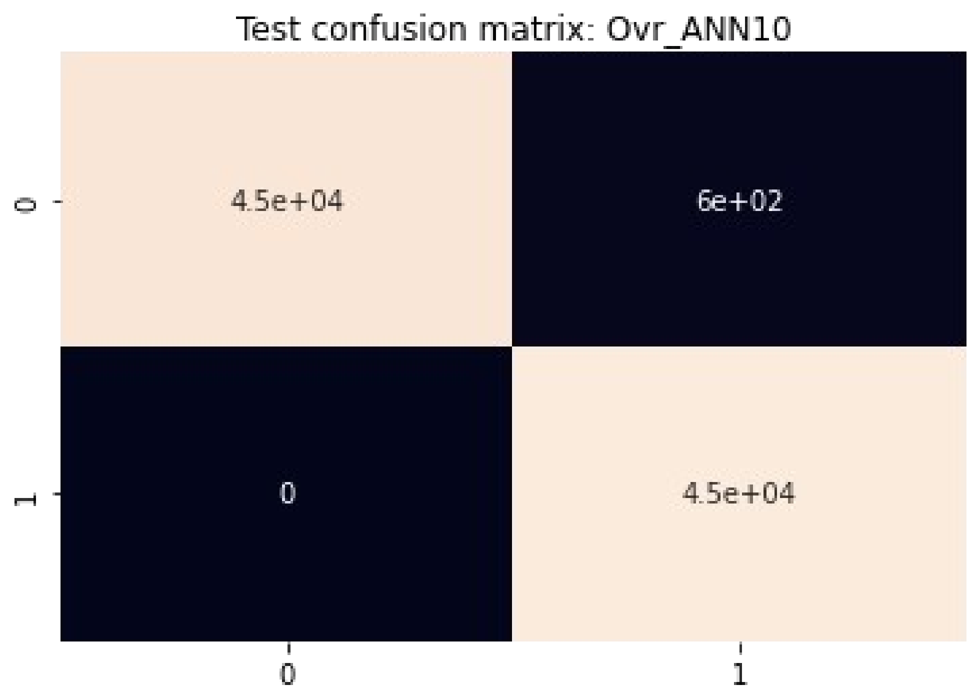
```
buildANN(4, 256, 'relu', 'he_normal', 'l2', 'adam', 30, 10,
'Ovr_ANN10', 0.3)
```

```
Model: "model_31"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_39 (InputLayer)       [(None, 30)]              0

 dense_174 (Dense)           (None, 256)               7936

 dense_175 (Dense)           (None, 128)               32896

 dense_176 (Dense)           (None, 64)                8256

 dense_177 (Dense)           (None, 32)                2080

 dropout_11 (Dropout)        (None, 32)                0

 batch_normalization_11 (Bat  (None, 32)               128
 chNormalization)

 dense_178 (Dense)           (None, 10)                330

 dense_179 (Dense)           (None, 2)                 22

=================================================================
Total params: 51,648
Trainable params: 51,584
Non-trainable params: 64
_________________________________________________________________
None
Epoch 1/10
12054/12054 [==============================] - 48s 4ms/step - loss:
```

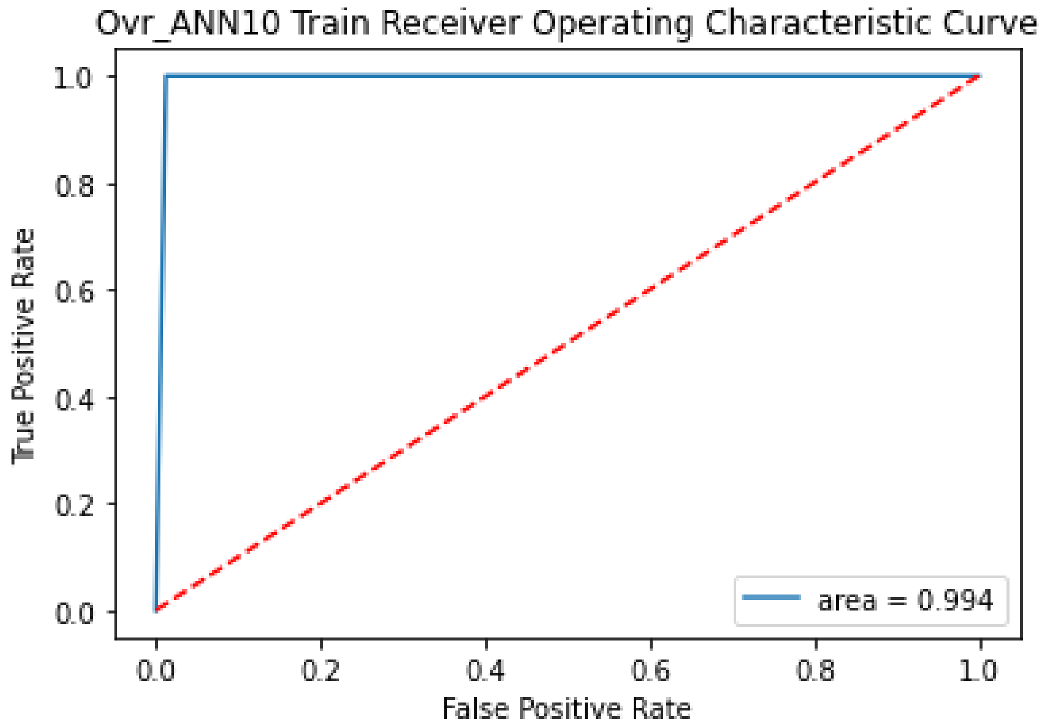
```
0.2785 - f1_score: 0.9837 - val_loss: 0.0701 - val_f1_score: 0.9936
Epoch 2/10
12054/12054 [==============================] - 46s 4ms/step - loss:
0.0757 - f1_score: 0.9908 - val_loss: 0.0623 - val_f1_score: 0.9935
Epoch 3/10
12054/12054 [==============================] - 44s 4ms/step - loss:
0.0738 - f1_score: 0.9913 - val_loss: 0.0630 - val_f1_score: 0.9950
Epoch 4/10
12054/12054 [==============================] - 44s 4ms/step - loss:
0.0745 - f1_score: 0.9911 - val_loss: 0.0798 - val_f1_score: 0.9928
Epoch 5/10
12054/12054 [==============================] - 45s 4ms/step - loss:
0.0773 - f1_score: 0.9906 - val_loss: 0.0589 - val_f1_score: 0.9961
Epoch 6/10
12054/12054 [==============================] - 45s 4ms/step - loss:
0.0754 - f1_score: 0.9911 - val_loss: 0.0708 - val_f1_score: 0.9931
Epoch 7/10
12054/12054 [==============================] - 45s 4ms/step - loss:
0.0724 - f1_score: 0.9915 - val_loss: 0.0623 - val_f1_score: 0.9945
Epoch 8/10
12054/12054 [==============================] - 46s 4ms/step - loss:
0.0689 - f1_score: 0.9920 - val_loss: 0.0666 - val_f1_score: 0.9934
11301/11301 [==============================] - 19s 2ms/step
2826/2826 [==============================] - 5s 2ms/step

Model performance Ovr_ANN10

accuracy score train 0.9938080923448773
accuracy score test 0.9933629052775965

Train classification report: Ovr_ANN10

              precision    recall  f1-score   support

           0       1.00      0.99      0.99    180800
           1       0.99      1.00      0.99    180801

    accuracy                           0.99    361601
   macro avg       0.99      0.99      0.99    361601
weighted avg       0.99      0.99      0.99    361601


Test classification report: Ovr_ANN10

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     45201
           1       0.99      1.00      0.99     45200
```

accuracy			0.99	90401
macro avg	0.99	0.99	0.99	90401
weighted avg	0.99	0.99	0.99	90401





```
roc auc score train 0.9938080752212389
```




```
roc auc score test 0.9933629786951615
```

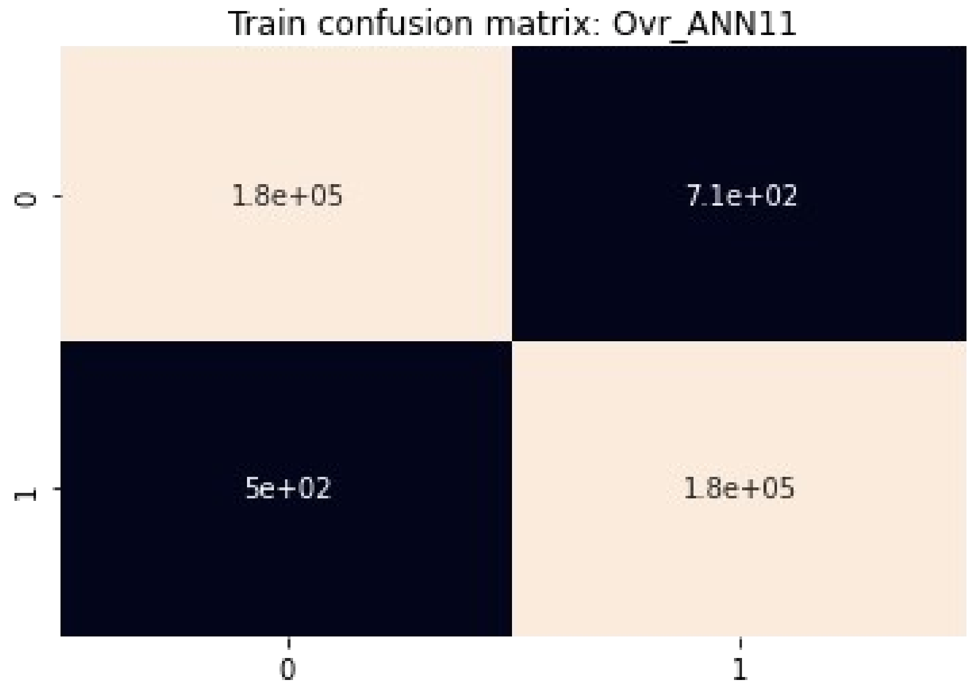
```
1781/1781 [==============================] - 3s 2ms/step

Test accuracy score 0.9870088831150592

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.11      0.88      0.19        98

    accuracy                           0.99     56962
   macro avg       0.55      0.93      0.59     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Ovr_ANN10
```

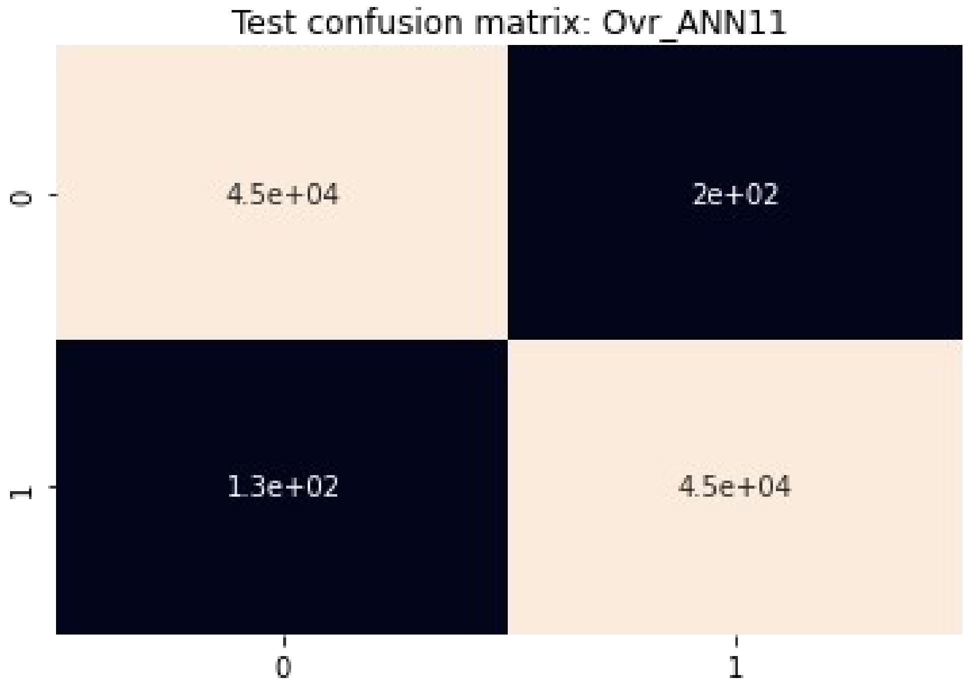
```
buildANN(3, 128, 'relu', 'he_normal', 'l2', 'adam', 30, 10,
'Ovr_ANN11')
```

```
Model: "model_32"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_40 (InputLayer)       [(None, 30)]              0

 dense_180 (Dense)           (None, 128)               3968

 dense_181 (Dense)           (None, 64)                8256

 dense_182 (Dense)           (None, 32)                2080

 dense_183 (Dense)           (None, 10)                330

 dense_184 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,656
Trainable params: 14,656
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
12054/12054 [==============================] - 41s 3ms/step - loss:
0.2486 - f1_score: 0.9825 - val_loss: 0.0913 - val_f1_score: 0.9913
Epoch 2/10
12054/12054 [==============================] - 37s 3ms/step - loss:
0.0810 - f1_score: 0.9921 - val_loss: 0.0717 - val_f1_score: 0.9944
Epoch 3/10
```

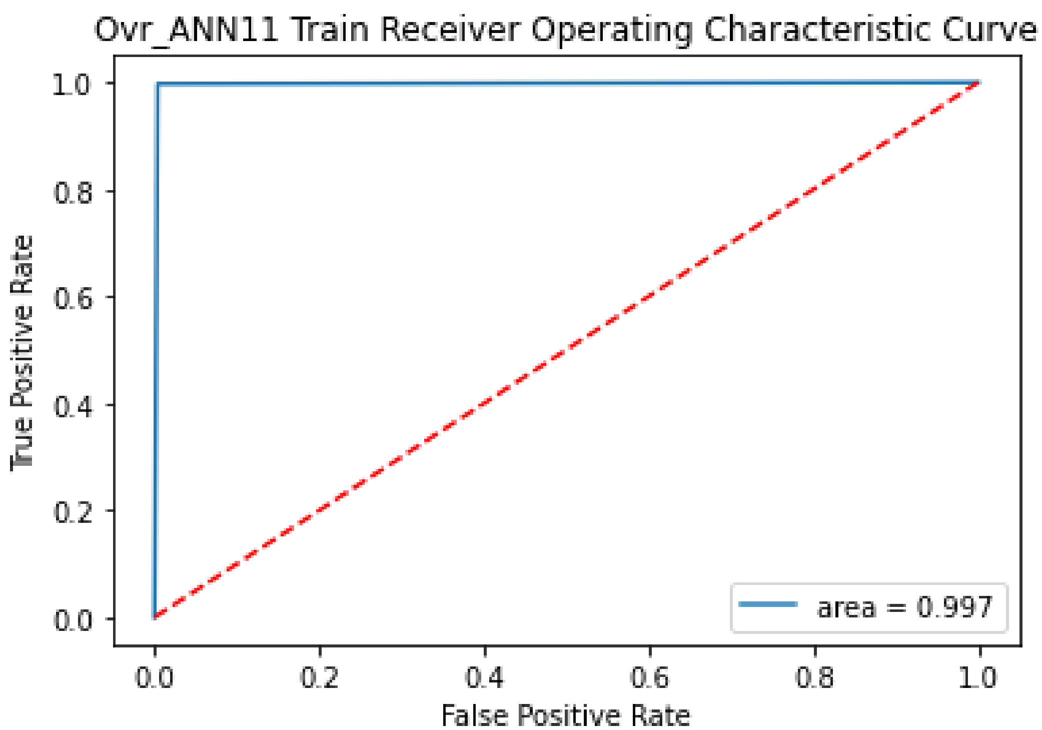
```
12054/12054 [==============================] - 35s 3ms/step - loss:
0.0712 - f1_score: 0.9934 - val_loss: 0.0669 - val_f1_score: 0.9944
Epoch 4/10
12054/12054 [==============================] - 35s 3ms/step - loss:
0.0656 - f1_score: 0.9941 - val_loss: 0.0598 - val_f1_score: 0.9965
Epoch 5/10
12054/12054 [==============================] - 35s 3ms/step - loss:
0.0627 - f1_score: 0.9944 - val_loss: 0.0682 - val_f1_score: 0.9940
Epoch 6/10
12054/12054 [==============================] - 35s 3ms/step - loss:
0.0599 - f1_score: 0.9946 - val_loss: 0.0574 - val_f1_score: 0.9944
Epoch 7/10
12054/12054 [==============================] - 38s 3ms/step - loss:
0.0589 - f1_score: 0.9945 - val_loss: 0.0519 - val_f1_score: 0.9958
Epoch 8/10
12054/12054 [==============================] - 37s 3ms/step - loss:
0.0574 - f1_score: 0.9944 - val_loss: 0.0614 - val_f1_score: 0.9925
Epoch 9/10
12054/12054 [==============================] - 35s 3ms/step - loss:
0.0557 - f1_score: 0.9947 - val_loss: 0.0558 - val_f1_score: 0.9933
Epoch 10/10
12054/12054 [==============================] - 35s 3ms/step - loss:
0.0558 - f1_score: 0.9945 - val_loss: 0.0633 - val_f1_score: 0.9964
11301/11301 [==============================] - 17s 1ms/step
2826/2826 [==============================] - 4s 1ms/step

Model performance Ovr_ANN11

accuracy score train 0.9966675977112895
accuracy score test 0.9963938452008274

Train classification report: Ovr_ANN11

              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       1.00      1.00      1.00    180801

    accuracy                           1.00    361601
   macro avg       1.00      1.00      1.00    361601
weighted avg       1.00      1.00      1.00    361601


Test classification report: Ovr_ANN11

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       1.00      1.00      1.00     45200
```

accuracy			1.00	90401
macro avg	1.00	1.00	1.00	90401
weighted avg	1.00	1.00	1.00	90401

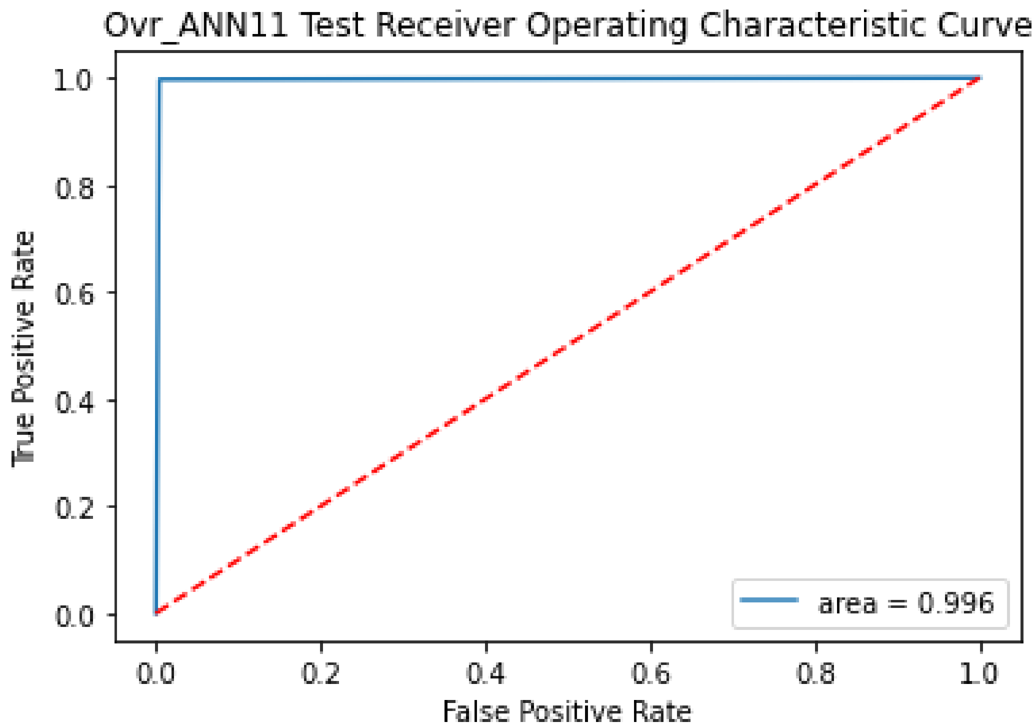




roc auc score train 0.9966675961128583



roc auc score test 0.9963938530316798




```
1781/1781 [==============================] - 3s 2ms/step

Test accuracy score 0.9957339981039992

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.27      0.88      0.41        98

    accuracy                           1.00     56962
   macro avg       0.64      0.94      0.71     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model Ovr_ANN11
```

We can select the model that gave higher macro f1-score on the test data. Model Ovr_ANN11 gave the best result till now (F1score macro= 0.71). So the number of layers and number of neurons mostly matters. Also its the optimizer that helps to get better performance.

So till now get the best result with 3 layers, (128, 64, 32) neurons respectively, relu acrivation, he_normal kernel initializer, l2 regularizer, adam optimizer, 30 batch size, 10 eochs.

The number of neurons also should be suitable for the input dimension.

Now we can try few models with undersamled data.

Undersampled data

```
finance_udr_train = pd.read_pickle('finance_udr_train.pkl')
finance_test = pd.read_pickle('finance_test.pkl')

train_udr_X = finance_udr_train.drop(['Class'], axis=1)
train_udr_y = finance_udr_train[['Class']]

test_X = finance_test.drop(['Class'], axis=1)
test_y = finance_test[['Class']]

x_train, x_test, y_train, y_test = train_test_split(train_udr_X,
train_udr_y,

stratify= train_udr_y,

test_size= 0.2, random_state= 0)

y_train = to_categorical(y_train)
y_test = to_categorical(y_test)
test_y = to_categorical(test_y)

print(x_train.shape)
print(y_train.shape)
print(x_test.shape)
print(y_test.shape)
print(test_X.shape)
print(test_y.shape)

(904, 30)
(904, 2)
(227, 30)
(227, 2)
(56962, 30)
(56962, 2)
```

ANN with undersampled data

```
buildANN(3, 128, 'relu', 'he_normal', 'l2', 'sgd', 30, 10, 'Udr_ANN1')

Model: "model_33"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_41 (InputLayer)       [(None, 30)]              0

 dense_185 (Dense)           (None, 128)               3968

 dense_186 (Dense)           (None, 64)                8256
```

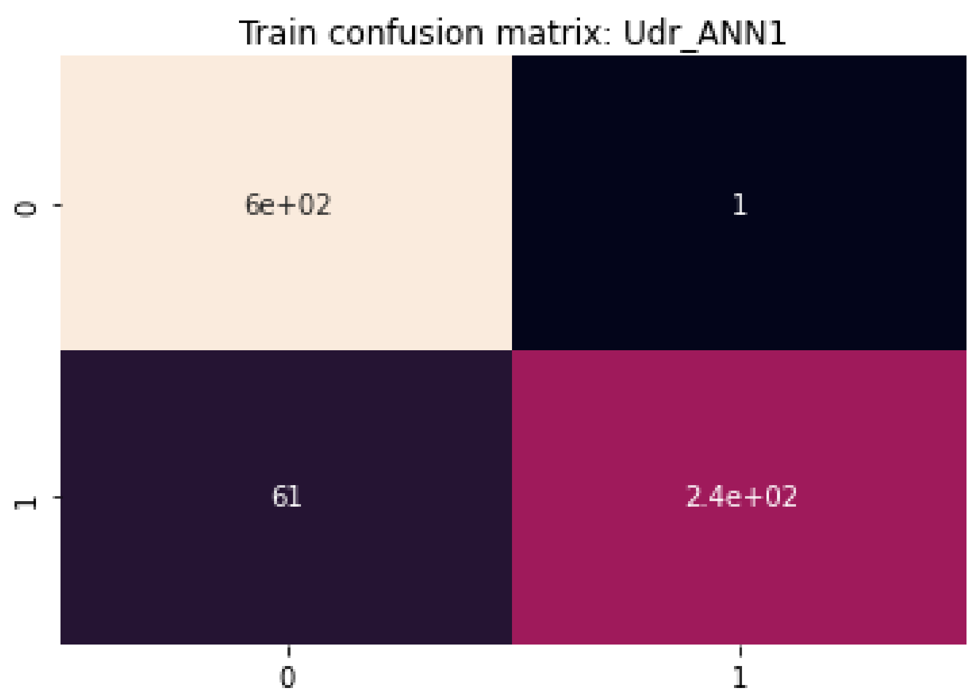
```
 dense_187 (Dense)           (None, 32)                2080

 dense_188 (Dense)           (None, 10)                330

 dense_189 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,656
Trainable params: 14,656
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
31/31 [==============================] - 1s 12ms/step - loss: 5.4097 -
f1_score: 0.4001 - val_loss: 5.2262 - val_f1_score: 0.3995
Epoch 2/10
31/31 [==============================] - 0s 4ms/step - loss: 5.1789 -
f1_score: 0.4001 - val_loss: 5.1380 - val_f1_score: 0.3995
Epoch 3/10
31/31 [==============================] - 0s 3ms/step - loss: 5.0930 -
f1_score: 0.4001 - val_loss: 5.0564 - val_f1_score: 0.3995
Epoch 4/10
31/31 [==============================] - 0s 3ms/step - loss: 5.0094 -
f1_score: 0.4001 - val_loss: 4.9748 - val_f1_score: 0.3995
Epoch 5/10
31/31 [==============================] - 0s 3ms/step - loss: 4.9277 -
f1_score: 0.4001 - val_loss: 4.8984 - val_f1_score: 0.3995
Epoch 6/10
31/31 [==============================] - 0s 3ms/step - loss: 4.8461 -
f1_score: 0.4001 - val_loss: 4.8288 - val_f1_score: 0.3995
Epoch 7/10
31/31 [==============================] - 0s 3ms/step - loss: 4.7681 -
f1_score: 0.4001 - val_loss: 4.7674 - val_f1_score: 0.3995
Epoch 8/10
31/31 [==============================] - 0s 3ms/step - loss: 4.6935 -
f1_score: 0.7848 - val_loss: 4.6859 - val_f1_score: 0.9047
Epoch 9/10
31/31 [==============================] - 0s 3ms/step - loss: 4.6200 -
f1_score: 0.9098 - val_loss: 4.6234 - val_f1_score: 0.8932
Epoch 10/10
31/31 [==============================] - 0s 4ms/step - loss: 4.5514 -
f1_score: 0.9169 - val_loss: 4.5559 - val_f1_score: 0.9104
29/29 [==============================] - 0s 2ms/step
8/8 [==============================] - 0s 2ms/step

Model performance Udr_ANN1

accuracy score train 0.9314159292035398
accuracy score test 0.9251101321585903
```

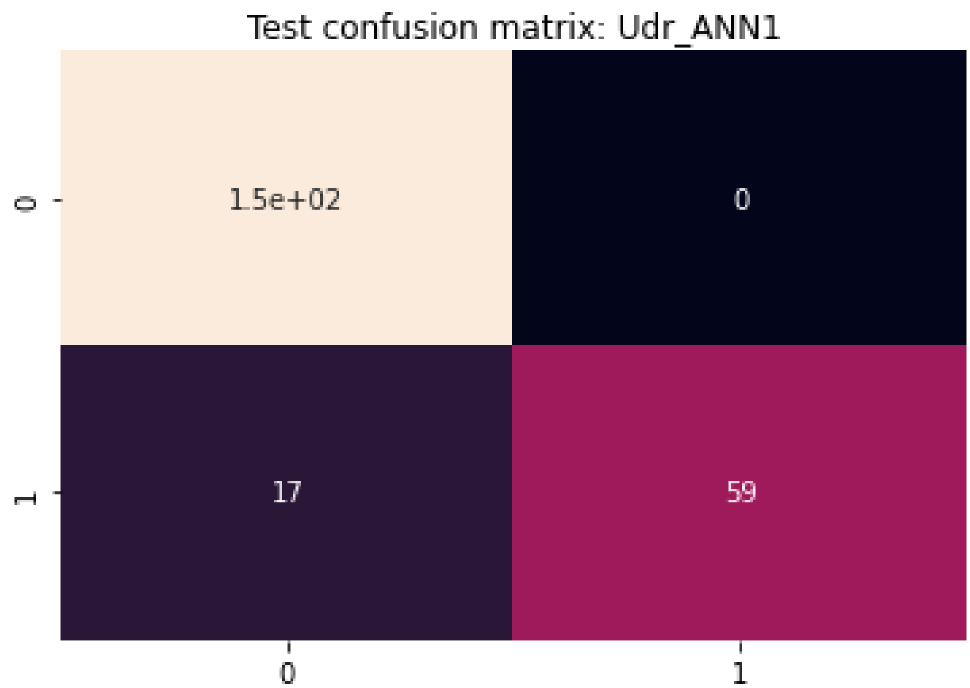
Train classification report: Udr_ANN1

	precision	recall	f1-score	support
0	0.91	1.00	0.95	603
1	1.00	0.80	0.89	301
accuracy			0.93	904
macro avg	0.95	0.90	0.92	904
weighted avg	0.94	0.93	0.93	904

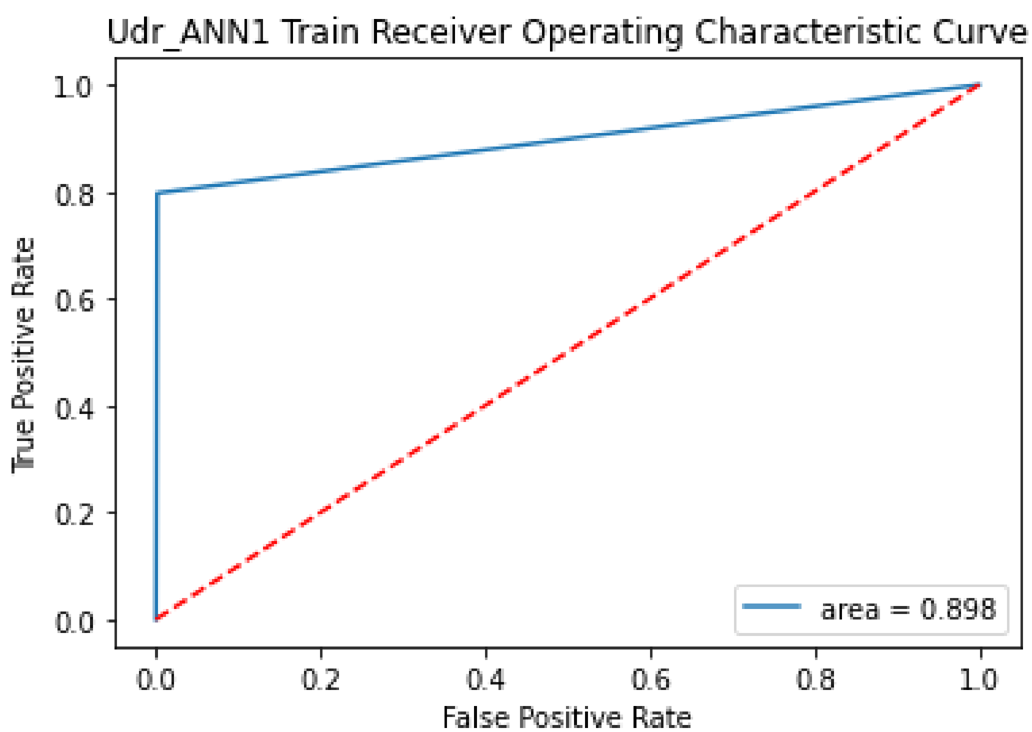
Test classification report: Udr_ANN1

	precision	recall	f1-score	support
0	0.90	1.00	0.95	151
1	1.00	0.78	0.87	76
accuracy			0.93	227
macro avg	0.95	0.89	0.91	227
weighted avg	0.93	0.93	0.92	227

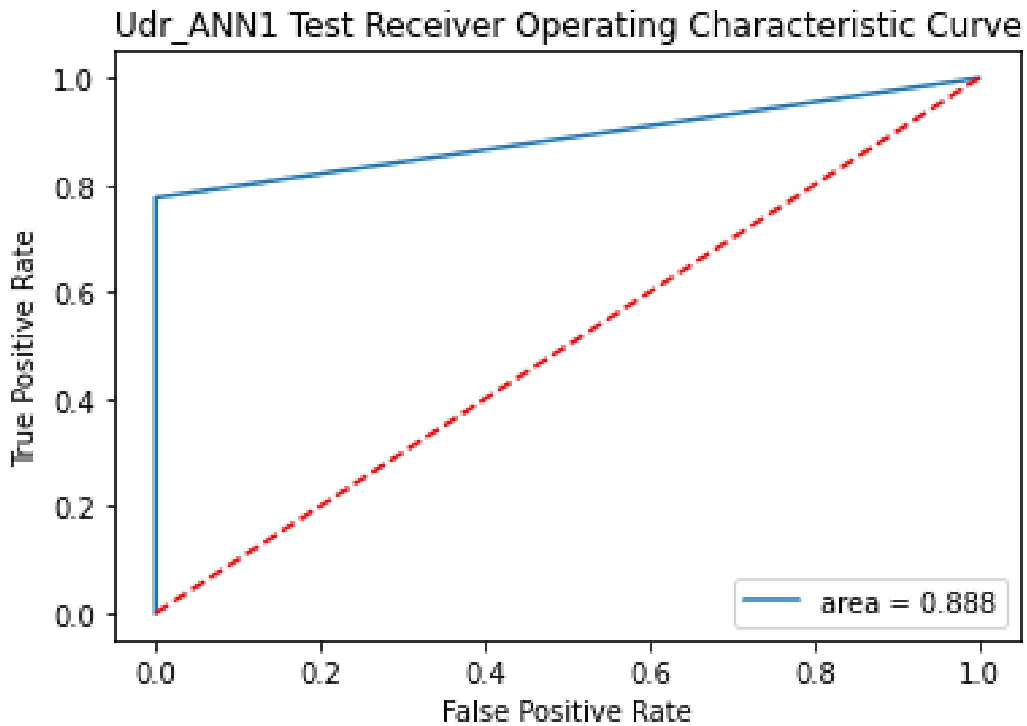




roc auc score train 0.8978419089491633



roc auc score test 0.888157894736842




```
1781/1781 [==============================] - 3s 1ms/step

Test accuracy score 0.9979284435237527

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.44      0.71      0.54        98

    accuracy                           1.00     56962
   macro avg       0.72      0.86      0.77     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model Udr_ANN1
```

```
buildANN(3, 128, 'relu', 'he_uniform', 'l2', 'adadelta', 30, 10,
'Udr_ANN2', 0.2)
```

```
Model: "model_34"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_42 (InputLayer)       [(None, 30)]              0
```

```
 dense_190 (Dense)           (None, 128)               3968

 dense_191 (Dense)           (None, 64)                8256

 dense_192 (Dense)           (None, 32)                2080

 dropout_12 (Dropout)        (None, 32)                0

 batch_normalization_12 (Bat  (None, 32)               128
 chNormalization)

 dense_193 (Dense)           (None, 10)                330

 dense_194 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,784
Trainable params: 14,720
Non-trainable params: 64
_________________________________________________________________
None
Epoch 1/10
31/31 [==============================] - 2s 13ms/step - loss: 5.3775 -
f1_score: 0.5585 - val_loss: 5.4278 - val_f1_score: 0.2914
Epoch 2/10
31/31 [==============================] - 0s 4ms/step - loss: 5.3913 -
f1_score: 0.5718 - val_loss: 5.3019 - val_f1_score: 0.4803
Epoch 3/10
31/31 [==============================] - 0s 4ms/step - loss: 5.3885 -
f1_score: 0.5638 - val_loss: 5.2665 - val_f1_score: 0.5845
Epoch 4/10
31/31 [==============================] - 0s 4ms/step - loss: 5.3936 -
f1_score: 0.5658 - val_loss: 5.2557 - val_f1_score: 0.6431
Epoch 5/10
31/31 [==============================] - 0s 4ms/step - loss: 5.3787 -
f1_score: 0.5796 - val_loss: 5.2520 - val_f1_score: 0.6644
Epoch 6/10
31/31 [==============================] - 0s 4ms/step - loss: 5.3890 -
f1_score: 0.5660 - val_loss: 5.2516 - val_f1_score: 0.6641
Epoch 7/10
31/31 [==============================] - 0s 4ms/step - loss: 5.3780 -
f1_score: 0.5701 - val_loss: 5.2525 - val_f1_score: 0.6722
Epoch 8/10
31/31 [==============================] - 0s 4ms/step - loss: 5.3834 -
f1_score: 0.5658 - val_loss: 5.2552 - val_f1_score: 0.6675
Epoch 9/10
31/31 [==============================] - 0s 4ms/step - loss: 5.3770 -
f1_score: 0.5835 - val_loss: 5.2573 - val_f1_score: 0.6670
29/29 [==============================] - 0s 2ms/step
8/8 [==============================] - 0s 2ms/step
```

Model performance Udr_ANN2

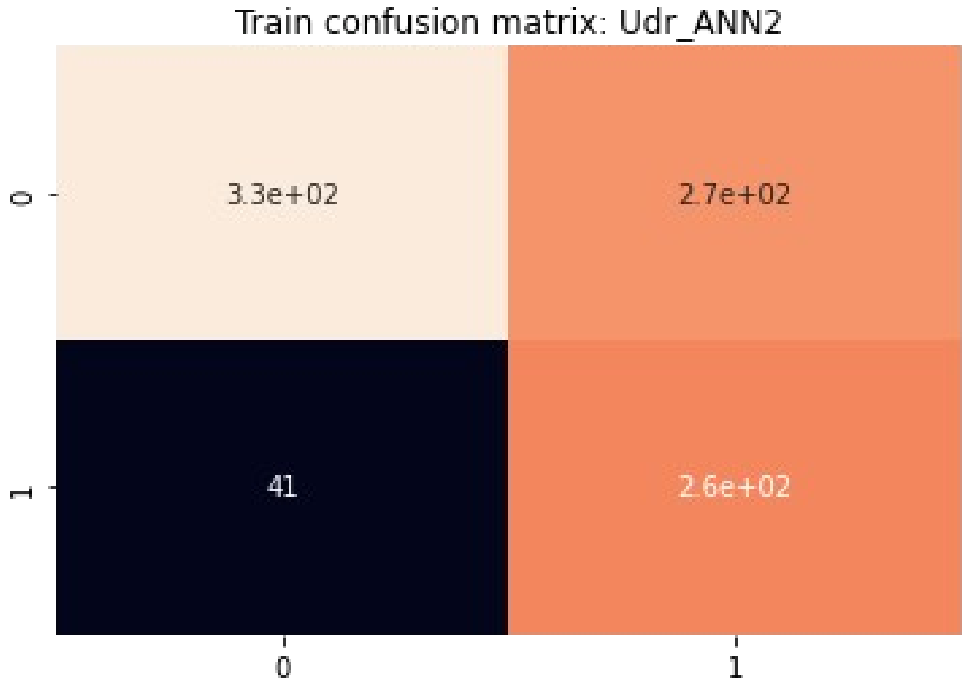
accuracy score train 0.6570796460176991
accuracy score test 0.6696035242290749

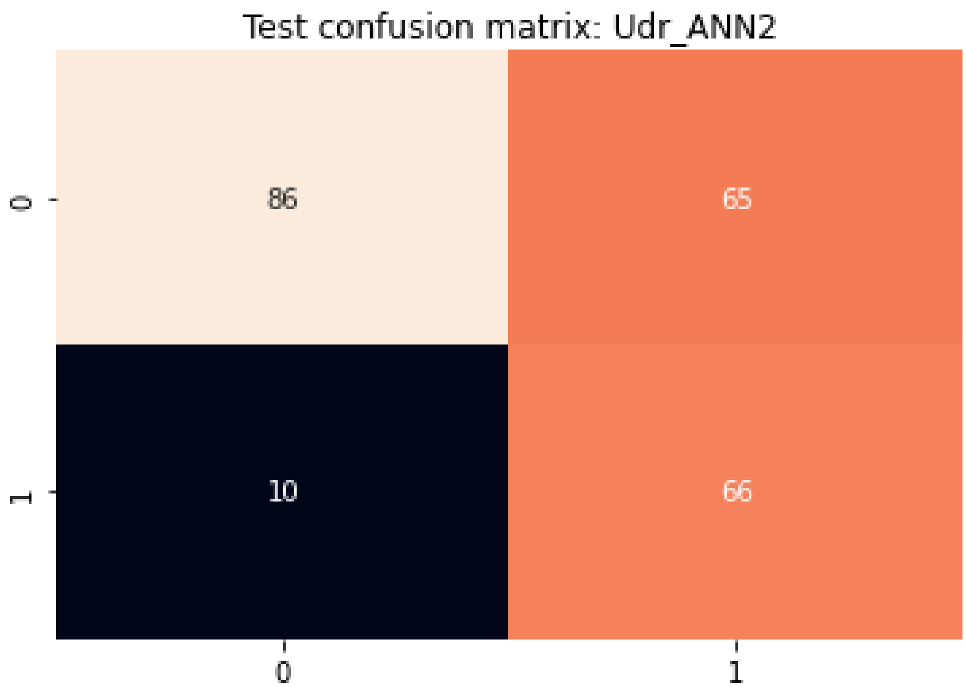
Train classification report: Udr_ANN2

	precision	recall	f1-score	support
0	0.89	0.55	0.68	603
1	0.49	0.86	0.63	301
accuracy			0.66	904
macro avg	0.69	0.71	0.65	904
weighted avg	0.76	0.66	0.66	904

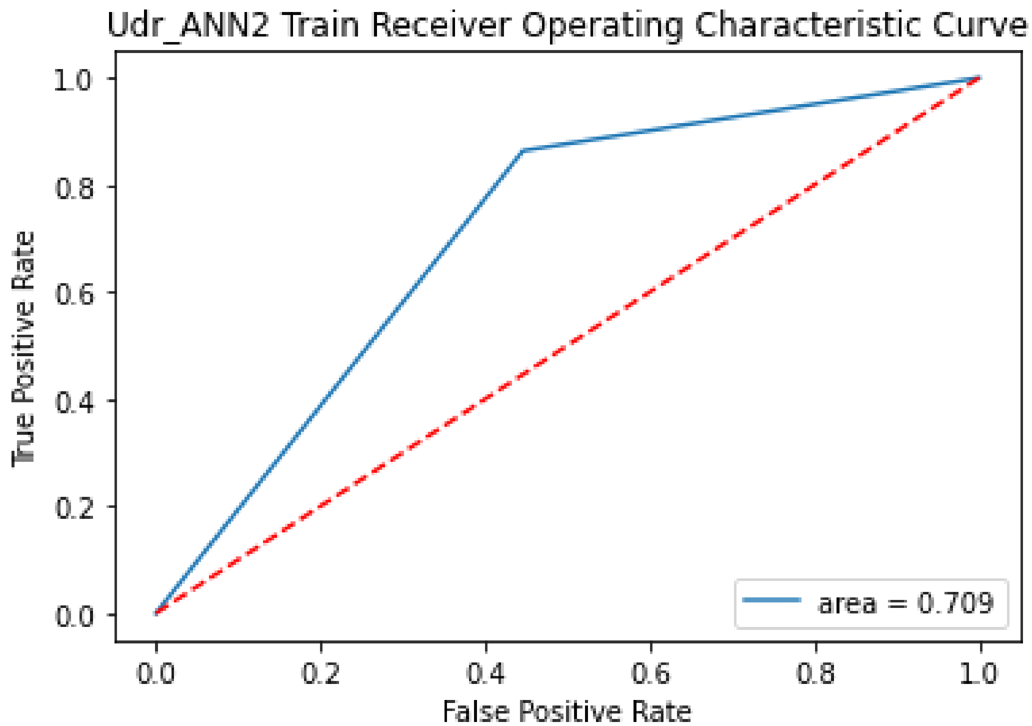
Test classification report: Udr_ANN2

	precision	recall	f1-score	support
0	0.90	0.57	0.70	151
1	0.50	0.87	0.64	76
accuracy			0.67	227
macro avg	0.70	0.72	0.67	227
weighted avg	0.76	0.67	0.68	227

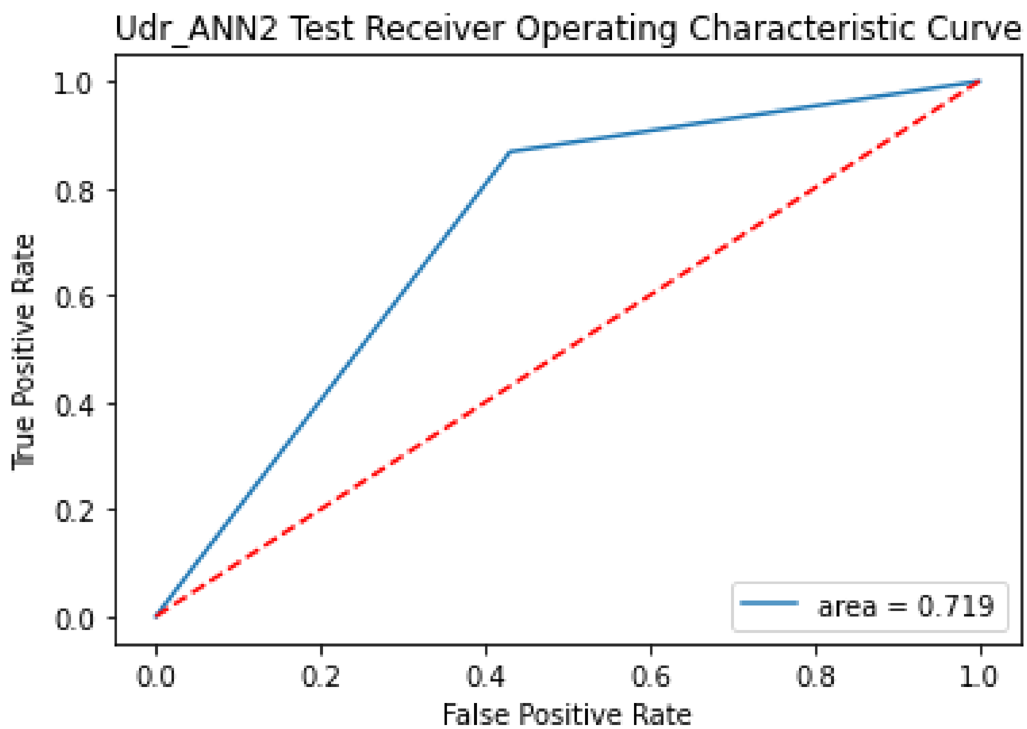





```
roc auc score train 0.7088422780890673
```




```
roc auc score test 0.7189787382363193
```




```
1781/1781 [==============================] - 3s 2ms/step
```

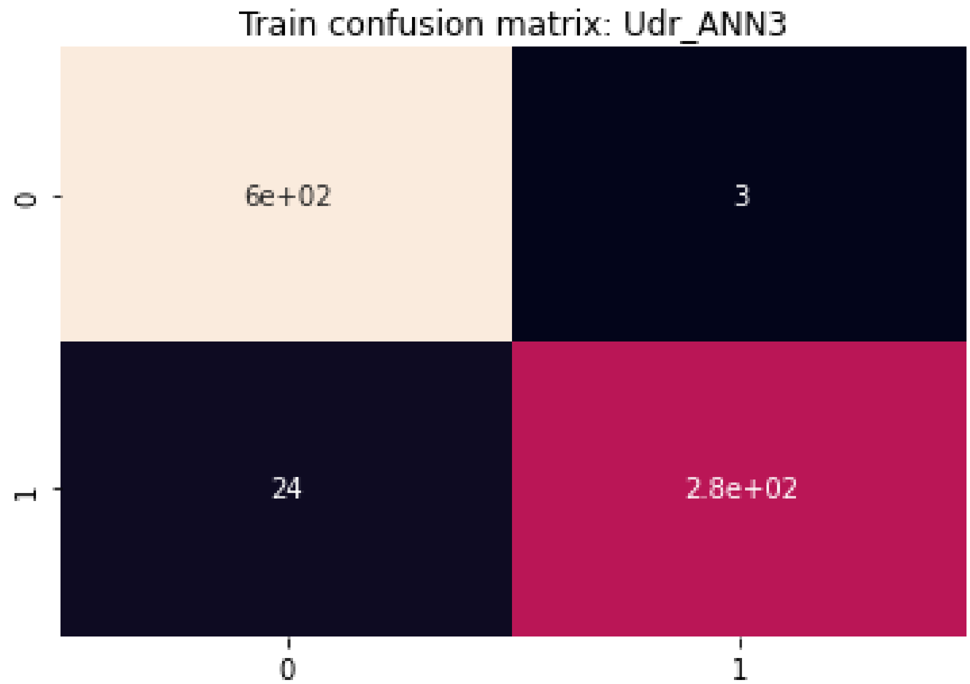
```
Test accuracy score 0.5401320178364524

Classification report

              precision    recall  f1-score   support

           0       1.00      0.54      0.70     56864
           1       0.00      0.83      0.01        98

    accuracy                           0.54     56962
   macro avg       0.50      0.68      0.35     56962
weighted avg       1.00      0.54      0.70     56962


Completed and saved for model Udr_ANN2
```

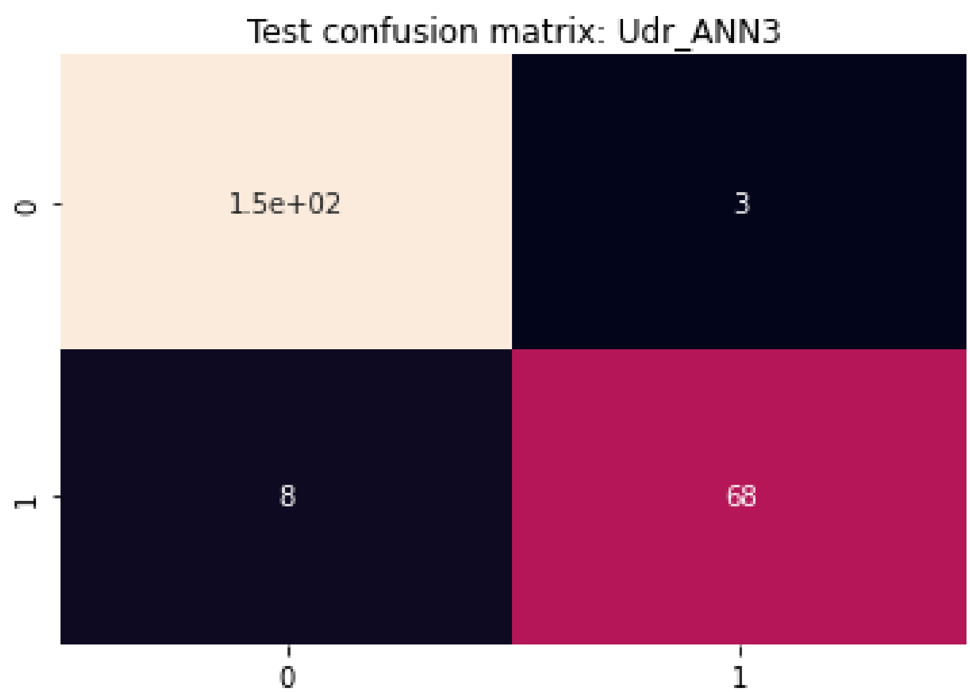
```
buildANN(3, 128, 'relu', 'he_normal', 'l2', 'rmsprop', 30, 10,
'Udr_ANN3')
```

```
Model: "model_35"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_43 (InputLayer)       [(None, 30)]              0

 dense_195 (Dense)           (None, 128)               3968

 dense_196 (Dense)           (None, 64)                8256

 dense_197 (Dense)           (None, 32)                2080

 dense_198 (Dense)           (None, 10)                330

 dense_199 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,656
Trainable params: 14,656
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
31/31 [==============================] - 1s 12ms/step - loss: 4.6311 -
f1_score: 0.8010 - val_loss: 4.0685 - val_f1_score: 0.9336
Epoch 2/10
31/31 [==============================] - 0s 3ms/step - loss: 3.7022 -
f1_score: 0.9410 - val_loss: 3.3467 - val_f1_score: 0.9341
Epoch 3/10
31/31 [==============================] - 0s 4ms/step - loss: 3.0338 -
f1_score: 0.9474 - val_loss: 2.7168 - val_f1_score: 0.9390
```

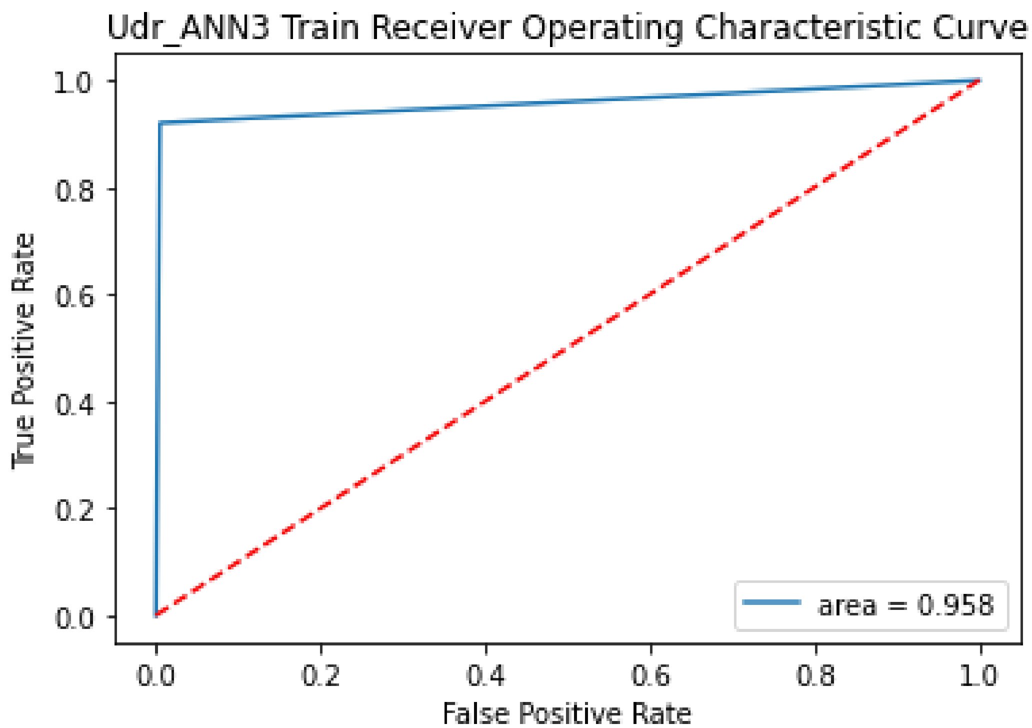
```
Epoch 4/10
31/31 [==============================] - 0s 3ms/step - loss: 2.4700 -
f1_score: 0.9437 - val_loss: 2.2080 - val_f1_score: 0.9390
Epoch 5/10
31/31 [==============================] - 0s 4ms/step - loss: 1.9993 -
f1_score: 0.9526 - val_loss: 1.7921 - val_f1_score: 0.9447
Epoch 6/10
31/31 [==============================] - 0s 4ms/step - loss: 1.6236 -
f1_score: 0.9541 - val_loss: 1.4544 - val_f1_score: 0.9447
Epoch 7/10
31/31 [==============================] - 0s 3ms/step - loss: 1.3098 -
f1_score: 0.9581 - val_loss: 1.1835 - val_f1_score: 0.9447
Epoch 8/10
31/31 [==============================] - 0s 4ms/step - loss: 1.0586 -
f1_score: 0.9644 - val_loss: 0.9876 - val_f1_score: 0.9303
Epoch 9/10
31/31 [==============================] - 0s 5ms/step - loss: 0.8678 -
f1_score: 0.9605 - val_loss: 0.8091 - val_f1_score: 0.9447
Epoch 10/10
31/31 [==============================] - 0s 4ms/step - loss: 0.7142 -
f1_score: 0.9581 - val_loss: 0.6705 - val_f1_score: 0.9447
29/29 [==============================] - 0s 1ms/step
8/8 [==============================] - 0s 2ms/step

Model performance Udr_ANN3

accuracy score train 0.9701327433628318
accuracy score test 0.9515418502202643

Train classification report: Udr_ANN3

              precision    recall  f1-score   support

           0       0.96      1.00      0.98       603
           1       0.99      0.92      0.95       301

    accuracy                           0.97       904
   macro avg       0.98      0.96      0.97       904
weighted avg       0.97      0.97      0.97       904


Test classification report: Udr_ANN3

              precision    recall  f1-score   support

           0       0.95      0.98      0.96       151
           1       0.96      0.89      0.93        76

    accuracy                           0.95       227
```

macro avg	0.95	0.94	0.94	227
weighted avg	0.95	0.95	0.95	227

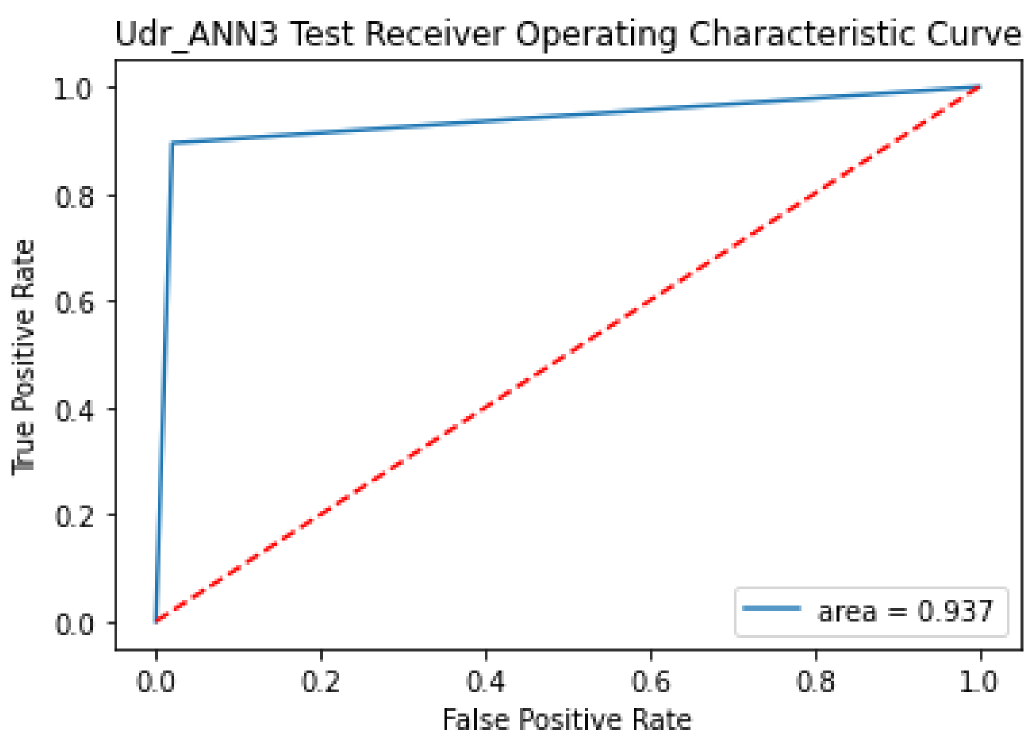




```
roc auc score train 0.9576453281763938
```




```
roc auc score test 0.9374346462181945
```



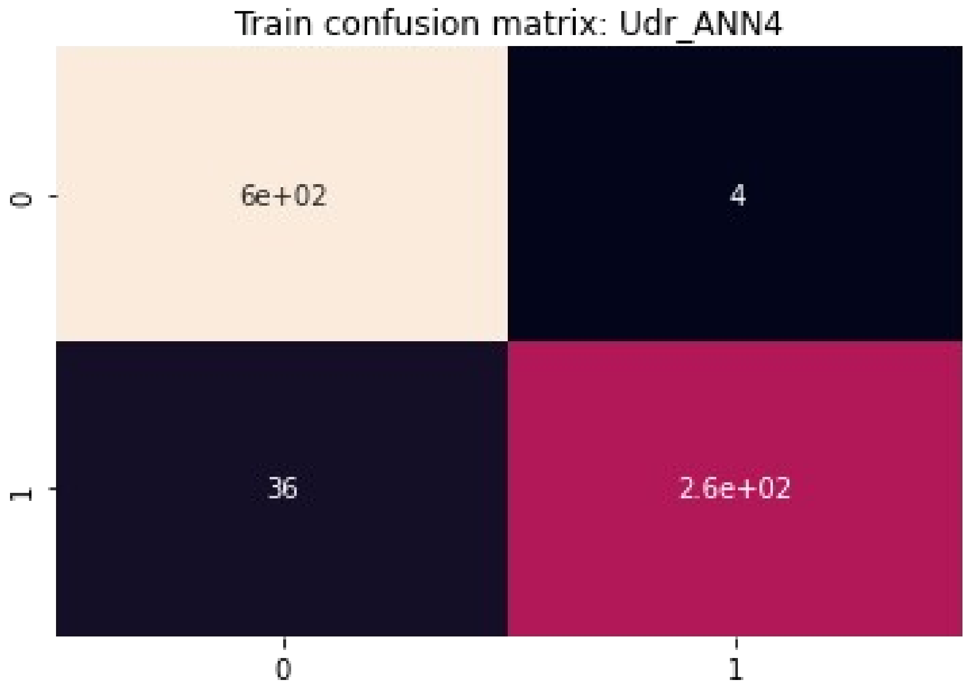
```
1781/1781 [==============================] - 3s 1ms/step

Test accuracy score 0.9858151048067132

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.10      0.87      0.17        98

    accuracy                           0.99     56962
   macro avg       0.55      0.93      0.58     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Udr_ANN3
```

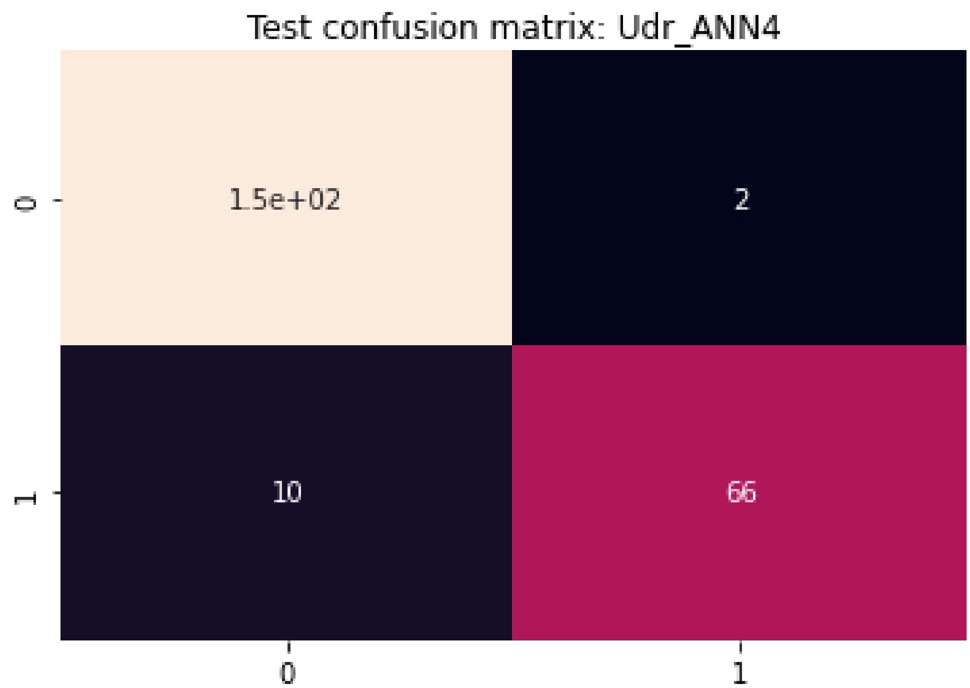
```
buildANN(3, 128, 'relu', 'he_normal', 'l1', 'rmsprop', 40, 10,
'Udr_ANN4')
```

```
Model: "model_36"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_44 (InputLayer)       [(None, 30)]              0

 dense_200 (Dense)           (None, 128)               3968

 dense_201 (Dense)           (None, 64)                8256

 dense_202 (Dense)           (None, 32)                2080

 dense_203 (Dense)           (None, 10)                330

 dense_204 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,656
Trainable params: 14,656
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
23/23 [==============================] - 1s 15ms/step - loss: 19.3082
- f1_score: 0.8279 - val_loss: 17.7791 - val_f1_score: 0.9341
Epoch 2/10
23/23 [==============================] - 0s 4ms/step - loss: 16.7145 -
f1_score: 0.9356 - val_loss: 15.5046 - val_f1_score: 0.9385
Epoch 3/10
```

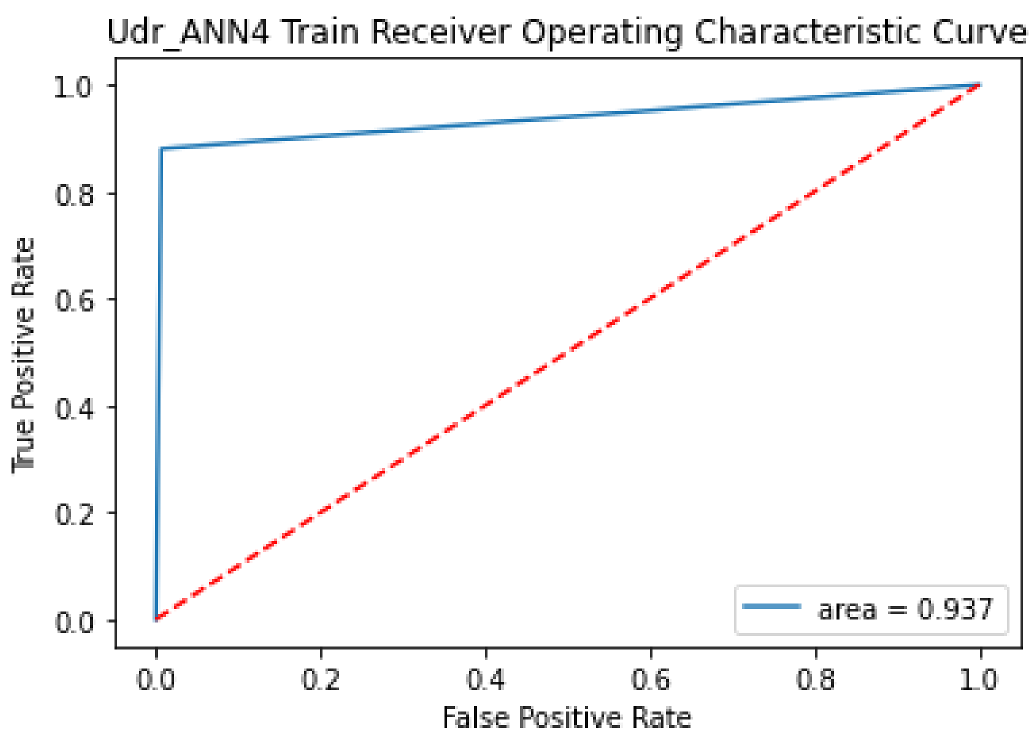
```
23/23 [==============================] - 0s 4ms/step - loss: 14.4683 -
f1_score: 0.9340 - val_loss: 13.3429 - val_f1_score: 0.9434
Epoch 4/10
23/23 [==============================] - 0s 5ms/step - loss: 12.3721 -
f1_score: 0.9418 - val_loss: 11.3592 - val_f1_score: 0.9390
Epoch 5/10
23/23 [==============================] - 0s 4ms/step - loss: 10.5088 -
f1_score: 0.9417 - val_loss: 9.6300 - val_f1_score: 0.9390
Epoch 6/10
23/23 [==============================] - 0s 4ms/step - loss: 8.8789 -
f1_score: 0.9407 - val_loss: 8.1111 - val_f1_score: 0.9390
Epoch 7/10
23/23 [==============================] - 0s 4ms/step - loss: 7.4636 -
f1_score: 0.9448 - val_loss: 6.7906 - val_f1_score: 0.9390
Epoch 8/10
23/23 [==============================] - 0s 4ms/step - loss: 6.2296 -
f1_score: 0.9460 - val_loss: 5.6514 - val_f1_score: 0.9390
Epoch 9/10
23/23 [==============================] - 0s 4ms/step - loss: 5.1736 -
f1_score: 0.9406 - val_loss: 4.6817 - val_f1_score: 0.9390
Epoch 10/10
23/23 [==============================] - 0s 5ms/step - loss: 4.2913 -
f1_score: 0.9418 - val_loss: 3.8814 - val_f1_score: 0.9390
29/29 [==============================] - 0s 1ms/step
8/8 [==============================] - 0s 2ms/step

Model performance Udr_ANN4

accuracy score train 0.9557522123893806
accuracy score test 0.947136563876652

Train classification report: Udr_ANN4

              precision    recall  f1-score   support

           0       0.94      0.99      0.97       603
           1       0.99      0.88      0.93       301

    accuracy                           0.96       904
   macro avg       0.96      0.94      0.95       904
weighted avg       0.96      0.96      0.96       904


Test classification report: Udr_ANN4

              precision    recall  f1-score   support

           0       0.94      0.99      0.96       151
           1       0.97      0.87      0.92        76
```

accuracy			0.95	227
macro avg	0.95	0.93	0.94	227
weighted avg	0.95	0.95	0.95	227

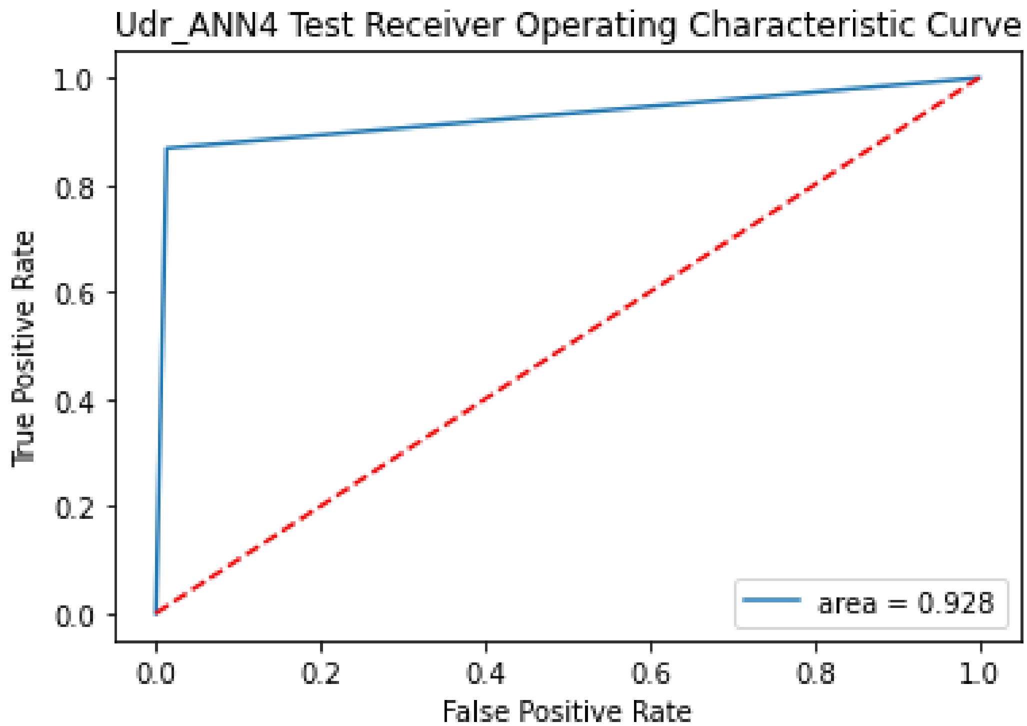




roc auc score train 0.9368825859627665



roc auc score test 0.9275880097594982



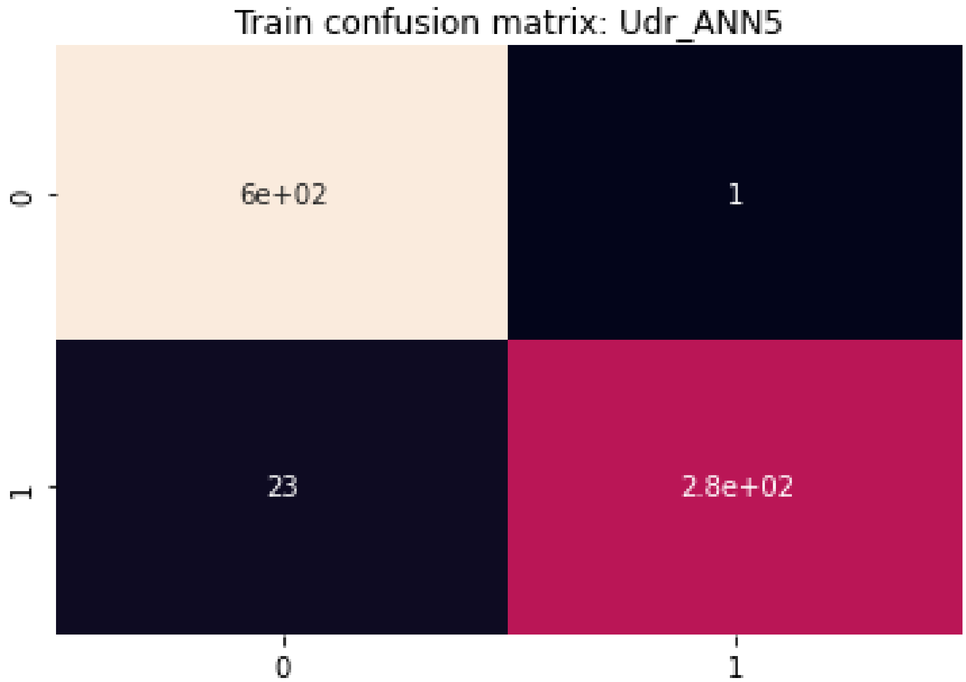

```
1781/1781 [==============================] - 3s 1ms/step

Test accuracy score 0.9876584389593062

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.11      0.84      0.19        98

    accuracy                           0.99     56962
   macro avg       0.55      0.91      0.59     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Udr_ANN4
```

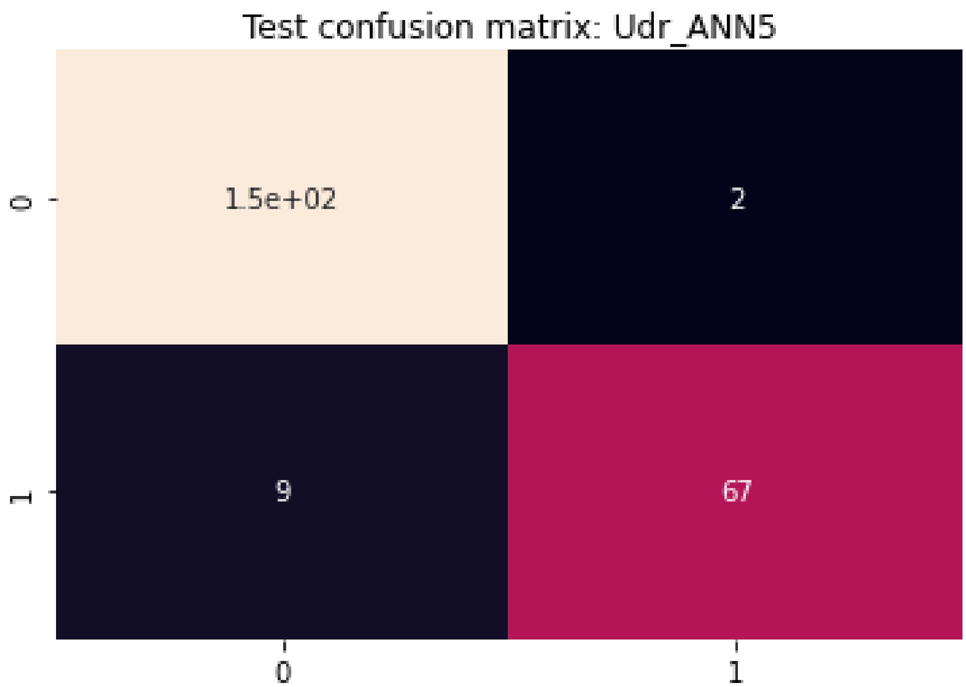
```
buildANN(3, 128, 'relu', 'he_normal', 'l2', 'adam', 30, 10,
'Udr_ANN5')
```

```
Model: "model_37"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_45 (InputLayer)       [(None, 30)]              0
```

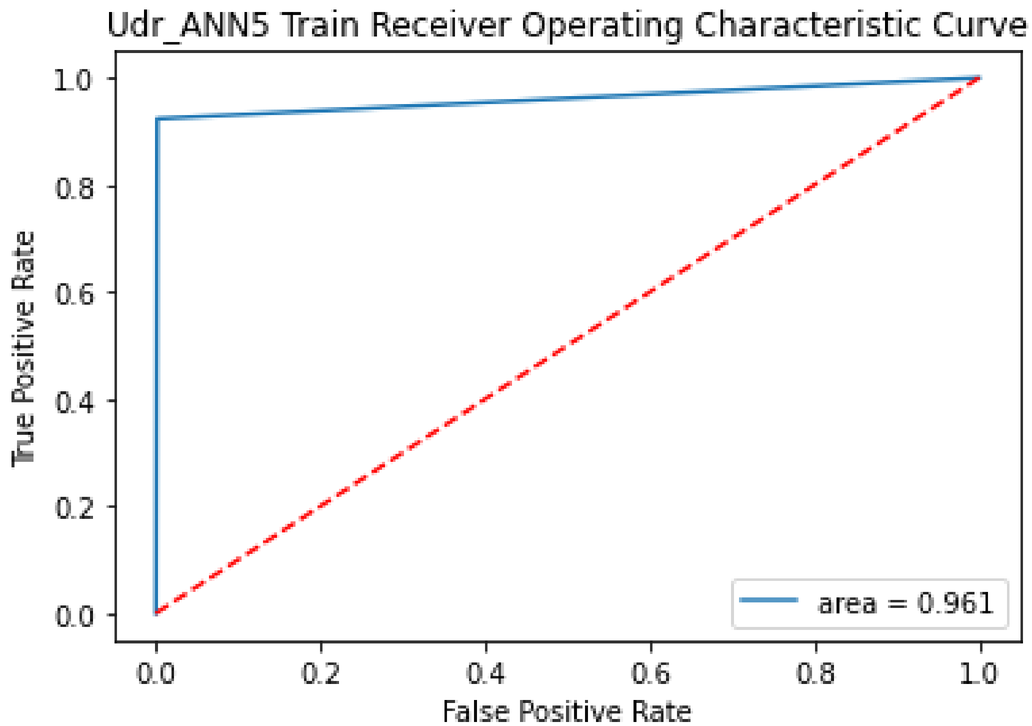
```
 dense_205 (Dense)           (None, 128)               3968

 dense_206 (Dense)           (None, 64)                8256

 dense_207 (Dense)           (None, 32)                2080

 dense_208 (Dense)           (None, 10)                330

 dense_209 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,656
Trainable params: 14,656
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
31/31 [==============================] - 1s 12ms/step - loss: 4.8078 -
f1_score: 0.8938 - val_loss: 4.3735 - val_f1_score: 0.9390
Epoch 2/10
31/31 [==============================] - 0s 4ms/step - loss: 4.0840 -
f1_score: 0.9441 - val_loss: 3.8031 - val_f1_score: 0.9390
Epoch 3/10
31/31 [==============================] - 0s 4ms/step - loss: 3.5507 -
f1_score: 0.9544 - val_loss: 3.3117 - val_f1_score: 0.9443
Epoch 4/10
31/31 [==============================] - 0s 4ms/step - loss: 3.0805 -
f1_score: 0.9605 - val_loss: 2.8854 - val_f1_score: 0.9443
Epoch 5/10
31/31 [==============================] - 0s 4ms/step - loss: 2.6728 -
f1_score: 0.9605 - val_loss: 2.5073 - val_f1_score: 0.9491
Epoch 6/10
31/31 [==============================] - 0s 4ms/step - loss: 2.3267 -
f1_score: 0.9619 - val_loss: 2.1998 - val_f1_score: 0.9443
Epoch 7/10
31/31 [==============================] - 0s 4ms/step - loss: 2.0173 -
f1_score: 0.9621 - val_loss: 1.9312 - val_f1_score: 0.9491
Epoch 8/10
31/31 [==============================] - 0s 4ms/step - loss: 1.7644 -
f1_score: 0.9633 - val_loss: 1.6844 - val_f1_score: 0.9443
Epoch 9/10
31/31 [==============================] - 0s 4ms/step - loss: 1.5358 -
f1_score: 0.9658 - val_loss: 1.4827 - val_f1_score: 0.9491
Epoch 10/10
31/31 [==============================] - 0s 4ms/step - loss: 1.3435 -
f1_score: 0.9671 - val_loss: 1.3004 - val_f1_score: 0.9443
29/29 [==============================] - 0s 2ms/step
8/8 [==============================] - 0s 2ms/step

Model performance Udr_ANN5
```

```
accuracy score train 0.9734513274336283
accuracy score test 0.9515418502202643

Train classification report: Udr_ANN5

              precision    recall  f1-score   support

           0       0.96      1.00      0.98       603
           1       1.00      0.92      0.96       301

    accuracy                           0.97       904
   macro avg       0.98      0.96      0.97       904
weighted avg       0.97      0.97      0.97       904


Test classification report: Udr_ANN5

              precision    recall  f1-score   support

           0       0.94      0.99      0.96       151
           1       0.97      0.88      0.92        76

    accuracy                           0.95       227
   macro avg       0.96      0.93      0.94       227
weighted avg       0.95      0.95      0.95       227
```

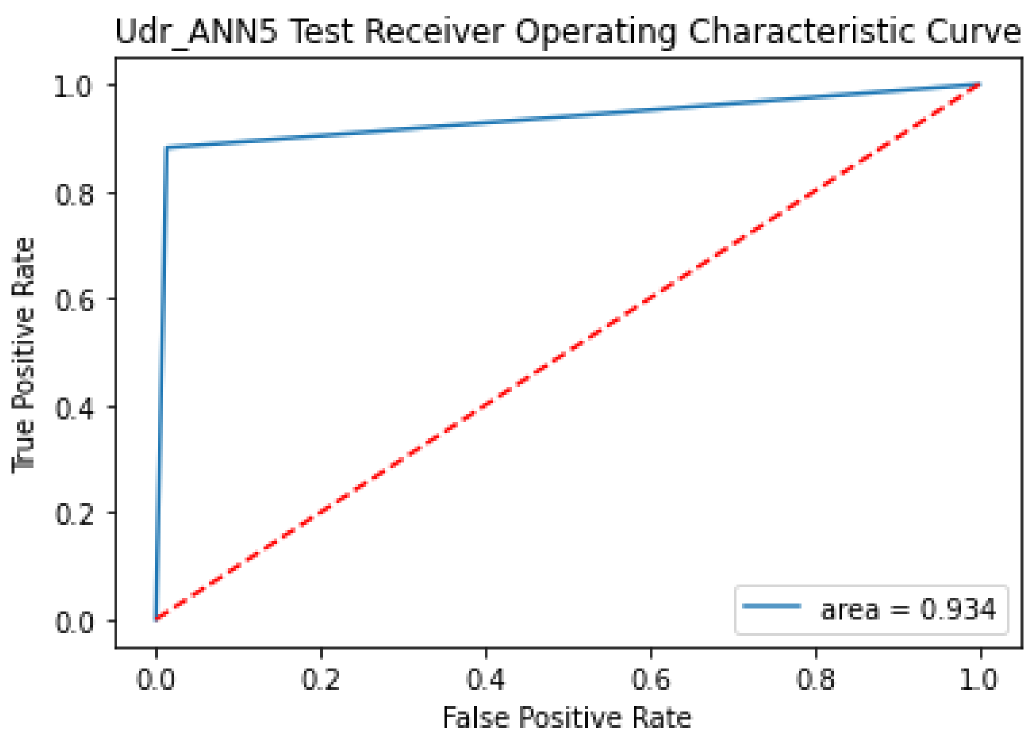





```
roc auc score train 0.9609648325372033
```




```
roc auc score test 0.9341669571279192
```




```
1781/1781 [==============================] - 3s 2ms/step
```

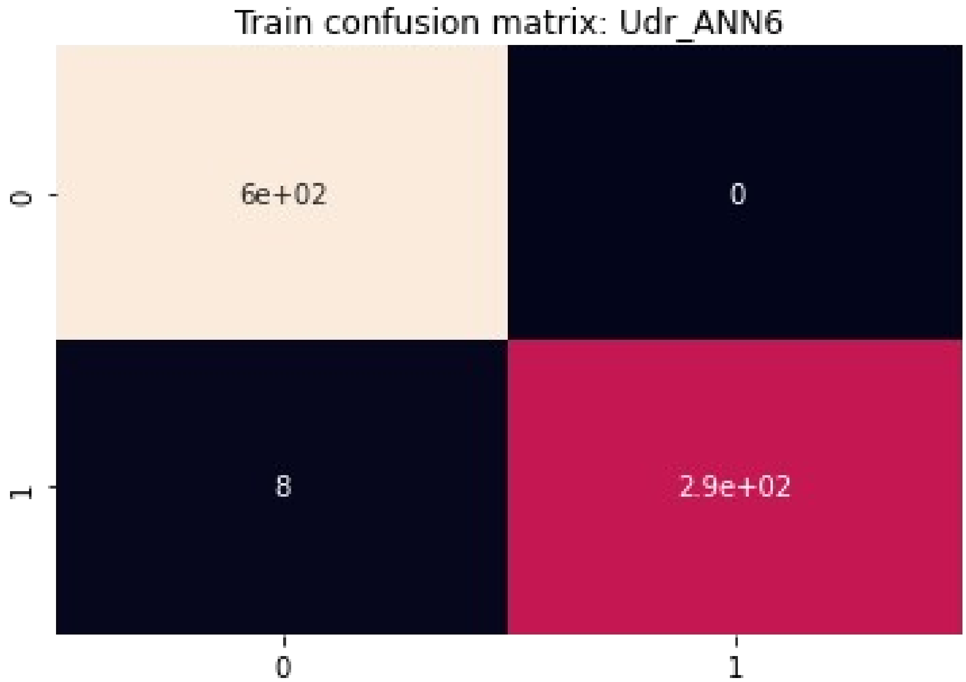
```
Test accuracy score 0.9893086619149608

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.12      0.87      0.22        98

    accuracy                           0.99     56962
   macro avg       0.56      0.93      0.61     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Udr_ANN5
```

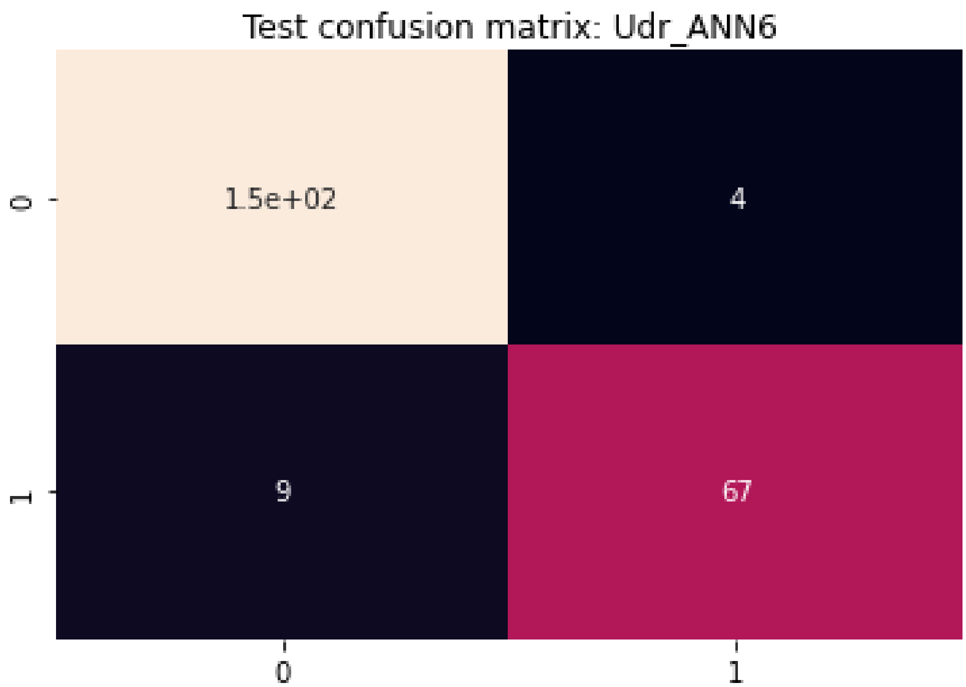
```
buildANN(3, 128, 'relu', 'he_normal', 'l2', 'adam', 40, 20,
'Udr_ANN6', 0.2)
```

```
Model: "model_38"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_46 (InputLayer)       [(None, 30)]              0

 dense_210 (Dense)           (None, 128)               3968

 dense_211 (Dense)           (None, 64)                8256

 dense_212 (Dense)           (None, 32)                2080

 dropout_13 (Dropout)        (None, 32)                0

 batch_normalization_13 (Bat  (None, 32)               128
 chNormalization)

 dense_213 (Dense)           (None, 10)                330

 dense_214 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,784
Trainable params: 14,720
Non-trainable params: 64
_________________________________________________________________
None
Epoch 1/20
23/23 [==============================] - 1s 18ms/step - loss: 5.0495 -
f1_score: 0.7302 - val_loss: 4.7523 - val_f1_score: 0.8971
Epoch 2/20
```

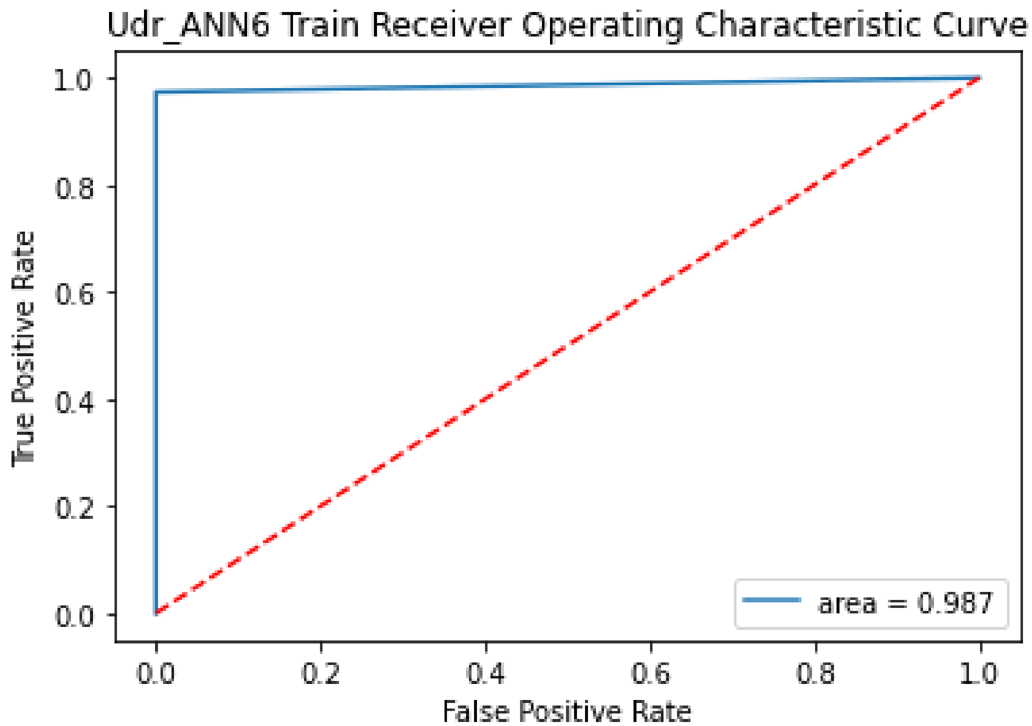
```
23/23 [==============================] - 0s 5ms/step - loss: 4.5570 -
f1_score: 0.9019 - val_loss: 4.3585 - val_f1_score: 0.9443
Epoch 3/20
23/23 [==============================] - 0s 5ms/step - loss: 4.1544 -
f1_score: 0.9327 - val_loss: 3.9809 - val_f1_score: 0.9390
Epoch 4/20
23/23 [==============================] - 0s 5ms/step - loss: 3.8134 -
f1_score: 0.9341 - val_loss: 3.6527 - val_f1_score: 0.9390
Epoch 5/20
23/23 [==============================] - 0s 4ms/step - loss: 3.5031 -
f1_score: 0.9501 - val_loss: 3.3595 - val_f1_score: 0.9390
Epoch 6/20
23/23 [==============================] - 0s 4ms/step - loss: 3.2158 -
f1_score: 0.9464 - val_loss: 3.0960 - val_f1_score: 0.9439
Epoch 7/20
23/23 [==============================] - 0s 5ms/step - loss: 2.9510 -
f1_score: 0.9582 - val_loss: 2.8505 - val_f1_score: 0.9390
Epoch 8/20
23/23 [==============================] - 0s 4ms/step - loss: 2.7148 -
f1_score: 0.9569 - val_loss: 2.6244 - val_f1_score: 0.9390
Epoch 9/20
23/23 [==============================] - 0s 5ms/step - loss: 2.4912 -
f1_score: 0.9608 - val_loss: 2.4151 - val_f1_score: 0.9390
Epoch 10/20
23/23 [==============================] - 0s 5ms/step - loss: 2.2849 -
f1_score: 0.9634 - val_loss: 2.2253 - val_f1_score: 0.9443
Epoch 11/20
23/23 [==============================] - 0s 5ms/step - loss: 2.0902 -
f1_score: 0.9722 - val_loss: 2.0528 - val_f1_score: 0.9443
Epoch 12/20
23/23 [==============================] - 0s 5ms/step - loss: 1.9234 -
f1_score: 0.9711 - val_loss: 1.8977 - val_f1_score: 0.9443
Epoch 13/20
23/23 [==============================] - 0s 5ms/step - loss: 1.7654 -
f1_score: 0.9674 - val_loss: 1.7534 - val_f1_score: 0.9394
Epoch 14/20
23/23 [==============================] - 0s 4ms/step - loss: 1.6299 -
f1_score: 0.9648 - val_loss: 1.6256 - val_f1_score: 0.9346
Epoch 15/20
23/23 [==============================] - 0s 5ms/step - loss: 1.4813 -
f1_score: 0.9775 - val_loss: 1.5027 - val_f1_score: 0.9394
Epoch 16/20
23/23 [==============================] - 0s 4ms/step - loss: 1.3544 -
f1_score: 0.9862 - val_loss: 1.3976 - val_f1_score: 0.9394
Epoch 17/20
23/23 [==============================] - 0s 4ms/step - loss: 1.2577 -
f1_score: 0.9799 - val_loss: 1.3013 - val_f1_score: 0.9346
Epoch 18/20
23/23 [==============================] - 0s 4ms/step - loss: 1.1614 -
f1_score: 0.9825 - val_loss: 1.2115 - val_f1_score: 0.9443
```

```
Epoch 19/20
23/23 [==============================] - 0s 4ms/step - loss: 1.0664 -
f1_score: 0.9775 - val_loss: 1.1294 - val_f1_score: 0.9443
Epoch 20/20
23/23 [==============================] - 0s 4ms/step - loss: 0.9909 -
f1_score: 0.9788 - val_loss: 1.0726 - val_f1_score: 0.9346
29/29 [==============================] - 0s 2ms/step
8/8 [==============================] - 0s 2ms/step

Model performance Udr_ANN6

accuracy score train 0.9911504424778761
accuracy score test 0.9427312775330396

Train classification report: Udr_ANN6

              precision    recall  f1-score   support

           0       0.99      1.00      0.99       603
           1       1.00      0.97      0.99       301

    accuracy                           0.99       904
   macro avg       0.99      0.99      0.99       904
weighted avg       0.99      0.99      0.99       904


Test classification report: Udr_ANN6

              precision    recall  f1-score   support

           0       0.94      0.97      0.96       151
           1       0.94      0.88      0.91        76

    accuracy                           0.94       227
   macro avg       0.94      0.93      0.93       227
weighted avg       0.94      0.94      0.94       227
```

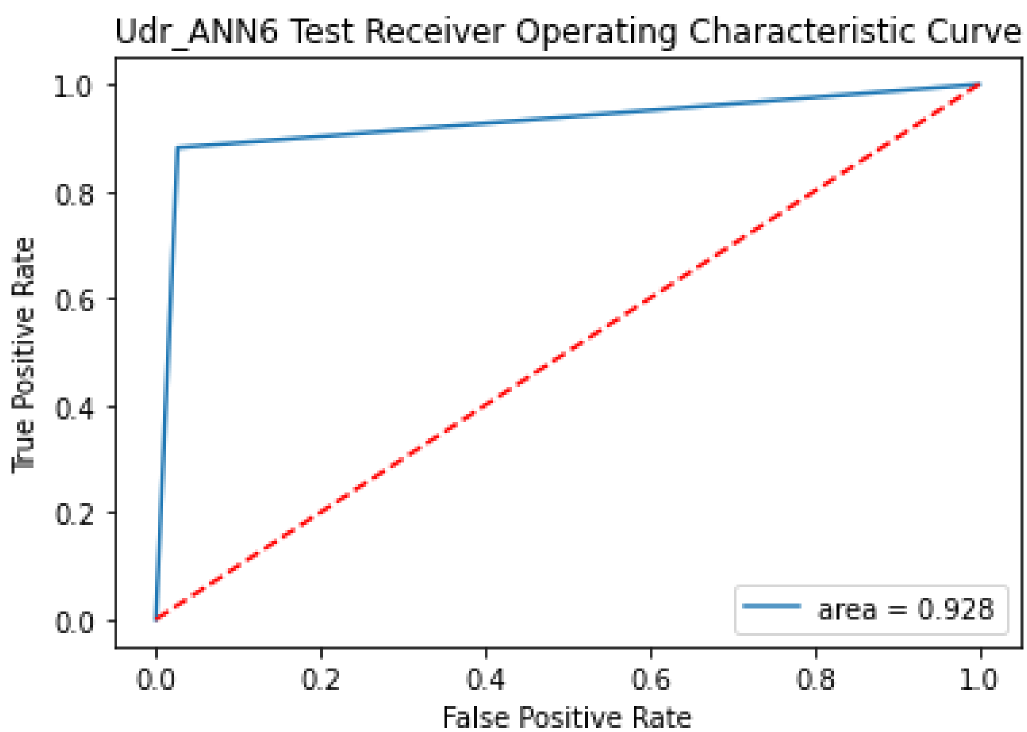





```
roc auc score train 0.9867109634551495
```




```
roc auc score test 0.9275444405716278
```




```
1781/1781 [==============================] - 3s 2ms/step
```

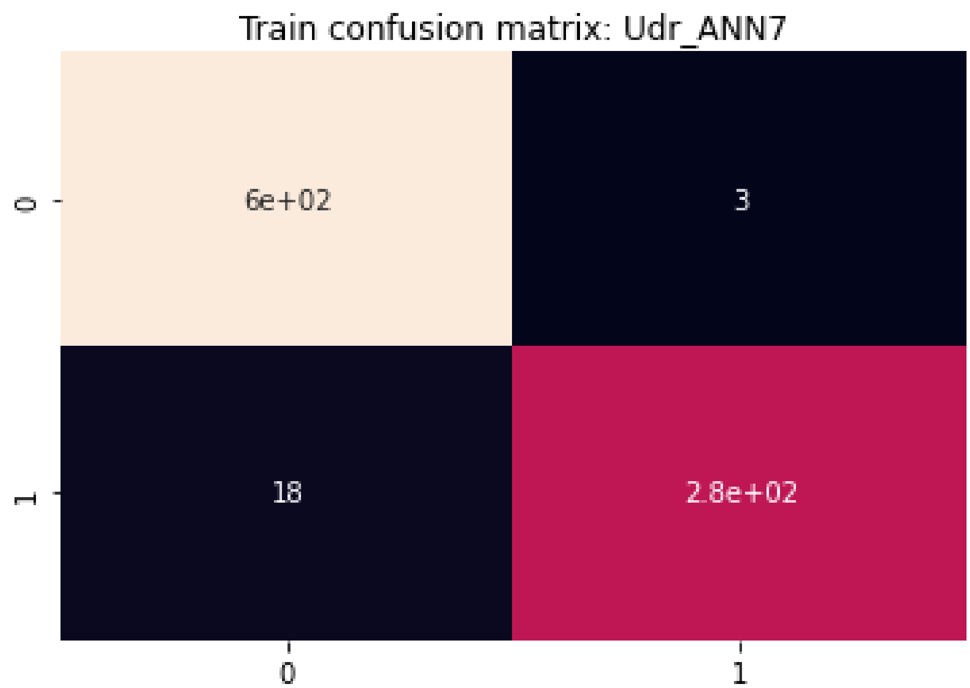
```
Test accuracy score 0.9871142164952074

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.11      0.88      0.19        98

    accuracy                           0.99     56962
   macro avg       0.55      0.93      0.59     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Udr_ANN6
```

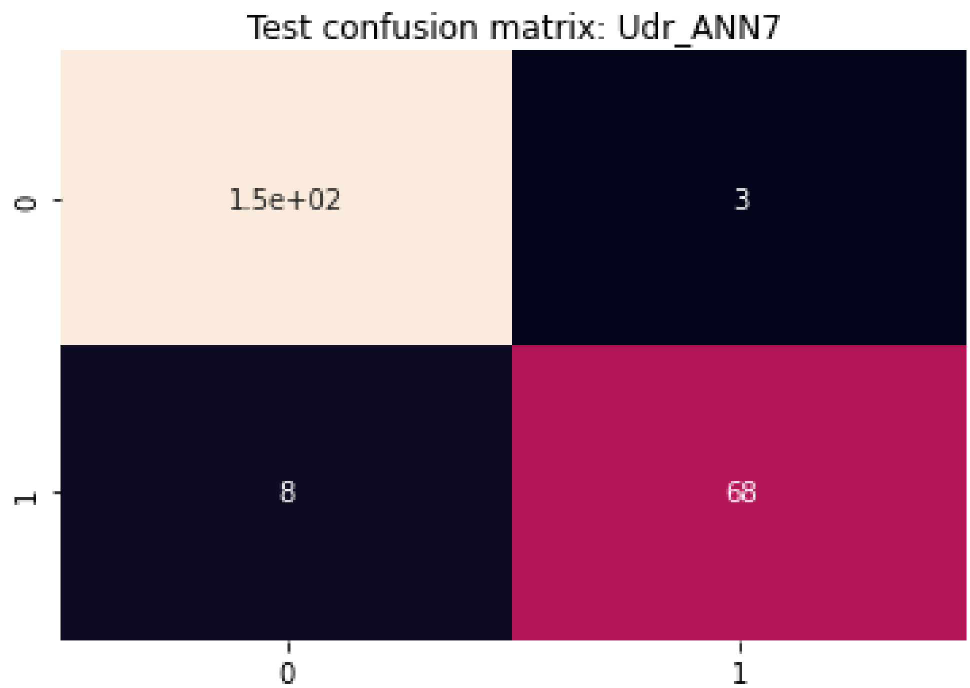
```
buildANN(4, 128, 'relu', 'he_normal', 'l2', 'adam', 30, 10,
'Udr_ANN7')
```

```
Model: "model_39"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_47 (InputLayer)       [(None, 30)]              0

 dense_215 (Dense)           (None, 128)               3968

 dense_216 (Dense)           (None, 64)                8256

 dense_217 (Dense)           (None, 32)                2080

 dense_218 (Dense)           (None, 16)                528

 dense_219 (Dense)           (None, 10)                170

 dense_220 (Dense)           (None, 2)                 22

=================================================================
Total params: 15,024
Trainable params: 15,024
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
31/31 [==============================] - 2s 14ms/step - loss: 5.1768 -
f1_score: 0.8608 - val_loss: 4.7930 - val_f1_score: 0.9341
Epoch 2/10
31/31 [==============================] - 0s 4ms/step - loss: 4.5212 -
f1_score: 0.9450 - val_loss: 4.3060 - val_f1_score: 0.9390
Epoch 3/10
```

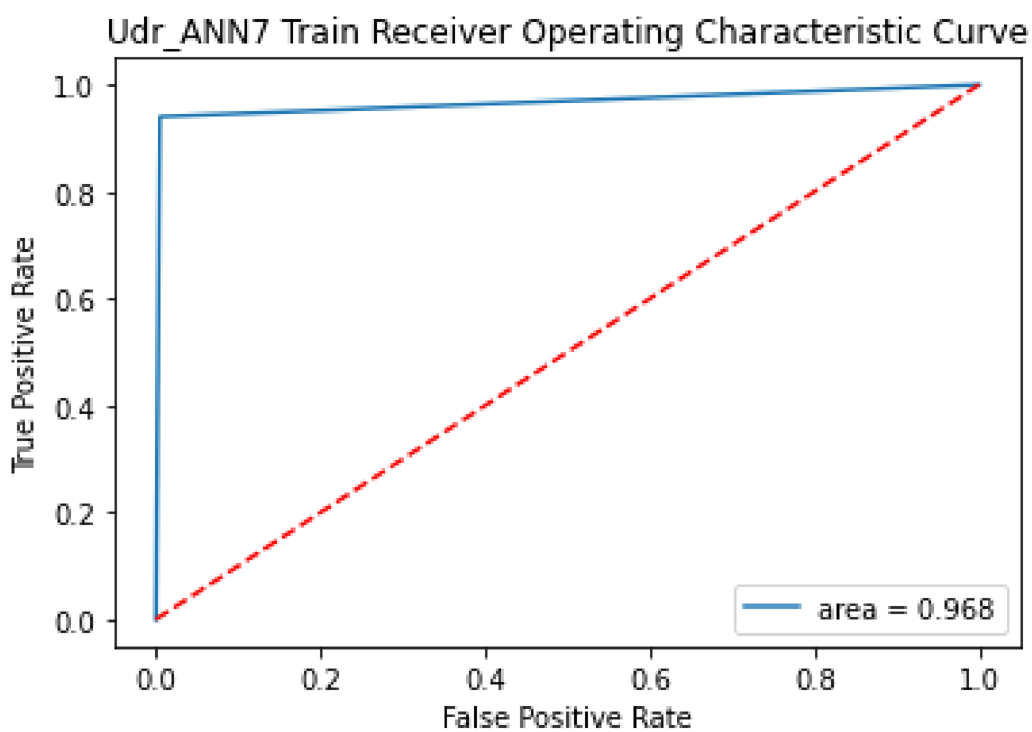
```
31/31 [==============================] - 0s 4ms/step - loss: 4.0416 -
f1_score: 0.9541 - val_loss: 3.8510 - val_f1_score: 0.9390
Epoch 4/10
31/31 [==============================] - 0s 4ms/step - loss: 3.6087 -
f1_score: 0.9606 - val_loss: 3.4518 - val_f1_score: 0.9390
Epoch 5/10
31/31 [==============================] - 0s 4ms/step - loss: 3.2220 -
f1_score: 0.9632 - val_loss: 3.1023 - val_f1_score: 0.9390
Epoch 6/10
31/31 [==============================] - 0s 4ms/step - loss: 2.8798 -
f1_score: 0.9632 - val_loss: 2.7689 - val_f1_score: 0.9341
Epoch 7/10
31/31 [==============================] - 0s 4ms/step - loss: 2.5693 -
f1_score: 0.9671 - val_loss: 2.4943 - val_f1_score: 0.9390
Epoch 8/10
31/31 [==============================] - 0s 4ms/step - loss: 2.2997 -
f1_score: 0.9608 - val_loss: 2.2250 - val_f1_score: 0.9341
Epoch 9/10
31/31 [==============================] - 0s 4ms/step - loss: 2.0626 -
f1_score: 0.9684 - val_loss: 2.0094 - val_f1_score: 0.9390
Epoch 10/10
31/31 [==============================] - 0s 4ms/step - loss: 1.8514 -
f1_score: 0.9722 - val_loss: 1.8076 - val_f1_score: 0.9447
29/29 [==============================] - 0s 2ms/step
8/8 [==============================] - 0s 3ms/step

Model performance Udr_ANN7

accuracy score train 0.9767699115044248
accuracy score test 0.9515418502202643

Train classification report: Udr_ANN7

              precision    recall  f1-score   support

           0       0.97      1.00      0.98       603
           1       0.99      0.94      0.96       301

    accuracy                           0.98       904
   macro avg       0.98      0.97      0.97       904
weighted avg       0.98      0.98      0.98       904


Test classification report: Udr_ANN7

              precision    recall  f1-score   support

           0       0.95      0.98      0.96       151
           1       0.96      0.89      0.93        76
```

accuracy			0.95	227
macro avg	0.95	0.94	0.94	227
weighted avg	0.95	0.95	0.95	227

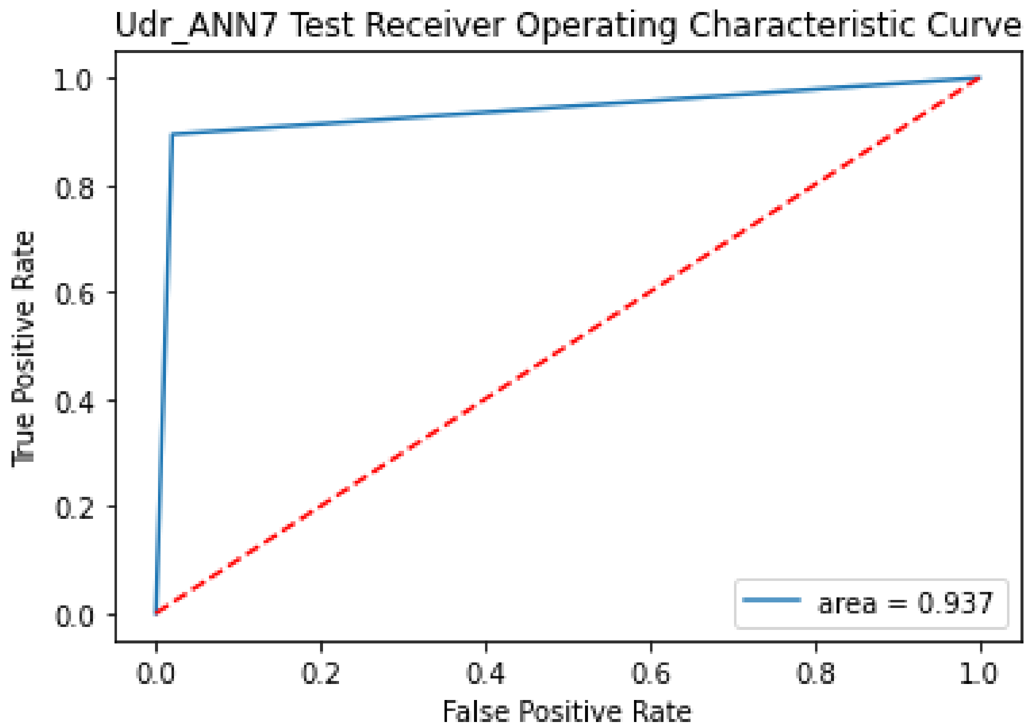




roc auc score train 0.9676121055850317



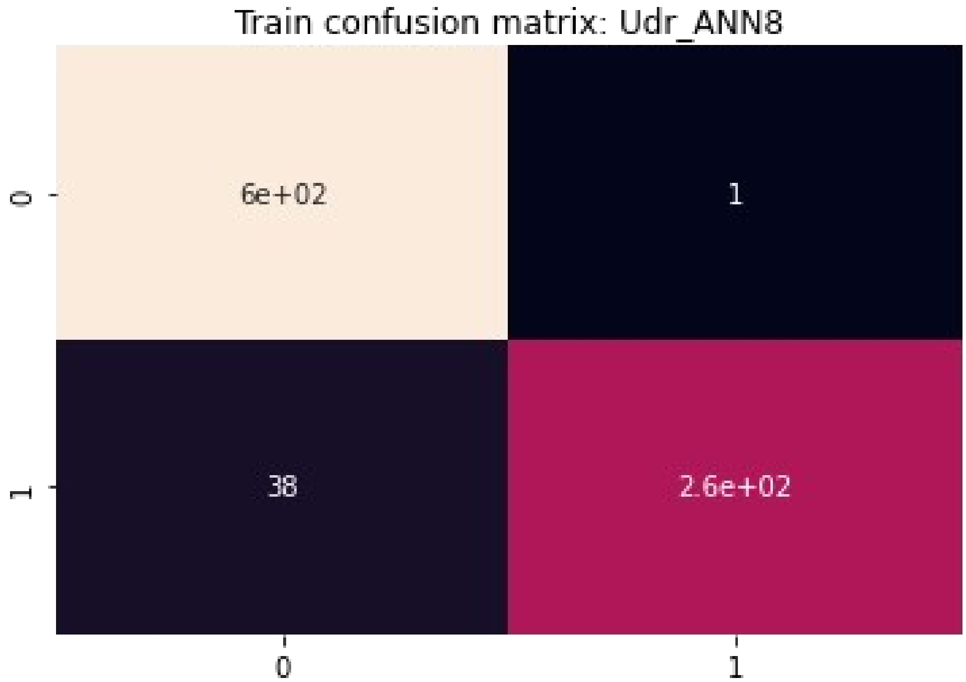
roc auc score test 0.9374346462181945

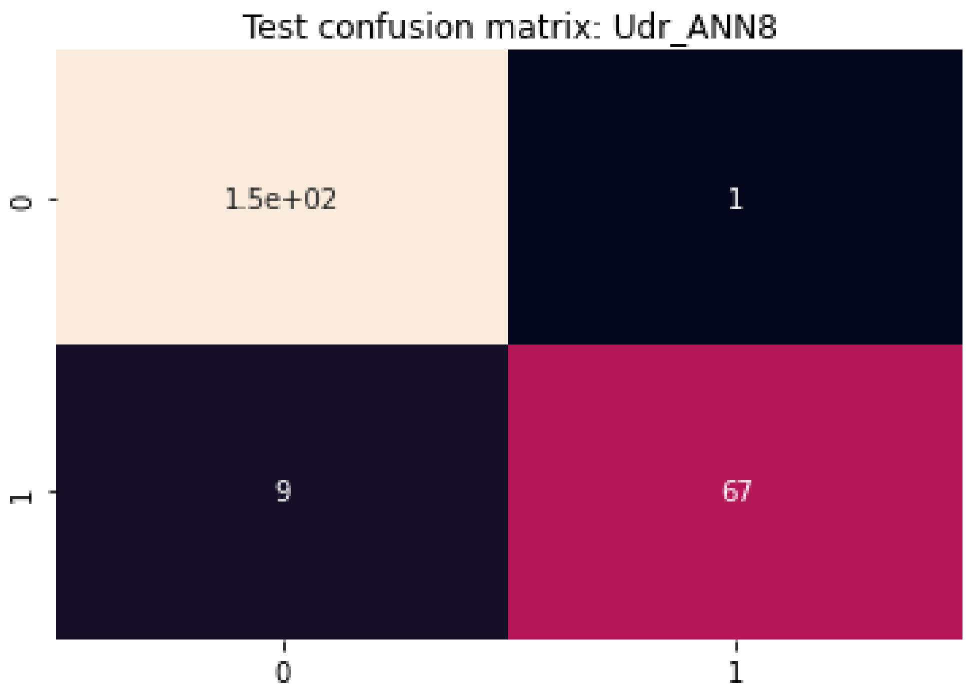



```
1781/1781 [==============================] - 3s 2ms/step

Test accuracy score 0.9850777711456761

Classification report

              precision    recall  f1-score   support

           0       1.00      0.99      0.99     56864
           1       0.09      0.87      0.17        98

    accuracy                           0.99     56962
   macro avg       0.55      0.93      0.58     56962
weighted avg       1.00      0.99      0.99     56962


Completed and saved for model Udr_ANN7

buildANN(4, 256, 'relu', 'he_normal', 'l2', 'adam', 30, 10,
'Udr_ANN8', 0.2)

Model: "model_40"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_48 (InputLayer)       [(None, 30)]              0
```

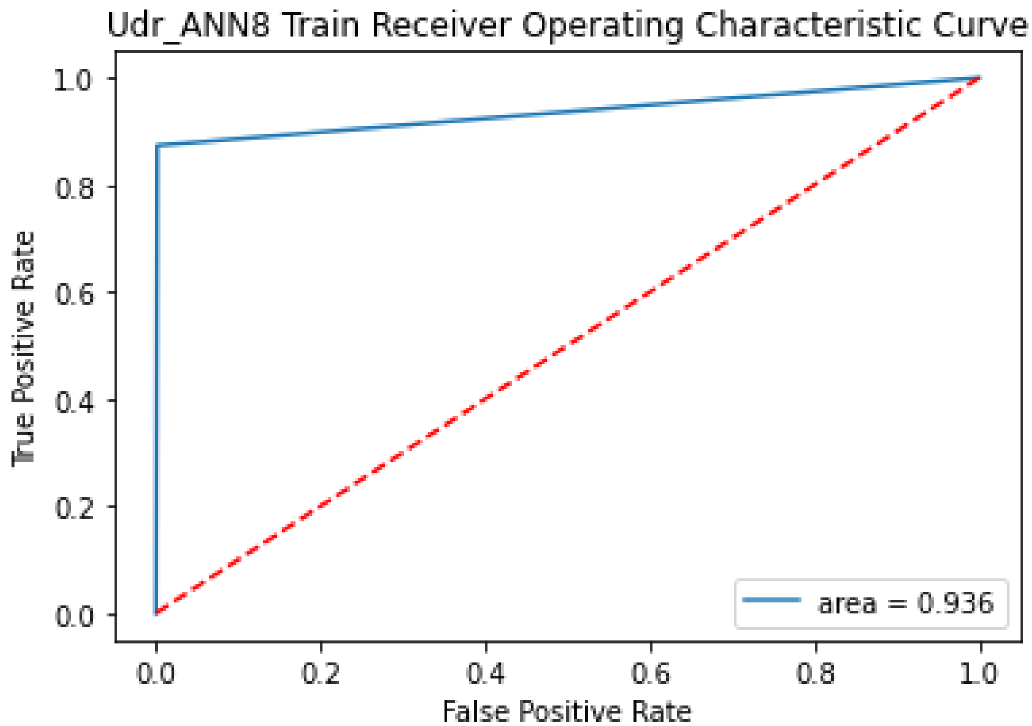
```
 dense_221 (Dense)           (None, 256)               7936

 dense_222 (Dense)           (None, 128)               32896

 dense_223 (Dense)           (None, 64)                8256

 dense_224 (Dense)           (None, 32)                2080

 dropout_14 (Dropout)        (None, 32)                0

 batch_normalization_14 (Bat  (None, 32)               128
 chNormalization)

 dense_225 (Dense)           (None, 10)                330

 dense_226 (Dense)           (None, 2)                 22

=================================================================
Total params: 51,648
Trainable params: 51,584
Non-trainable params: 64
_________________________________________________________________
None
Epoch 1/10
31/31 [==============================] - 2s 15ms/step - loss: 9.7260 - f1_score: 0.8183 - val_loss: 8.7859 - val_f1_score: 0.9126
Epoch 2/10
31/31 [==============================] - 0s 5ms/step - loss: 8.1771 - f1_score: 0.9132 - val_loss: 7.3770 - val_f1_score: 0.9390
Epoch 3/10
31/31 [==============================] - 0s 7ms/step - loss: 6.8184 - f1_score: 0.9398 - val_loss: 6.1774 - val_f1_score: 0.9390
Epoch 4/10
31/31 [==============================] - 0s 5ms/step - loss: 5.7595 - f1_score: 0.9427 - val_loss: 5.3181 - val_f1_score: 0.9488
Epoch 5/10
31/31 [==============================] - 0s 5ms/step - loss: 4.9396 - f1_score: 0.9380 - val_loss: 4.5652 - val_f1_score: 0.9488
Epoch 6/10
31/31 [==============================] - 0s 5ms/step - loss: 4.2270 - f1_score: 0.9467 - val_loss: 3.9231 - val_f1_score: 0.9439
Epoch 7/10
31/31 [==============================] - 0s 5ms/step - loss: 3.6413 - f1_score: 0.9483 - val_loss: 3.4173 - val_f1_score: 0.9380
Epoch 8/10
31/31 [==============================] - 0s 5ms/step - loss: 3.1325 - f1_score: 0.9453 - val_loss: 2.9751 - val_f1_score: 0.9434
Epoch 9/10
31/31 [==============================] - 0s 5ms/step - loss: 2.7314 - f1_score: 0.9342 - val_loss: 2.6309 - val_f1_score: 0.9160
```

```
Epoch 10/10
31/31 [==============================] - 0s 5ms/step - loss: 2.3701 -
f1_score: 0.9532 - val_loss: 2.2774 - val_f1_score: 0.9491
29/29 [==============================] - 0s 2ms/step
8/8 [==============================] - 0s 3ms/step

Model performance Udr_ANN8

accuracy score train 0.956858407079646
accuracy score test 0.9559471365638766

Train classification report: Udr_ANN8

              precision    recall  f1-score   support

           0       0.94      1.00      0.97       603
           1       1.00      0.87      0.93       301

    accuracy                           0.96       904
   macro avg       0.97      0.94      0.95       904
weighted avg       0.96      0.96      0.96       904


Test classification report: Udr_ANN8

              precision    recall  f1-score   support

           0       0.94      0.99      0.97       151
           1       0.99      0.88      0.93        76

    accuracy                           0.96       227
   macro avg       0.96      0.94      0.95       227
weighted avg       0.96      0.96      0.96       227
```

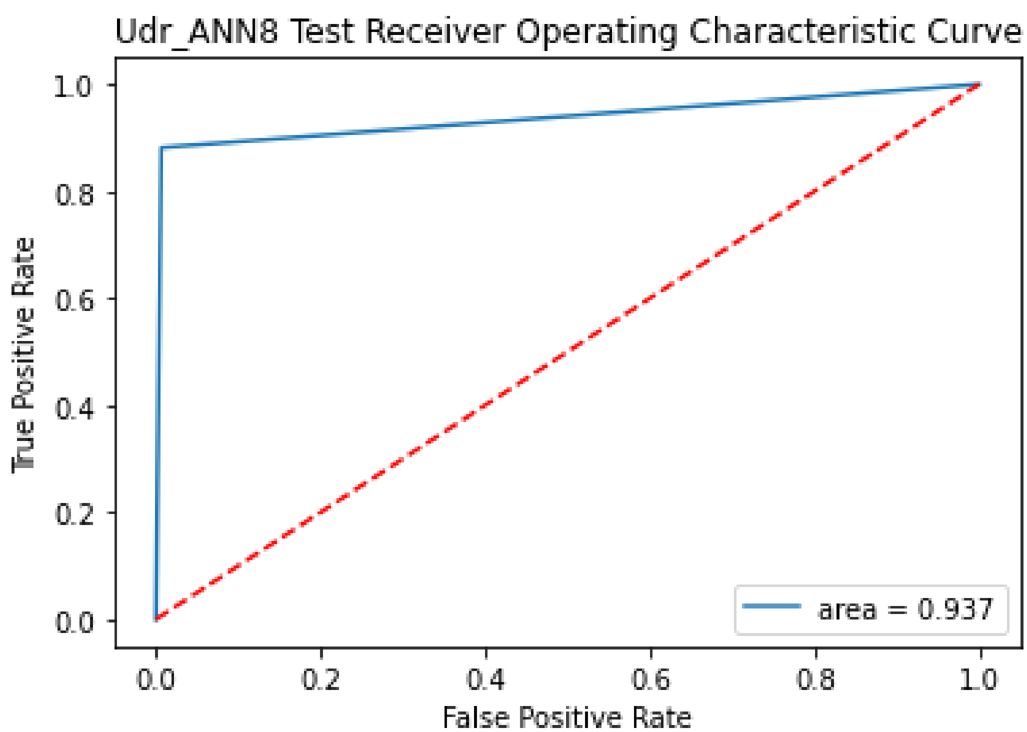





```
roc auc score train 0.9360478890156085
```



roc auc score test 0.9374782154060647



1781/1781 [==============================] - 3s 2ms/step

```
Test accuracy score 0.996892665285629

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.34      0.83      0.48        98

    accuracy                           1.00     56962
   macro avg       0.67      0.91      0.74     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model Udr_ANN8
```

With undersampled data, Udr_ANN1 gave better result than the other undersampled models (f1-score macro= 0.77).

Also by comparing the performance with the oversampled models, undersampled ANN8 model gave the best performance.

So till now get the best result with 3 layers, (128, 64, 32) neurons respectively, relu acrivation, he_normal kernel initializer, l2 regularizer, sgd optimizer, 30 batch size, 10 eochs.

Further we can try with original data.

Original data

```
finance_train = pd.read_pickle('finance_train.pkl')
finance_test = pd.read_pickle('finance_test.pkl')

train_X = finance_train.drop(['Class'], axis=1)
train_y = finance_train[['Class']]

test_X = finance_test.drop(['Class'], axis=1)
test_y = finance_test[['Class']]

x_train, x_test, y_train, y_test = train_test_split(train_X, train_y,

stratify= train_y,

test_size= 0.2, random_state= 0)

y_train = to_categorical(y_train)
y_test = to_categorical(y_test)
test_y = to_categorical(test_y)

print(x_train.shape)
print(y_train.shape)
print(x_test.shape)
```

```
print(y_test.shape)
print(test_X.shape)
print(test_y.shape)
```

```
(181102, 30)
(181102, 2)
(45276, 30)
(45276, 2)
(56962, 30)
(56962, 2)
```

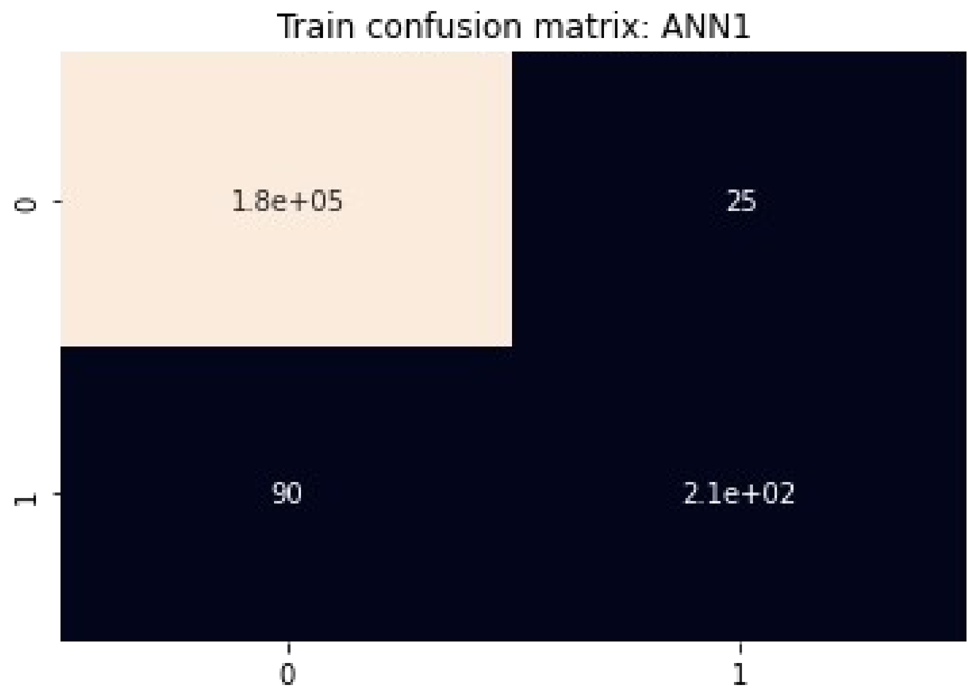
ANN with original data

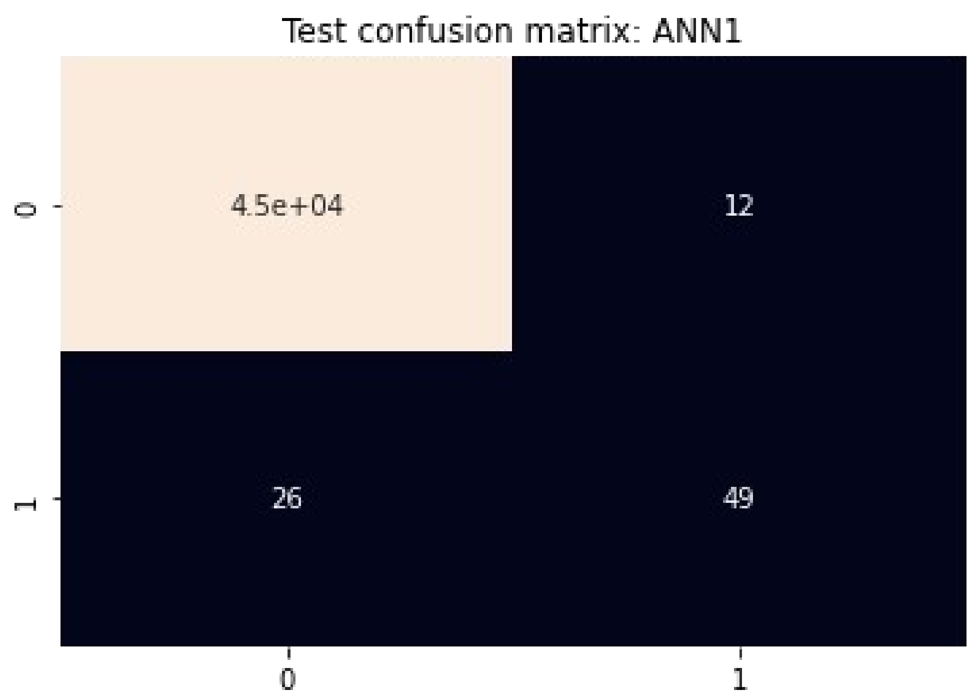
```
buildANN(3, 128, 'relu', 'he_normal', 'l2', 'sgd', 30, 10, 'ANN1',
0.2)
```

```
Model: "model_41"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 input_49 (InputLayer)       [(None, 30)]              0         
                                                                 
 dense_227 (Dense)           (None, 128)               3968      
                                                                 
 dense_228 (Dense)           (None, 64)                8256      
                                                                 
 dense_229 (Dense)           (None, 32)                2080      
                                                                 
 dropout_15 (Dropout)        (None, 32)                0         
                                                                 
 batch_normalization_15 (Bat  (None, 32)               128       
 chNormalization)                                                
                                                                 
 dense_230 (Dense)           (None, 10)                330       
                                                                 
 dense_231 (Dense)           (None, 2)                 22        
                                                                 
=================================================================
Total params: 14,784
Trainable params: 14,720
Non-trainable params: 64
_________________________________________________________________
None
Epoch 1/10
6037/6037 [==============================] - 18s 3ms/step - loss:
1.8209 - f1_score: 0.5611 - val_loss: 0.4391 - val_f1_score: 0.7854
Epoch 2/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.1710 - f1_score: 0.6288 - val_loss: 0.0473 - val_f1_score: 0.6731
Epoch 3/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0224 - f1_score: 0.6568 - val_loss: 0.0119 - val_f1_score: 0.7146
```

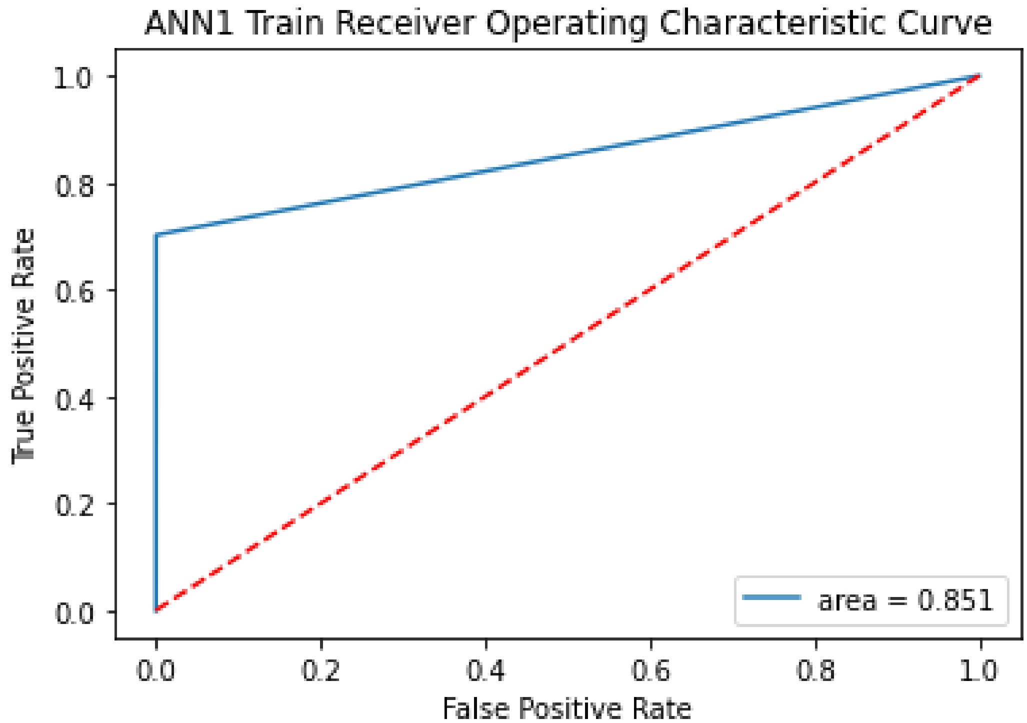
```
Epoch 4/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0088 - f1_score: 0.7596 - val_loss: 0.0084 - val_f1_score: 0.7756
Epoch 5/10
6037/6037 [==============================] - 15s 3ms/step - loss:
0.0073 - f1_score: 0.8247 - val_loss: 0.0081 - val_f1_score: 0.8143
Epoch 6/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0070 - f1_score: 0.8399 - val_loss: 0.0080 - val_f1_score: 0.8648
Epoch 7/10
6037/6037 [==============================] - 15s 3ms/step - loss:
0.0069 - f1_score: 0.8645 - val_loss: 0.0078 - val_f1_score: 0.8456
Epoch 8/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0067 - f1_score: 0.8715 - val_loss: 0.0078 - val_f1_score: 0.8739
Epoch 9/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0067 - f1_score: 0.8762 - val_loss: 0.0077 - val_f1_score: 0.8739
Epoch 10/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0065 - f1_score: 0.8801 - val_loss: 0.0076 - val_f1_score: 0.8601
5660/5660 [==============================] - 9s 2ms/step
1415/1415 [==============================] - 2s 2ms/step

Model performance ANN1

accuracy score train 0.9993649987299975
accuracy score test 0.9991607032423359

Train classification report: ANN1

              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       0.89      0.70      0.79       302

    accuracy                           1.00    181102
   macro avg       0.95      0.85      0.89    181102
weighted avg       1.00      1.00      1.00    181102


Test classification report: ANN1

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       0.80      0.65      0.72        75

    accuracy                           1.00     45276
```

macro avg	0.90	0.83	0.86	45276
weighted avg	1.00	1.00	1.00	45276

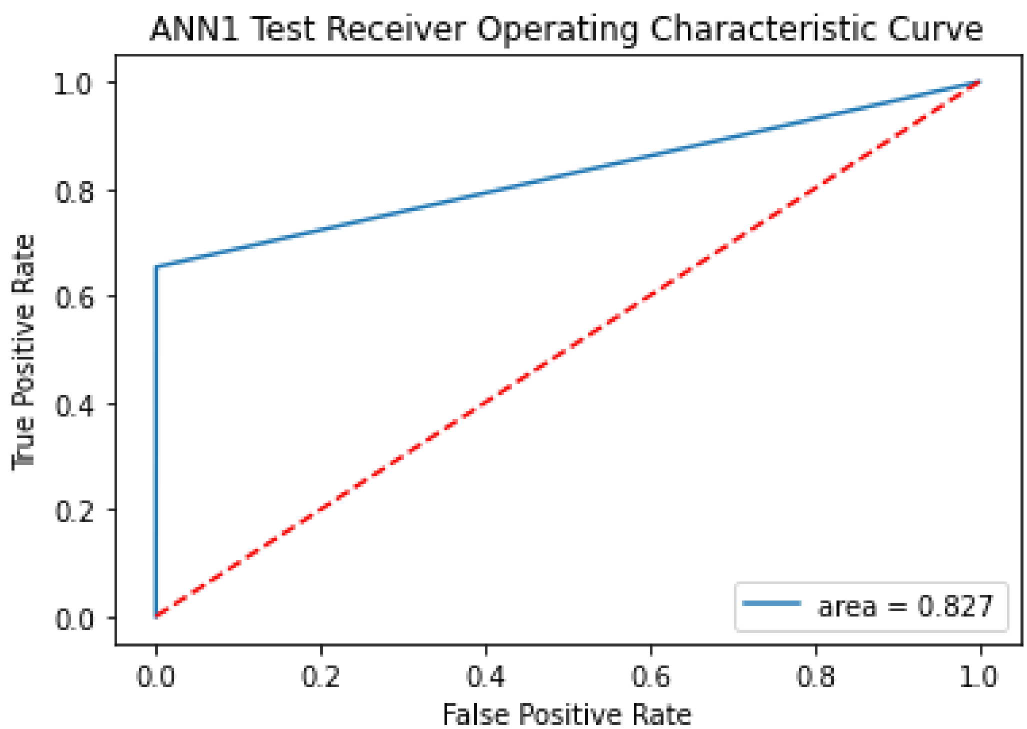




```
roc auc score train 0.8509242403153021
```




```
roc auc score test 0.8265339262405699
```



```
1781/1781 [==============================] - 3s 2ms/step

Test accuracy score 0.9991924440855307

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.85      0.64      0.73        98

    accuracy                           1.00     56962
   macro avg       0.93      0.82      0.87     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model ANN1
```

```
buildANN(3, 128, 'relu', 'he_uniform', 'l2', 'adadelta', 30, 10,
'ANN2')
```

```
Model: "model_42"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_50 (InputLayer)       [(None, 30)]              0

 dense_232 (Dense)           (None, 128)               3968

 dense_233 (Dense)           (None, 64)                8256

 dense_234 (Dense)           (None, 32)                2080

 dense_235 (Dense)           (None, 10)                330

 dense_236 (Dense)           (None, 2)                 22

=================================================================
Total params: 14,656
Trainable params: 14,656
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
6037/6037 [==============================] - 17s 3ms/step - loss:
5.3073 - f1_score: 0.4093 - val_loss: 5.0166 - val_f1_score: 0.4858
Epoch 2/10
6037/6037 [==============================] - 16s 3ms/step - loss:
4.7432 - f1_score: 0.4971 - val_loss: 4.4870 - val_f1_score: 0.4994
Epoch 3/10
```

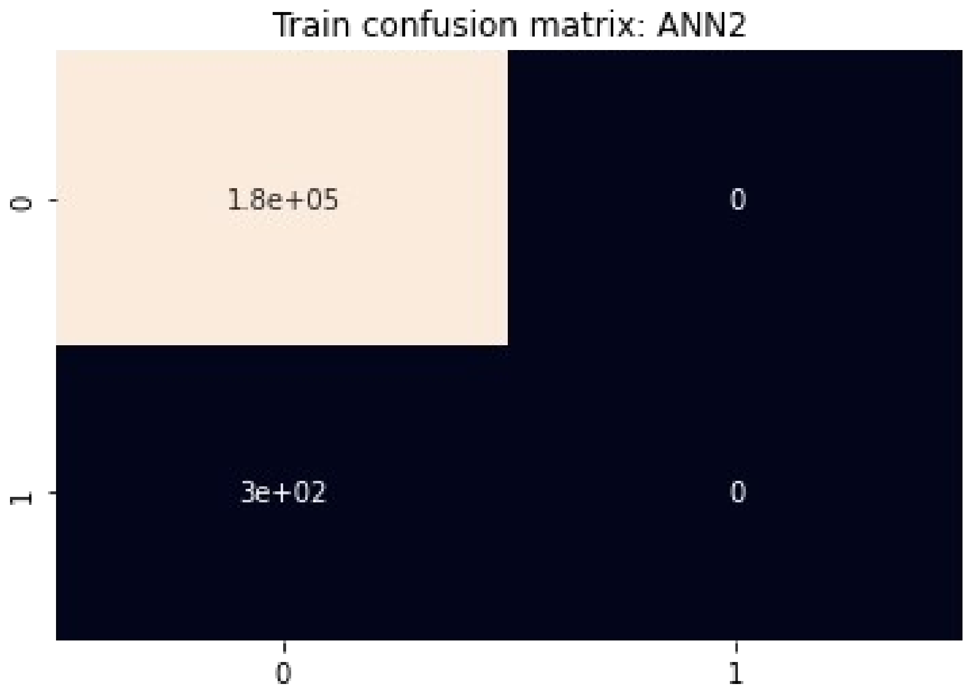
```
6037/6037 [==============================] - 16s 3ms/step - loss:
4.2634 - f1_score: 0.4995 - val_loss: 4.0395 - val_f1_score: 0.4996
Epoch 4/10
6037/6037 [==============================] - 16s 3ms/step - loss:
3.8236 - f1_score: 0.4996 - val_loss: 3.6098 - val_f1_score: 0.4996
Epoch 5/10
6037/6037 [==============================] - 15s 3ms/step - loss:
3.4094 - f1_score: 0.4996 - val_loss: 3.2148 - val_f1_score: 0.4996
Epoch 6/10
6037/6037 [==============================] - 16s 3ms/step - loss:
3.0436 - f1_score: 0.4996 - val_loss: 2.8752 - val_f1_score: 0.4996
Epoch 7/10
6037/6037 [==============================] - 18s 3ms/step - loss:
2.7290 - f1_score: 0.4996 - val_loss: 2.5823 - val_f1_score: 0.4996
Epoch 8/10
6037/6037 [==============================] - 16s 3ms/step - loss:
2.4535 - f1_score: 0.4996 - val_loss: 2.3272 - val_f1_score: 0.4996
Epoch 9/10
6037/6037 [==============================] - 15s 3ms/step - loss:
2.2171 - f1_score: 0.4996 - val_loss: 2.1089 - val_f1_score: 0.4996
Epoch 10/10
6037/6037 [==============================] - 15s 3ms/step - loss:
2.0155 - f1_score: 0.4996 - val_loss: 1.9215 - val_f1_score: 0.4996
5660/5660 [==============================] - 8s 1ms/step
1415/1415 [==============================] - 2s 2ms/step

Model performance ANN2

accuracy score train 0.9983324314474716
accuracy score test 0.9983434932414524

Train classification report: ANN2


/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
```

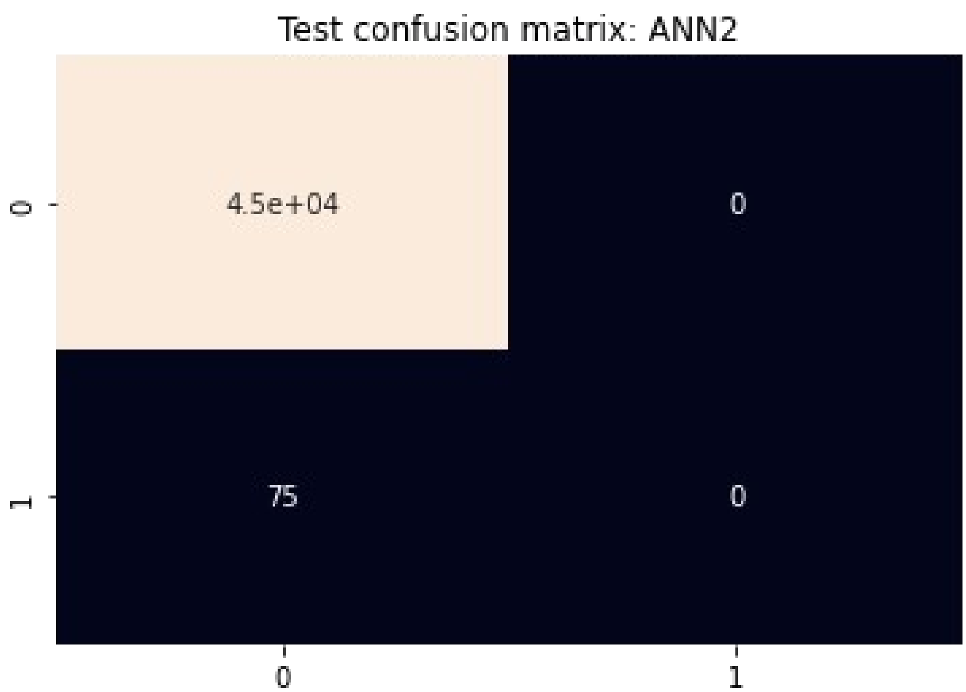
```
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

	precision	recall	f1-score	support
0	1.00	1.00	1.00	180800
1	0.00	0.00	0.00	302
accuracy			1.00	181102
macro avg	0.50	0.50	0.50	181102
weighted avg	1.00	1.00	1.00	181102

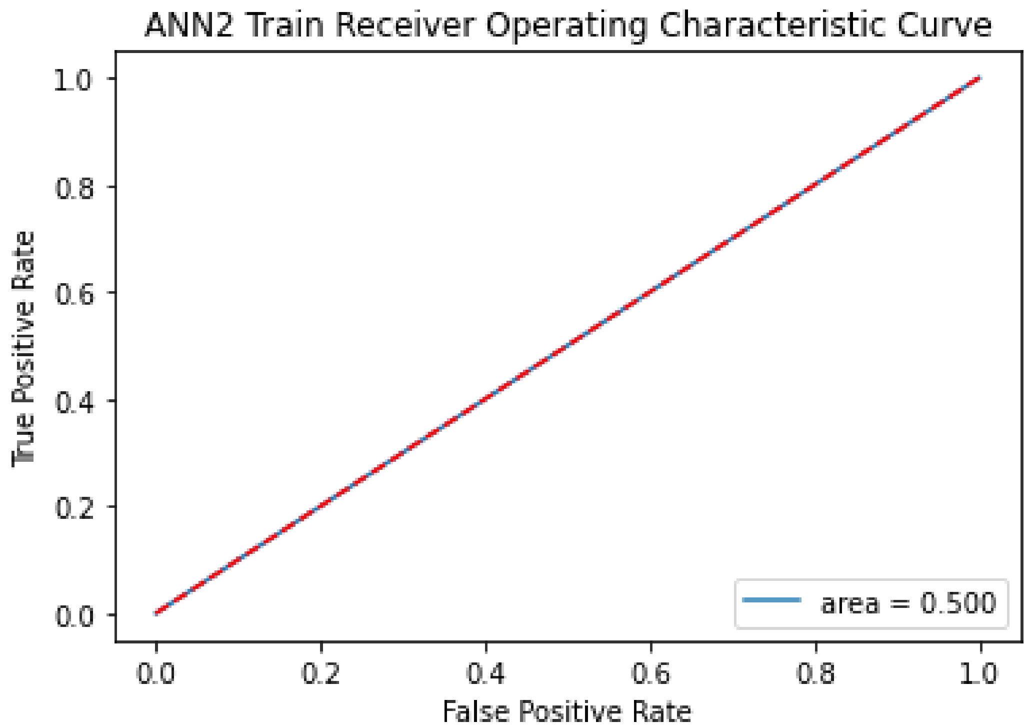
Test classification report: ANN2

	precision	recall	f1-score	support
0	1.00	1.00	1.00	45201
1	0.00	0.00	0.00	75
accuracy			1.00	45276
macro avg	0.50	0.50	0.50	45276
weighted avg	1.00	1.00	1.00	45276

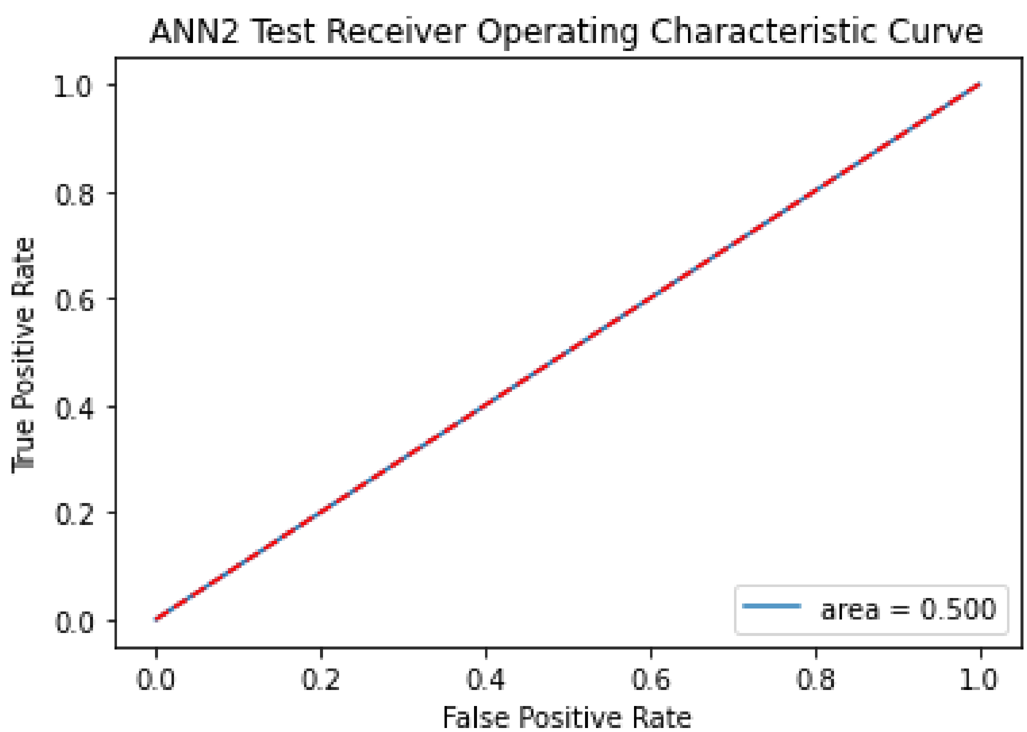





```
roc auc score train 0.5
```




```
roc auc score test 0.5
```




```
1781/1781 [==============================] - 3s 2ms/step
```

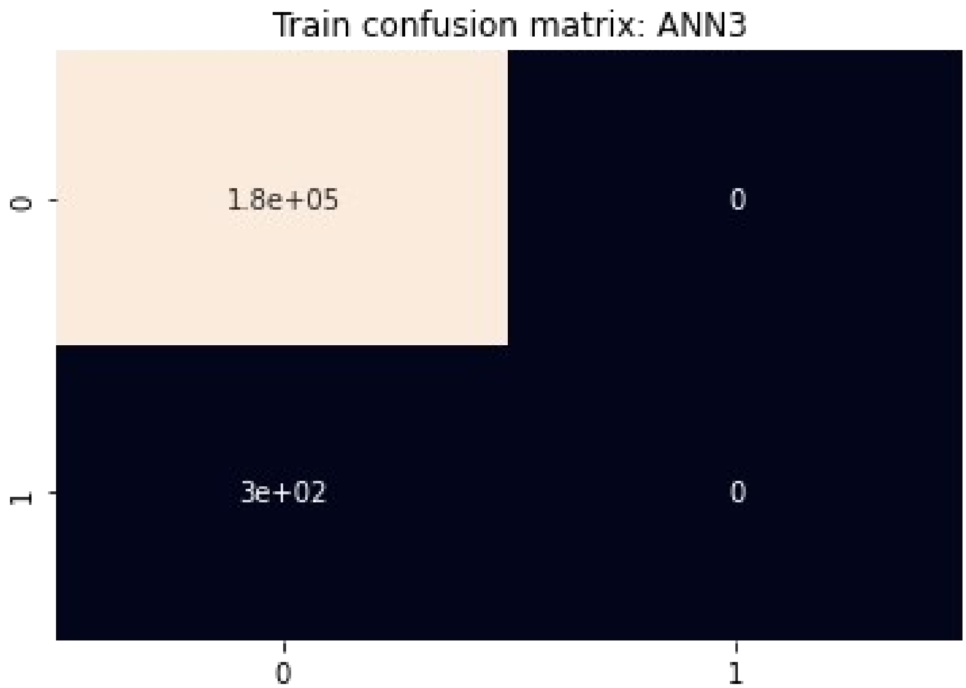
```
Test accuracy score 0.9982795547909132

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.00      0.00      0.00        98

    accuracy                           1.00     56962
   macro avg       0.50      0.50      0.50     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model ANN2

/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

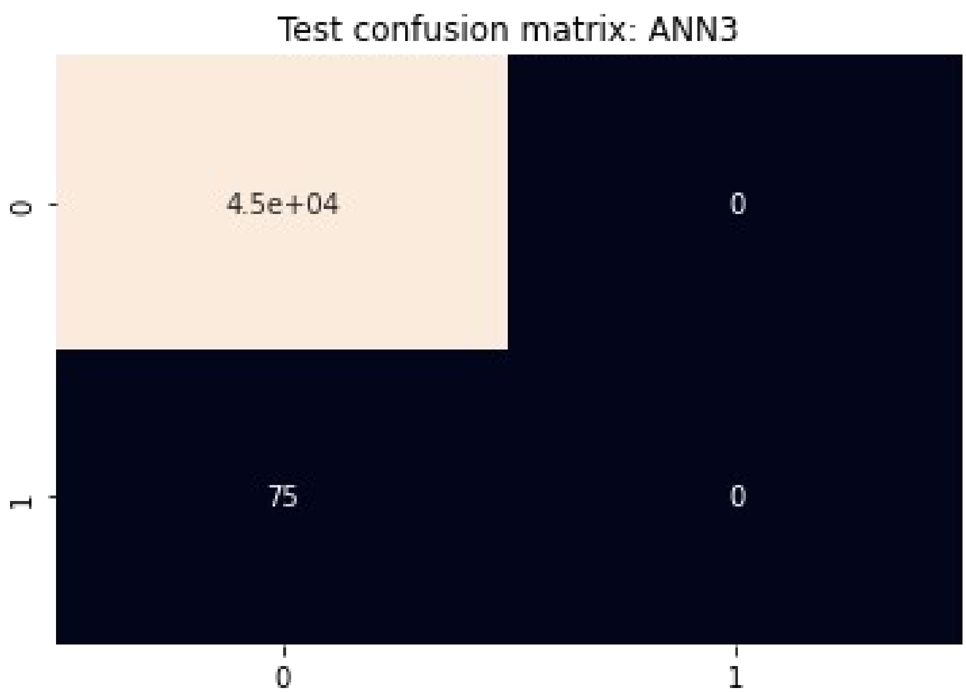
```
buildANN(3, 64, 'relu', 'he_normal', 'l1', 'rmsprop', 30, 10, 'ANN3')
```

```
Model: "model_43"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_51 (InputLayer)       [(None, 30)]              0

 dense_237 (Dense)           (None, 64)                1984

 dense_238 (Dense)           (None, 32)                2080

 dense_239 (Dense)           (None, 16)                528

 dense_240 (Dense)           (None, 10)                170

 dense_241 (Dense)           (None, 2)                 22
```

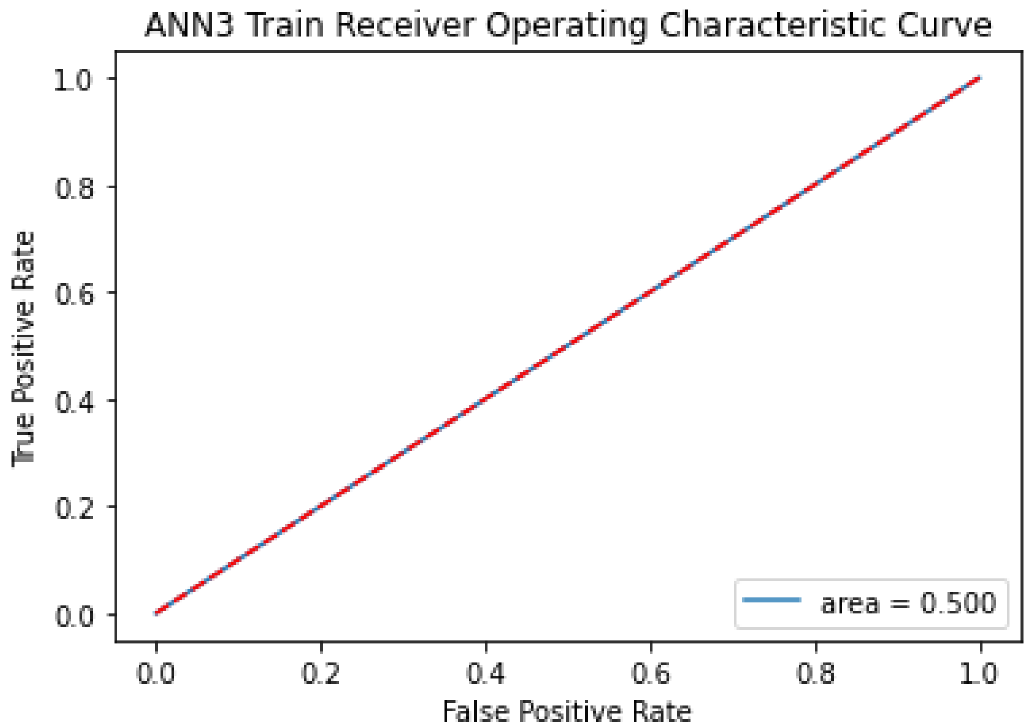
```
=================================================================
Total params: 4,784
Trainable params: 4,784
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
6037/6037 [==============================] - 16s 3ms/step - loss: 
0.2765 - f1_score: 0.5012 - val_loss: 0.0367 - val_f1_score: 0.4996
Epoch 2/10
6037/6037 [==============================] - 15s 3ms/step - loss: 
0.0369 - f1_score: 0.4996 - val_loss: 0.0360 - val_f1_score: 0.4996
Epoch 3/10
6037/6037 [==============================] - 16s 3ms/step - loss: 
0.0367 - f1_score: 0.4996 - val_loss: 0.0372 - val_f1_score: 0.4996
Epoch 4/10
6037/6037 [==============================] - 15s 2ms/step - loss: 
0.0366 - f1_score: 0.4996 - val_loss: 0.0362 - val_f1_score: 0.4996
Epoch 5/10
6037/6037 [==============================] - 15s 3ms/step - loss: 
0.0366 - f1_score: 0.4996 - val_loss: 0.0364 - val_f1_score: 0.4996
5660/5660 [==============================] - 8s 1ms/step
1415/1415 [==============================] - 2s 1ms/step

Model performance ANN3

accuracy score train 0.9983324314474716
accuracy score test 0.9983434932414524

Train classification report: ANN3


/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))

              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       0.00      0.00      0.00       302

    accuracy                           1.00    181102
   macro avg       0.50      0.50      0.50    181102
```

```
weighted avg       1.00      1.00      1.00    181102


Test classification report: ANN3

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       0.00      0.00      0.00        75

    accuracy                           1.00     45276
   macro avg       0.50      0.50      0.50     45276
weighted avg       1.00      1.00      1.00     45276




/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

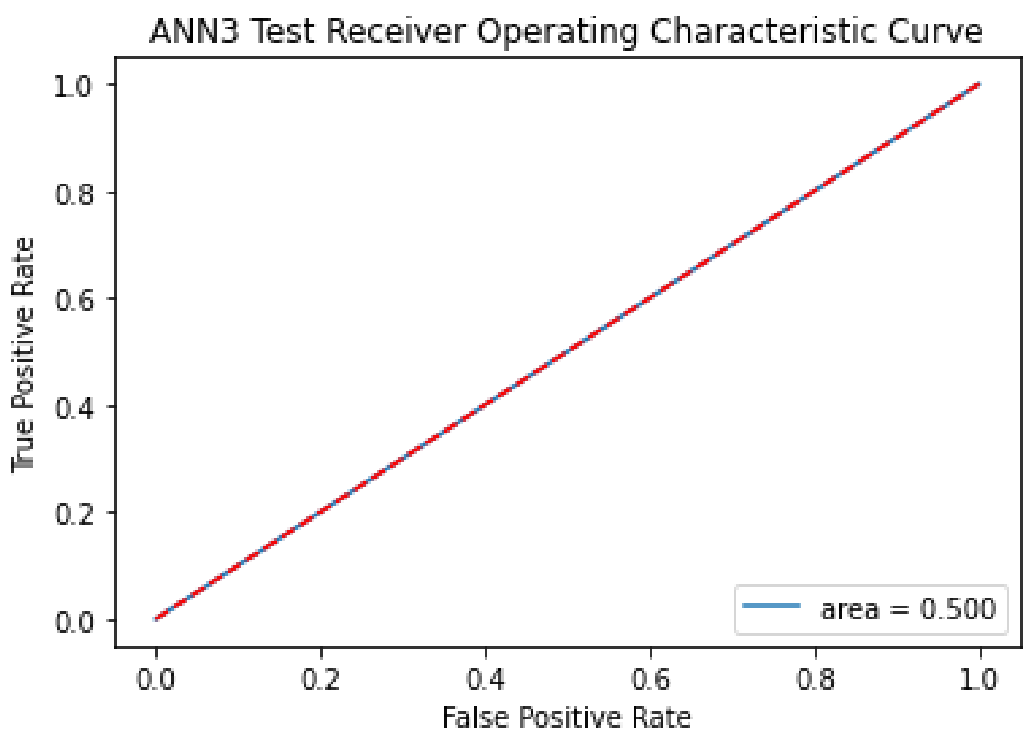





```
roc auc score train 0.5
```



roc auc score test 0.5



1781/1781 [==============================] - 3s 1ms/step

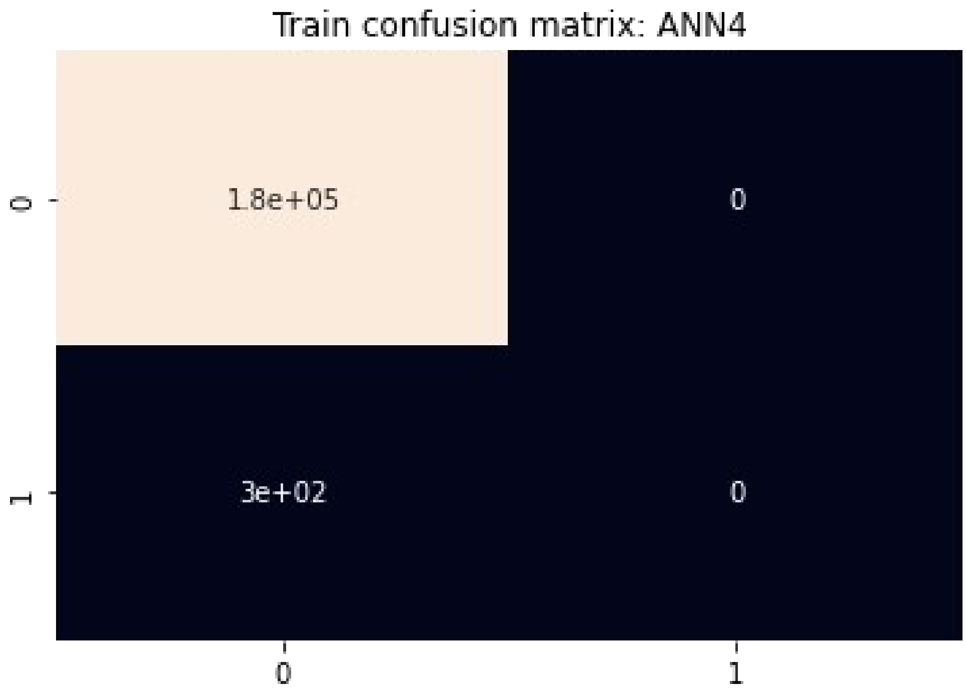
```
Test accuracy score 0.9982795547909132

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.00      0.00      0.00        98

    accuracy                           1.00     56962
   macro avg       0.50      0.50      0.50     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model ANN3

/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

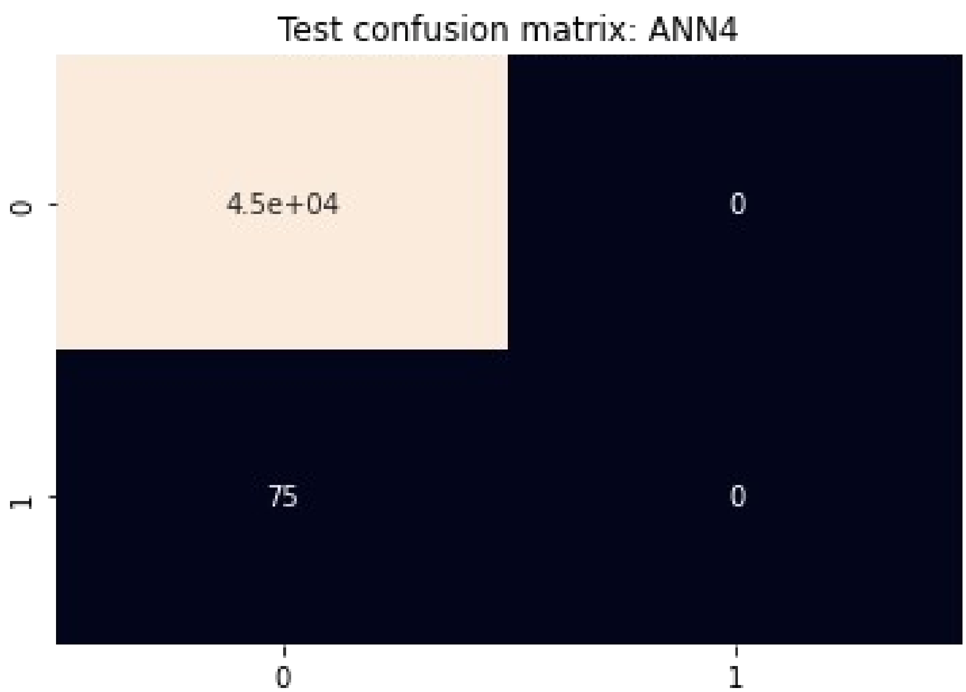
```
buildANN(3, 128, 'relu', 'he_normal', 'l2', 'rmsprop', 30, 10, 'ANN4')
```

```
Model: "model_44"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_52 (InputLayer)       [(None, 30)]              0

 dense_242 (Dense)           (None, 128)               3968

 dense_243 (Dense)           (None, 64)                8256

 dense_244 (Dense)           (None, 32)                2080

 dense_245 (Dense)           (None, 10)                330

 dense_246 (Dense)           (None, 2)                 22
```

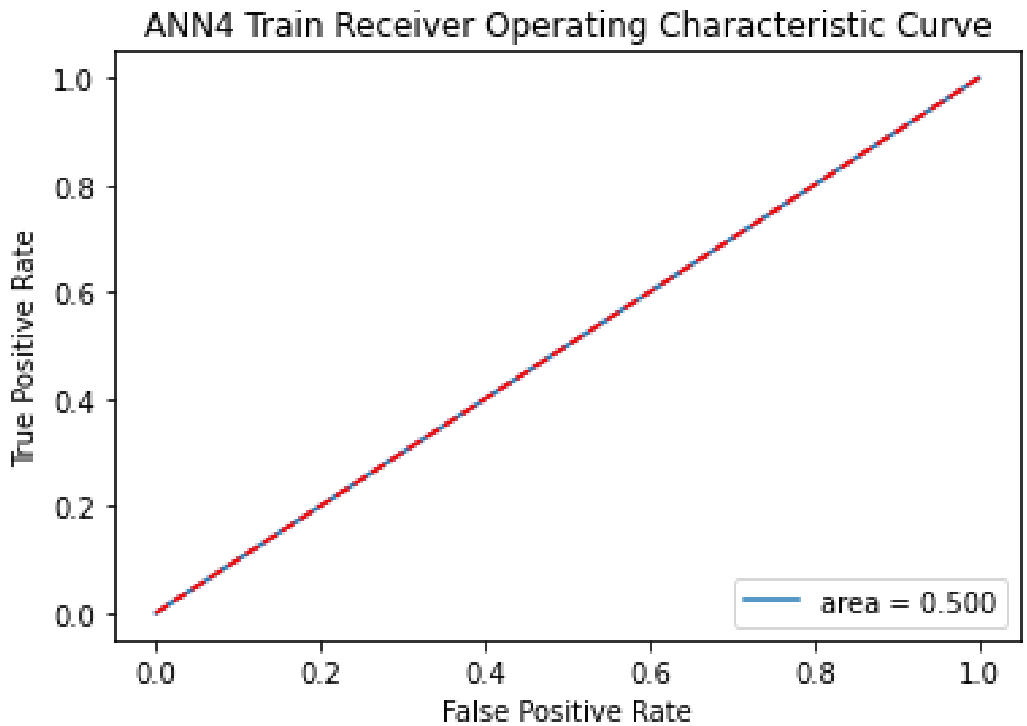
```
=================================================================
Total params: 14,656
Trainable params: 14,656
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
6037/6037 [==============================] - 17s 3ms/step - loss:
0.1142 - f1_score: 0.5013 - val_loss: 0.0133 - val_f1_score: 0.4996
Epoch 2/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0136 - f1_score: 0.4996 - val_loss: 0.0137 - val_f1_score: 0.4996
Epoch 3/10
6037/6037 [==============================] - 15s 3ms/step - loss:
0.0135 - f1_score: 0.4996 - val_loss: 0.0138 - val_f1_score: 0.4996
Epoch 4/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0134 - f1_score: 0.4996 - val_loss: 0.0128 - val_f1_score: 0.4996
Epoch 5/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0134 - f1_score: 0.4996 - val_loss: 0.0125 - val_f1_score: 0.4996
Epoch 6/10
6037/6037 [==============================] - 15s 3ms/step - loss:
0.0134 - f1_score: 0.4996 - val_loss: 0.0126 - val_f1_score: 0.4996
Epoch 7/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0135 - f1_score: 0.4996 - val_loss: 0.0132 - val_f1_score: 0.4996
Epoch 8/10
6037/6037 [==============================] - 16s 3ms/step - loss:
0.0137 - f1_score: 0.4996 - val_loss: 0.0132 - val_f1_score: 0.4996
5660/5660 [==============================] - 8s 1ms/step
1415/1415 [==============================] - 2s 1ms/step

Model performance ANN4

accuracy score train 0.9983324314474716
accuracy score test 0.9983434932414524

Train classification report: ANN4


/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
```

```
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       0.00      0.00      0.00       302

    accuracy                           1.00    181102
   macro avg       0.50      0.50      0.50    181102
weighted avg       1.00      1.00      1.00    181102


Test classification report: ANN4

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       0.00      0.00      0.00        75

    accuracy                           1.00     45276
   macro avg       0.50      0.50      0.50     45276
weighted avg       1.00      1.00      1.00     45276



/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

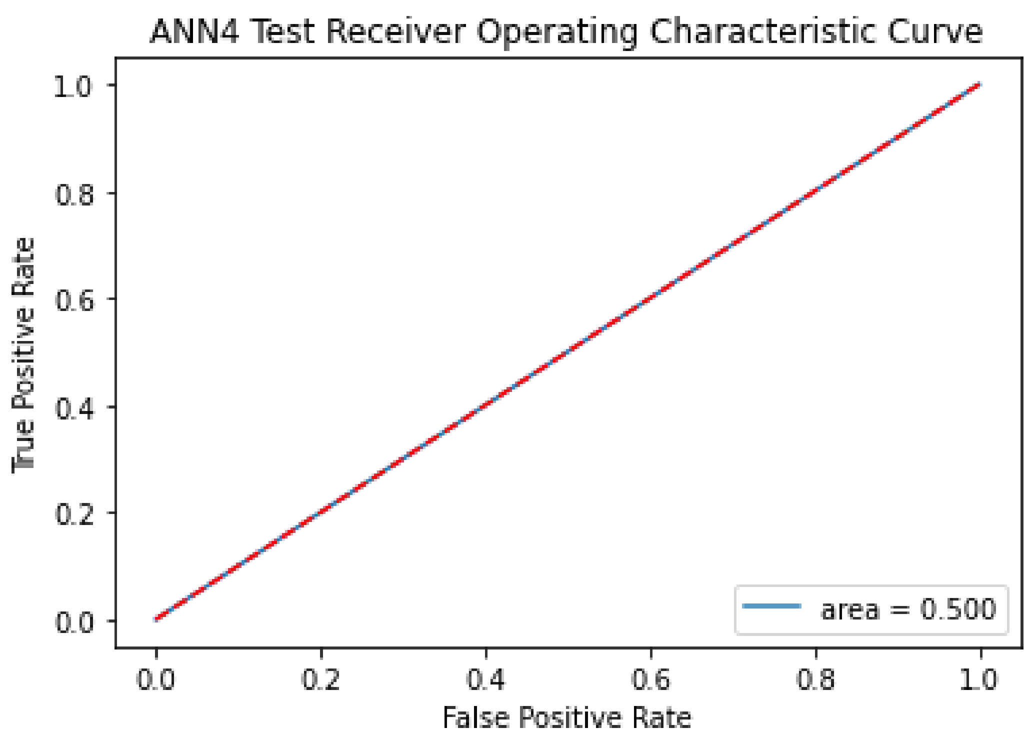





```
roc auc score train 0.5
```




```
roc auc score test 0.5
```




```
1781/1781 [==============================] - 3s 2ms/step
```

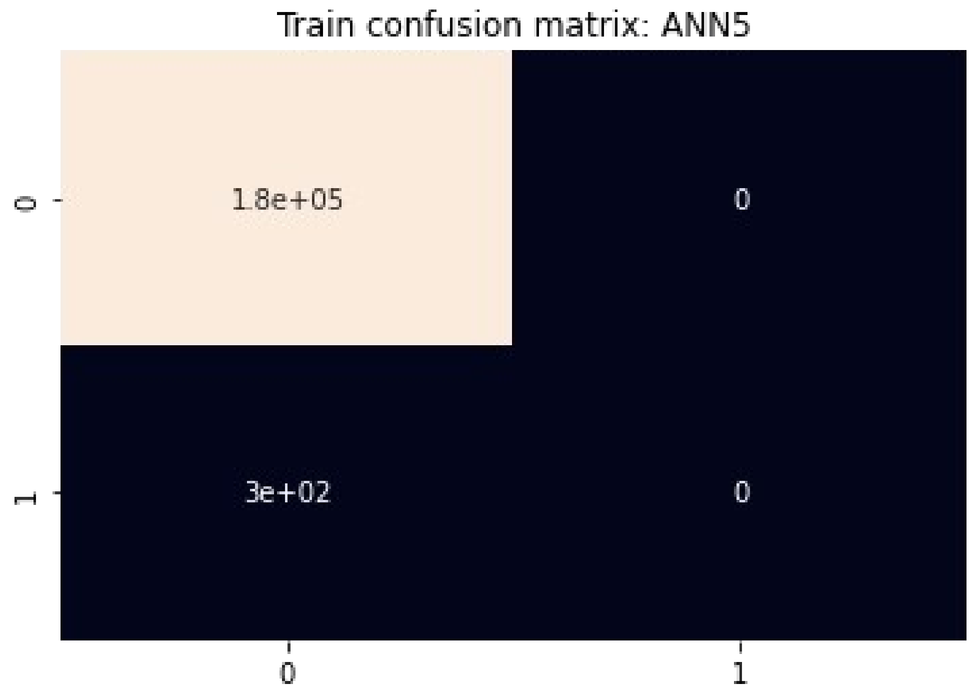
```
Test accuracy score 0.9982795547909132

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.00      0.00      0.00        98

    accuracy                           1.00     56962
   macro avg       0.50      0.50      0.50     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model ANN4

/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

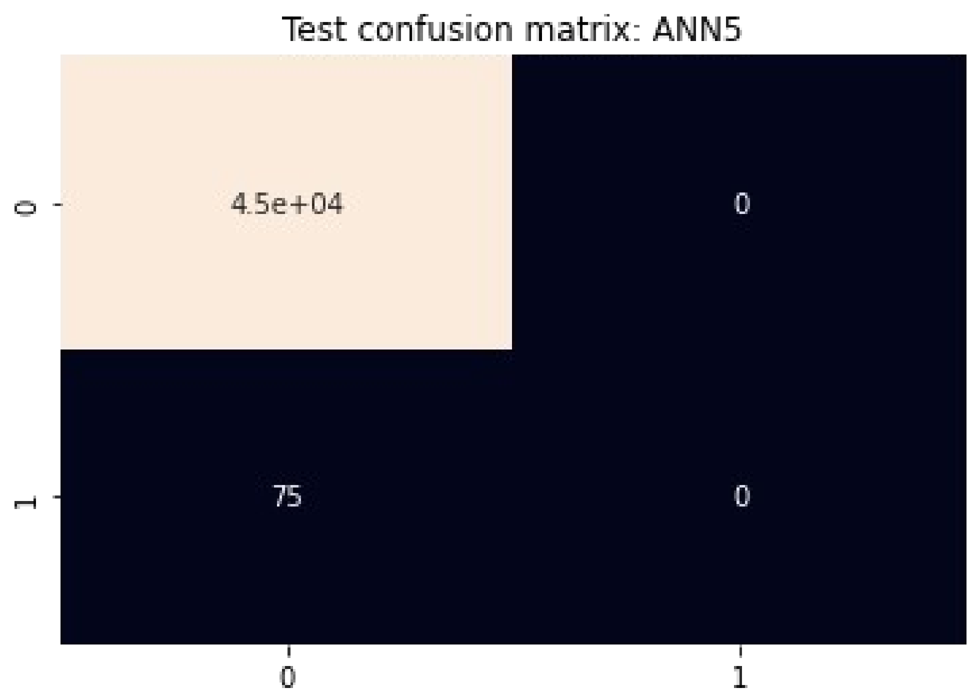
```
buildANN(3, 128, 'relu', 'he_normal', 'l2', 'adam', 30, 20, 'ANN5')
```

```
Model: "model_45"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_53 (InputLayer)       [(None, 30)]              0

 dense_247 (Dense)           (None, 128)               3968

 dense_248 (Dense)           (None, 64)                8256

 dense_249 (Dense)           (None, 32)                2080

 dense_250 (Dense)           (None, 10)                330

 dense_251 (Dense)           (None, 2)                 22
```

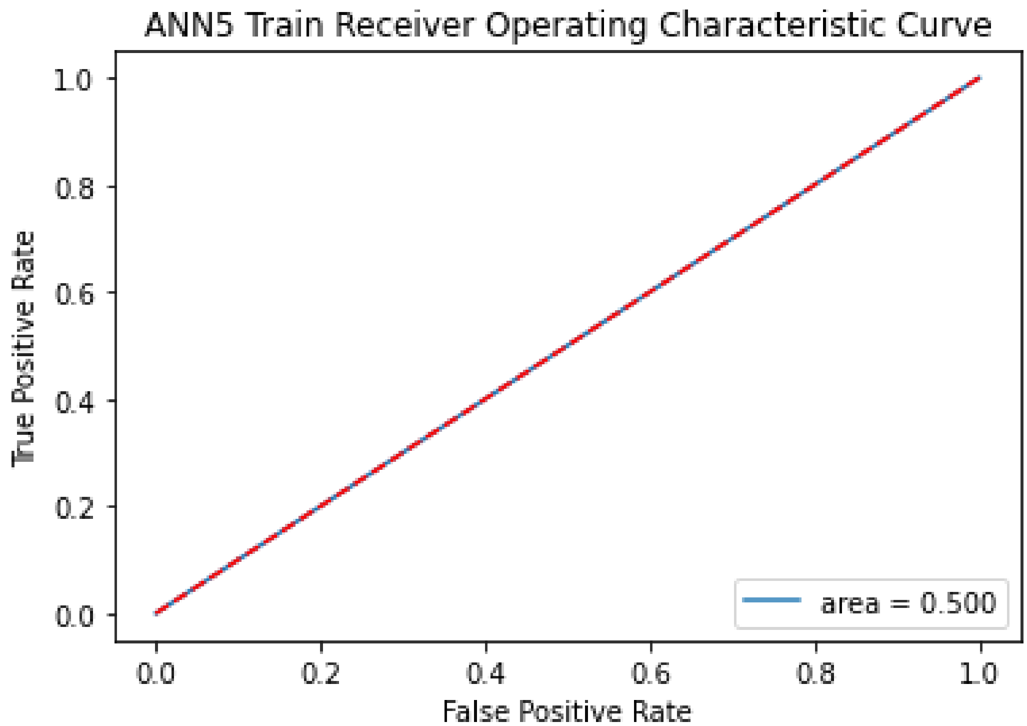
```
=================================================================
Total params: 14,656
Trainable params: 14,656
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/20
6037/6037 [==============================] - 18s 3ms/step - loss:
0.1524 - f1_score: 0.5254 - val_loss: 0.0125 - val_f1_score: 0.4996
Epoch 2/20
6037/6037 [==============================] - 18s 3ms/step - loss:
0.0125 - f1_score: 0.4996 - val_loss: 0.0124 - val_f1_score: 0.4996
Epoch 3/20
6037/6037 [==============================] - 17s 3ms/step - loss:
0.0124 - f1_score: 0.4996 - val_loss: 0.0123 - val_f1_score: 0.4996
Epoch 4/20
6037/6037 [==============================] - 17s 3ms/step - loss:
0.0124 - f1_score: 0.4996 - val_loss: 0.0123 - val_f1_score: 0.4996
Epoch 5/20
6037/6037 [==============================] - 18s 3ms/step - loss:
0.0124 - f1_score: 0.4996 - val_loss: 0.0123 - val_f1_score: 0.4996
Epoch 6/20
6037/6037 [==============================] - 18s 3ms/step - loss:
0.0124 - f1_score: 0.4996 - val_loss: 0.0123 - val_f1_score: 0.4996
5660/5660 [==============================] - 9s 2ms/step
1415/1415 [==============================] - 2s 1ms/step

Model performance ANN5

accuracy score train 0.9983324314474716
accuracy score test 0.9983434932414524

Train classification report: ANN5


/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       0.00      0.00      0.00       302

    accuracy                           1.00    181102
   macro avg       0.50      0.50      0.50    181102
weighted avg       1.00      1.00      1.00    181102


Test classification report: ANN5

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       0.00      0.00      0.00        75

    accuracy                           1.00     45276
   macro avg       0.50      0.50      0.50     45276
weighted avg       1.00      1.00      1.00     45276
```

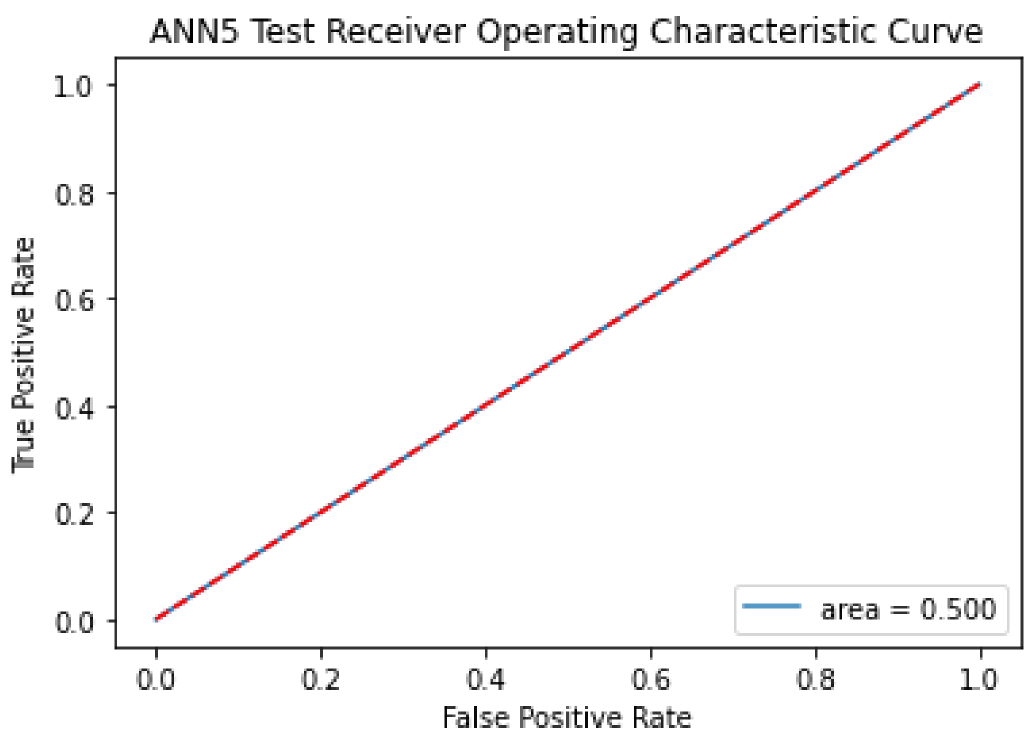





```
roc auc score train 0.5
```




```
roc auc score test 0.5
```




```
1781/1781 [==============================] - 3s 1ms/step
```

```
Test accuracy score 0.9982795547909132

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.00      0.00      0.00        98

    accuracy                           1.00     56962
   macro avg       0.50      0.50      0.50     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model ANN5

/usr/local/lib/python3.7/dist-packages/sklearn/metrics/
_classification.py:1318: UndefinedMetricWarning: Precision and F-score
are ill-defined and being set to 0.0 in labels with no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification
.py:1318: UndefinedMetricWarning: Precision and F-score are ill-
defined and being set to 0.0 in labels with no predicted samples. Use
`zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

```
buildANN(4, 256, 'relu', 'he_normal', 'l2', 'adam', 30, 10, 'ANN6',
0.2)
```

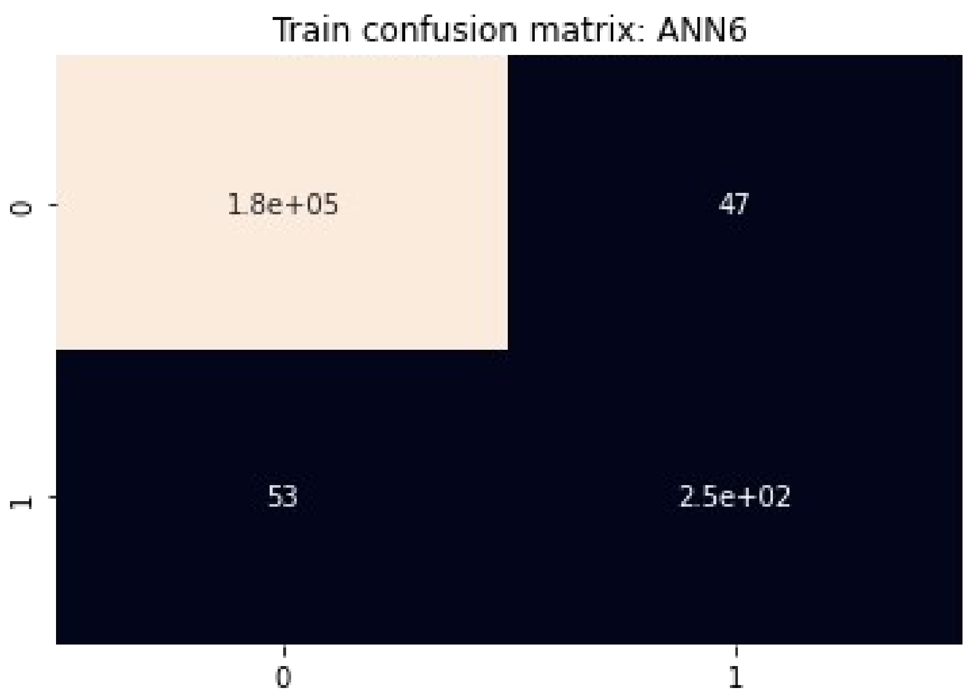
```
Model: "model_46"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_54 (InputLayer)       [(None, 30)]              0

 dense_252 (Dense)           (None, 256)               7936

 dense_253 (Dense)           (None, 128)               32896

 dense_254 (Dense)           (None, 64)                8256

 dense_255 (Dense)           (None, 32)                2080

 dropout_16 (Dropout)        (None, 32)                0
```

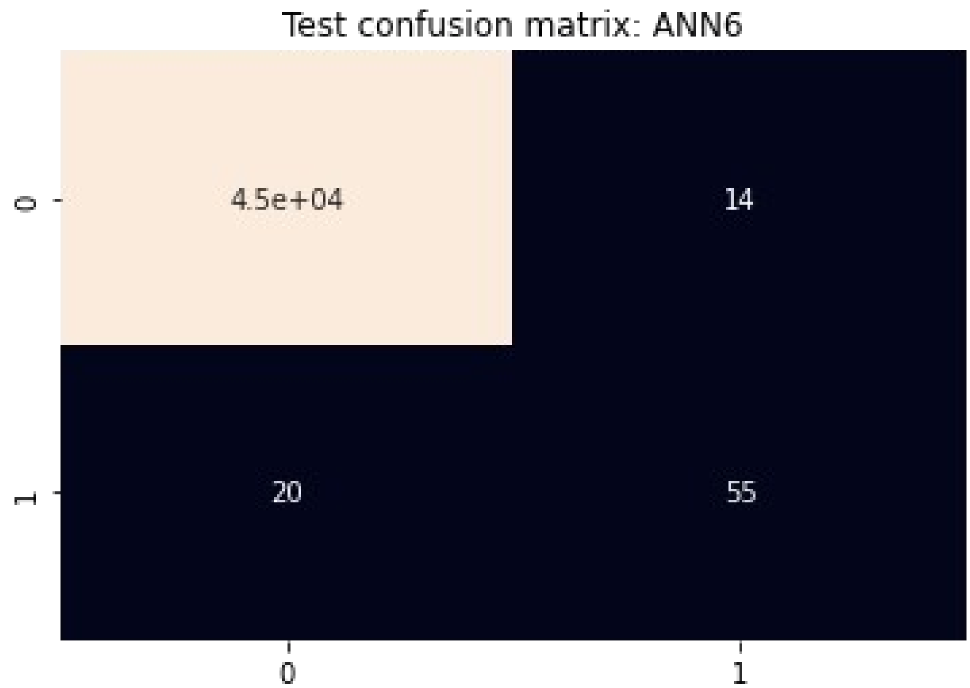
```
 batch_normalization_16 (Bat  (None, 32)               128
 chNormalization)

 dense_256 (Dense)           (None, 10)                330

 dense_257 (Dense)           (None, 2)                 22

=================================================================
Total params: 51,648
Trainable params: 51,584
Non-trainable params: 64
_________________________________________________________________
None
Epoch 1/10
6037/6037 [==============================] - 28s 5ms/step - loss: 
0.3764 - f1_score: 0.5799 - val_loss: 0.0126 - val_f1_score: 0.8648
Epoch 2/10
6037/6037 [==============================] - 24s 4ms/step - loss: 
0.0097 - f1_score: 0.8228 - val_loss: 0.0103 - val_f1_score: 0.7497
Epoch 3/10
6037/6037 [==============================] - 24s 4ms/step - loss: 
0.0086 - f1_score: 0.8558 - val_loss: 0.0089 - val_f1_score: 0.8381
Epoch 4/10
6037/6037 [==============================] - 24s 4ms/step - loss: 
0.0082 - f1_score: 0.8608 - val_loss: 0.0094 - val_f1_score: 0.7261
Epoch 5/10
6037/6037 [==============================] - 25s 4ms/step - loss: 
0.0080 - f1_score: 0.8610 - val_loss: 0.0084 - val_f1_score: 0.8784
Epoch 6/10
6037/6037 [==============================] - 24s 4ms/step - loss: 
0.0079 - f1_score: 0.8615 - val_loss: 0.0084 - val_f1_score: 0.7647
Epoch 7/10
6037/6037 [==============================] - 23s 4ms/step - loss: 
0.0075 - f1_score: 0.8675 - val_loss: 0.0085 - val_f1_score: 0.8784
Epoch 8/10
6037/6037 [==============================] - 23s 4ms/step - loss: 
0.0072 - f1_score: 0.8827 - val_loss: 0.0096 - val_f1_score: 0.7072
Epoch 9/10
6037/6037 [==============================] - 23s 4ms/step - loss: 
0.0073 - f1_score: 0.8788 - val_loss: 0.0086 - val_f1_score: 0.8818
5660/5660 [==============================] - 10s 2ms/step
1415/1415 [==============================] - 3s 2ms/step

Model performance ANN6

accuracy score train 0.9994478249826065
accuracy score test 0.9992490502694584

Train classification report: ANN6
```

	precision	recall	f1-score	support
0	1.00	1.00	1.00	180800
1	0.84	0.82	0.83	302
accuracy			1.00	181102
macro avg	0.92	0.91	0.92	181102
weighted avg	1.00	1.00	1.00	181102

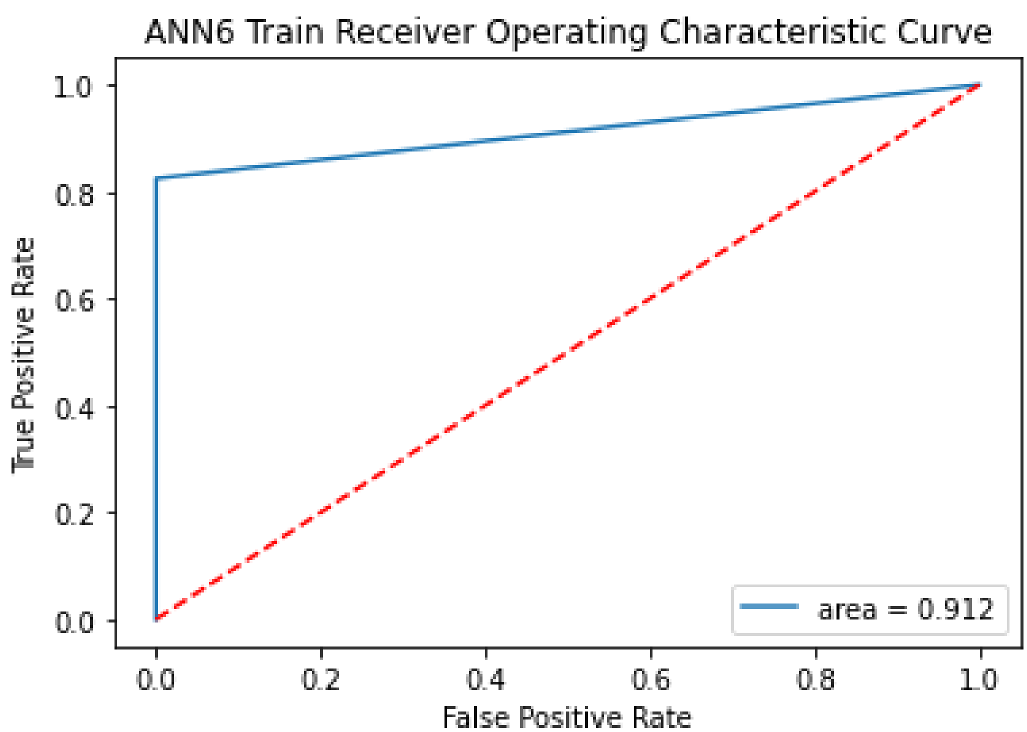
Test classification report: ANN6

	precision	recall	f1-score	support
0	1.00	1.00	1.00	45201
1	0.80	0.73	0.76	75
accuracy			1.00	45276
macro avg	0.90	0.87	0.88	45276
weighted avg	1.00	1.00	1.00	45276

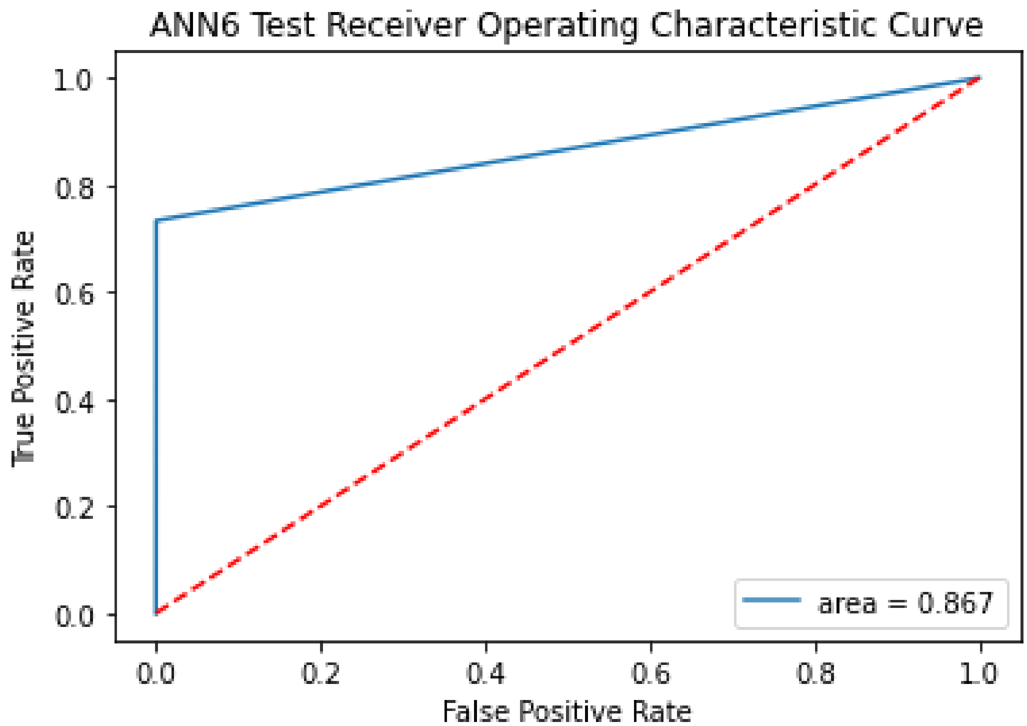





```
roc auc score train 0.9121216777530329
```




```
roc auc score test 0.8665118028362204
```




```
1781/1781 [==============================] - 3s 2ms/step

Test accuracy score 0.9993153330290369

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.82      0.77      0.79        98

    accuracy                           1.00     56962
   macro avg       0.91      0.88      0.90     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model ANN6
```

Among all the models with oversampled, undersampled and original inputs, we got the best model with highest performance.

ANN6 with original input gave best score (f1-score macro= 0.90).

So going forward, for froud prediction, we can use this model.

Now with the original input data, we can do hyper-parameter tunning.

Hyper-parameter tunning for ANN models

```
finance_train = pd.read_pickle('finance_train.pkl')
finance_test = pd.read_pickle('finance_test.pkl')

train_X = finance_train.drop(['Class'], axis=1)
train_y = finance_train[['Class']]

test_X = finance_test.drop(['Class'], axis=1)
test_y = finance_test[['Class']]

x_train, x_test, y_train, y_test = train_test_split(train_X, train_y,

stratify= train_y,

test_size= 0.2, random_state= 0)

y_train = to_categorical(y_train)
y_test = to_categorical(y_test)
test_y = to_categorical(test_y)

print(x_train.shape)
print(y_train.shape)
print(x_test.shape)
print(y_test.shape)
print(test_X.shape)
print(test_y.shape)
```

```
(181102, 30)
(181102, 2)
(45276, 30)
(45276, 2)
(56962, 30)
(56962, 2)
```

```
def modelBuilder(hy_param):
    # regularization param
    regL1 = hy_param.Float('regularization1', 0.0, 0.1, step=0.005)
    regL2 = hy_param.Float('regularization2', 0.0, 0.1, step=0.005)
    # kernel initialization param
    kernel_initializers = hy_param.Choice('kernel_initializer',
['he_uniform', 'he_normal'])
    # dropout param
    dropout = hy_param.Float('dropout', 0, 0.5, step=0.2)
    # actiation
    activation_fn = hy_param.Choice('activation', ['relu', 'tanh'])
    # kernel initializer
    initializer = hy_param.Choice('kernel initializer', ['he_normal',
'he_uniform', 'glorot_uniform', 'glorot_normal'])
    # Number of neurons and number of layers
    num_neuron = hy_param.Choice('nmber of neurons', [32, 64, 128,
256])
```

```
    nu_num = num_neuron
    num_layer = hy_param.Int('dense_layers', 1, math.log2(num_neuron
// 16))
    num_neuron_last = hy_param.Choice('nmber of neurons', [5, 10, 15])
    # Optimizers
    optimizerName = hy_param.Choice('optimizer', ['sgd', 'adadelta',
'adagrad', 'rmsprop', 'adam'])

    input = Input(x_train.shape[-1],)
    x = input

    for i in range(num_layer):
      x = Dense(units = nu_num, activation = activation_fn,
              kernel_initializer = initializer, kernel_regularizer =
L1L2(l1=regL1, l2=regL2))(x)
      nu_num //= 2

    x = Dropout(dropout)(x)
    x = BatchNormalization()(x)

    x = Dense(units = num_neuron_last, activation = activation_fn,
              kernel_initializer = initializer, kernel_regularizer =
L1L2(l1=regL1, l2=regL2))(x)
    output = Dense(2, activation = 'softmax')(x)

    model = Model(input, output)
    model.compile(loss='categorical_crossentropy', optimizer=
optimizerName, metrics=[F1Score(num_classes= 2, average= 'macro')])
    return model

tuner = BayesianOptimization(modelBuilder, objective='val_loss',
max_trials=3,
                     project_name='Finance ANN Result')

tuner.search_space_summary()
```

```
Search space summary
Default search space size: 9
regularization1 (Float)
{'default': 0.0, 'conditions': [], 'min_value': 0.0, 'max_value': 0.1,
'step': 0.005, 'sampling': None}
regularization2 (Float)
{'default': 0.0, 'conditions': [], 'min_value': 0.0, 'max_value': 0.1,
'step': 0.005, 'sampling': None}
kernel_initializer (Choice)
{'default': 'he_uniform', 'conditions': [], 'values': ['he_uniform',
'he_normal'], 'ordered': False}
dropout (Float)
{'default': 0.0, 'conditions': [], 'min_value': 0.0, 'max_value': 0.5,
'step': 0.2, 'sampling': None}
```

```
activation (Choice)
{'default': 'relu', 'conditions': [], 'values': ['relu', 'tanh'],
'ordered': False}
kernel initializer (Choice)
{'default': 'he_normal', 'conditions': [], 'values': ['he_normal',
'he_uniform', 'glorot_uniform', 'glorot_normal'], 'ordered': False}
nmber of neurons (Choice)
{'default': 32, 'conditions': [], 'values': [32, 64, 128, 256],
'ordered': True}
dense_layers (Int)
{'default': None, 'conditions': [], 'min_value': 1, 'max_value': 1,
'step': 1, 'sampling': None}
optimizer (Choice)
{'default': 'sgd', 'conditions': [], 'values': ['sgd', 'adadelta',
'adagrad', 'rmsprop', 'adam'], 'ordered': False}
```

```
callback = EarlyStopping(monitor='val_loss', patience=4)
```

```
tuner.search(x_train, y_train, batch_size=30, epochs=10,
             validation_data=(x_test, y_test), callbacks=[callback])
```

```
Trial 3 Complete [00h 05m 23s]
val_loss: 0.003881769487634301

Best val_loss So Far: 0.003881769487634301
Total elapsed time: 00h 09m 54s
```

```
tuner.results_summary()
```

```
Results summary
Results in ./Finance ANN Result
Showing 10 best trials
<keras_tuner.engine.objective.Objective object at 0x7f00556e3110>
Trial summary
Hyperparameters:
regularization1: 0.0
regularization2: 0.0
kernel_initializer: he_normal
dropout: 0.2
activation: tanh
kernel initializer: he_uniform
nmber of neurons: 256
dense_layers: 1
optimizer: sgd
Score: 0.003881769487634301
Trial summary
Hyperparameters:
regularization1: 0.045
regularization2: 0.015
kernel_initializer: he_normal
dropout: 0.2
```

```
activation: tanh
kernel initializer: he_uniform
nmber of neurons: 128
dense_layers: 1
optimizer: sgd
Score: 0.21482113003730774
Trial summary
Hyperparameters:
regularization1: 0.085
regularization2: 0.03
kernel_initializer: he_uniform
dropout: 0.2
activation: relu
kernel initializer: he_uniform
nmber of neurons: 64
dense_layers: 1
optimizer: sgd
Score: 0.22776171565055847
```

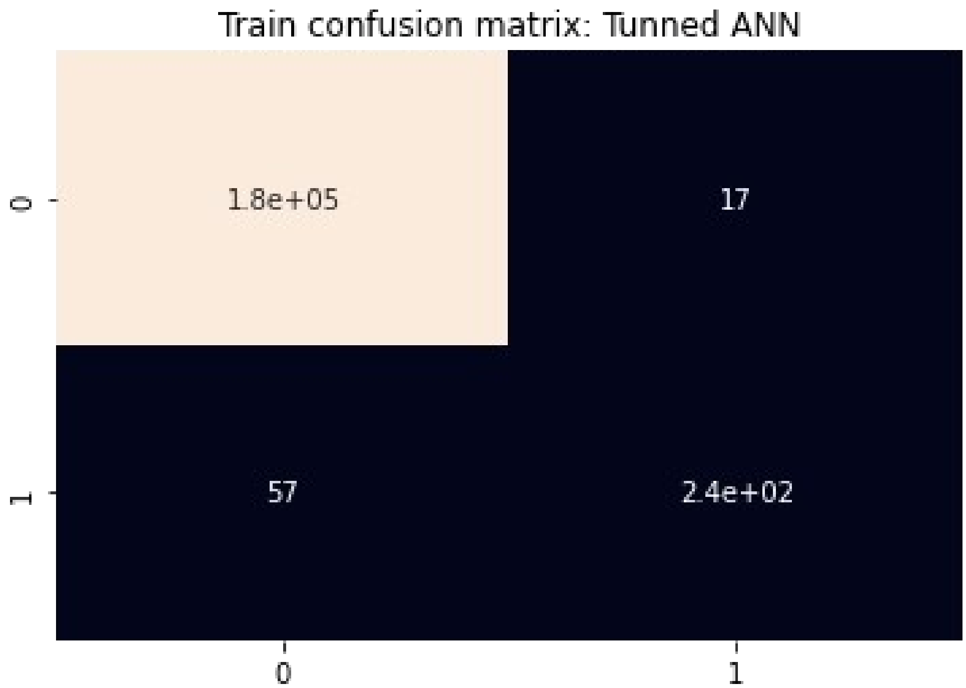
```
tunned_neural_model = tuner.get_best_models(num_models=1)[0]
tunned_neural_model.summary()
```

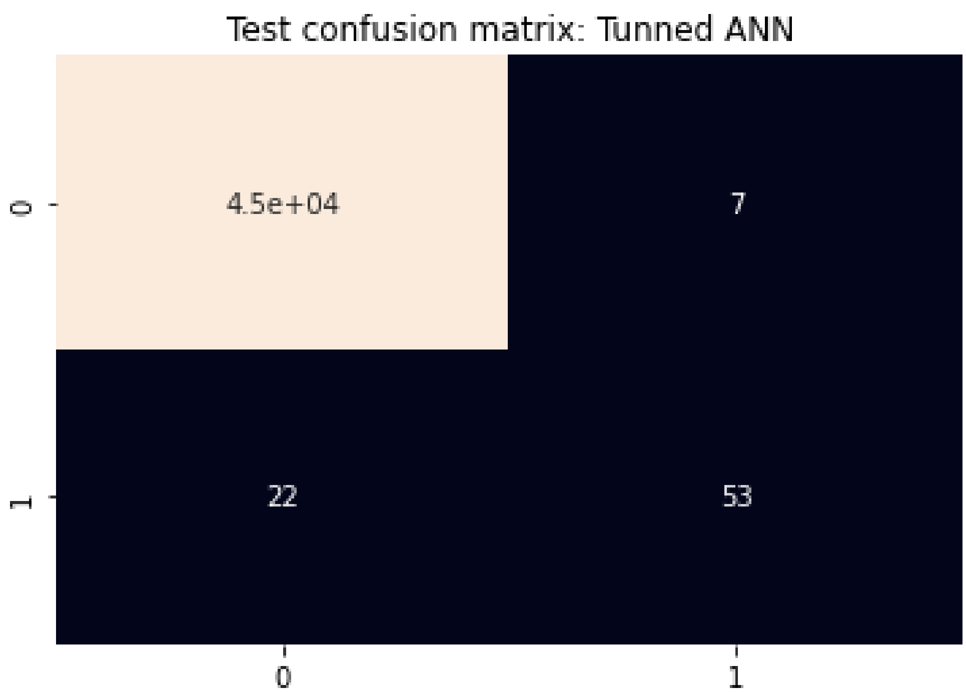
```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 30)]              0

 dense (Dense)               (None, 256)               7936

 dropout (Dropout)           (None, 256)               0

 batch_normalization (BatchN  (None, 256)              1024
 ormalization)

 dense_1 (Dense)             (None, 256)               65792

 dense_2 (Dense)             (None, 2)                 514

=================================================================
Total params: 75,266
Trainable params: 74,754
Non-trainable params: 512
_________________________________________________________________
```

```
y_train_pred = tunned_neural_model.predict(x_train)
y_test_pred = tunned_neural_model.predict(x_test)
y_train_label = np.argmax(y_train, axis= 1)
y_train_pred = np.argmax(y_train_pred, axis= 1)
y_test_label = np.argmax(y_test, axis= 1)
y_test_pred = np.argmax(y_test_pred, axis= 1)
```

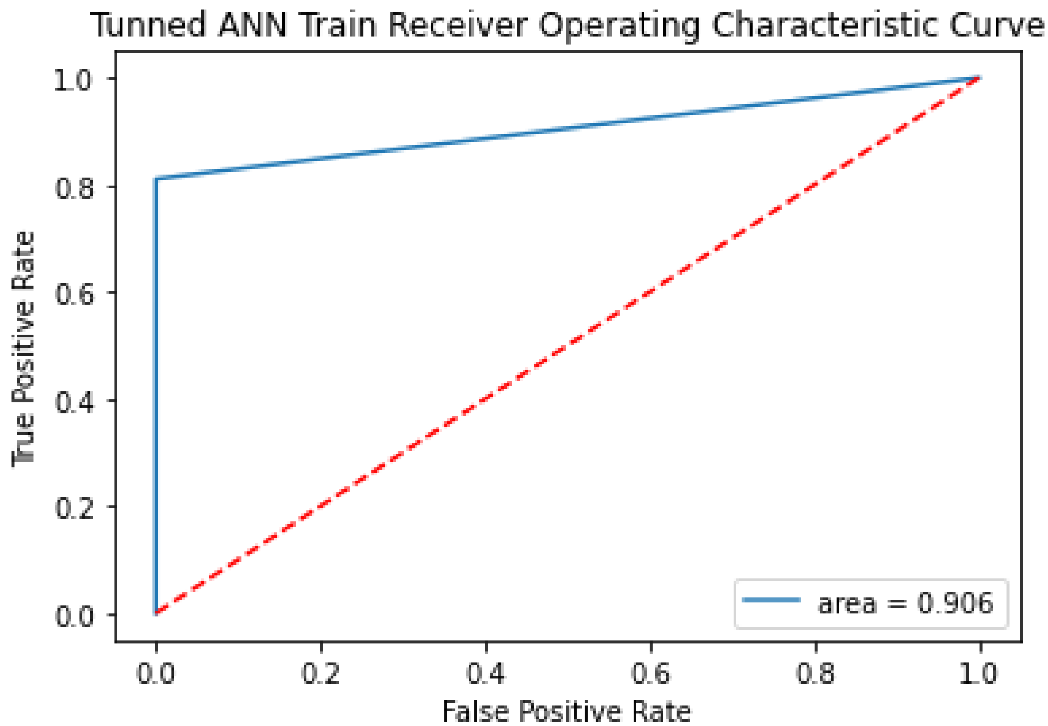
```
getPerformance(y_train_label, y_train_pred, y_test_label, y_test_pred,
'Tunned ANN')

test_y_pred = tunned_neural_model.predict(test_X)
test_y_label = np.argmax(test_y, axis= 1)
test_y_pred = np.argmax(test_y_pred, axis= 1)

print('\nTest accuracy score {} \
n'.format(accuracy_score(test_y_label, test_y_pred)))
print('Classification report\n')
print(classification_report(test_y_label, test_y_pred))
print('\nCompleted and saved for model Tunned ANN')
tunned_neural_model.save('Tunned ANN')
```

```
5660/5660 [==============================] - 11s 2ms/step
1415/1415 [==============================] - 3s 2ms/step

Model performance Tunned ANN

accuracy score train 0.9995913904871288
accuracy score test 0.9993594840533616

Train classification report: Tunned ANN

              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       0.94      0.81      0.87       302

    accuracy                           1.00    181102
   macro avg       0.97      0.91      0.93    181102
weighted avg       1.00      1.00      1.00    181102


Test classification report: Tunned ANN

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       0.88      0.71      0.79        75

    accuracy                           1.00     45276
   macro avg       0.94      0.85      0.89     45276
weighted avg       1.00      1.00      1.00     45276
```

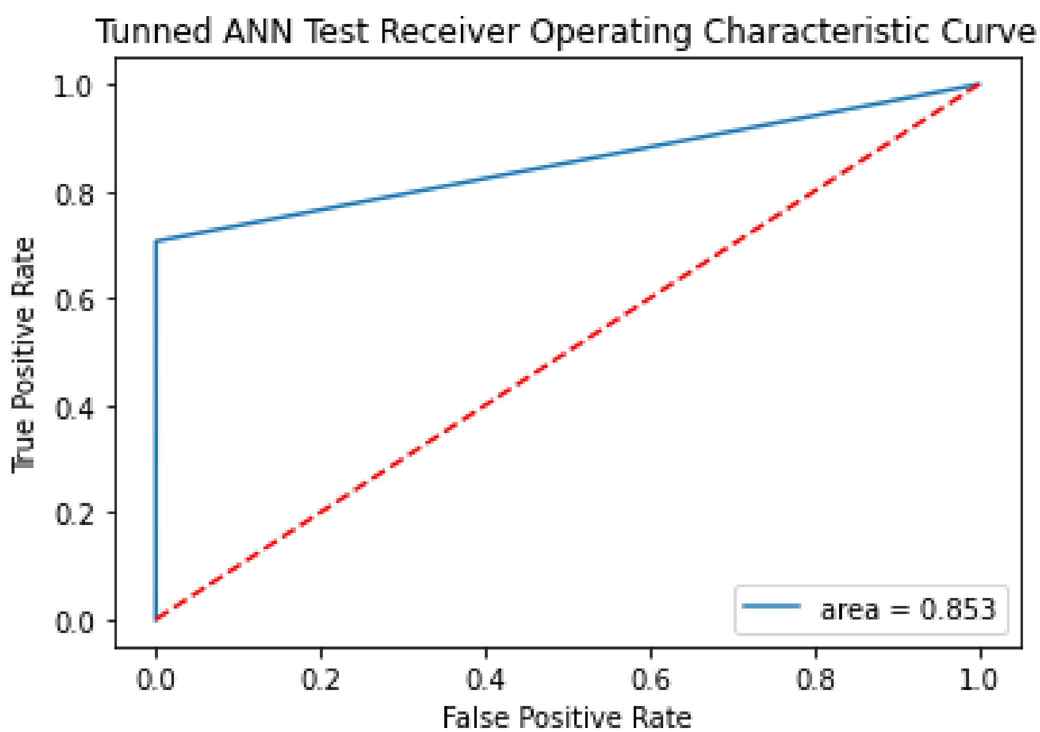





```
roc auc score train 0.9055821257985115
```




```
roc auc score test 0.8532559014181101
```




```
1781/1781 [==============================] - 4s 2ms/step
```

```
Test accuracy score 0.9994382219725431

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.93      0.72      0.82        98

    accuracy                           1.00     56962
   macro avg       0.97      0.86      0.91     56962
weighted avg       1.00      1.00      1.00     56962


Completed and saved for model Tunned ANN
```

As we can see the latest model gave the highest performance now among all the ANN models (f1-score macro= 0.91 with test data).

But again we can use other models as well giving top results.

If we consider both ML and DL models, still random forest classifier gae the highest score of 0.92.

Anomaly Detection

All the records we have, there is a possibility that we can have anomaly/outliers which lies with large separation as compared to other records. Based on the selected features, we can decide whether a point in feature space is anomaly or not. We can also assign scores to the points implying the chances of being a anomaly.

We can use IsolationForest model to provide anomaly label prediction and scores to the data points.

```
print(train_X.shape)
print(train_y.shape)
```

```
(226378, 30)
(226378, 1)
```

```
model  =  IsolationForest(n_estimators=50, max_samples=500, 
contamination=.05, max_features=10,
                         bootstrap=False, n_jobs=1, random_state=1, 
verbose=0, warm_start=False).fit(train_X)
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/base.py:451: 
UserWarning: X does not have valid feature names, but IsolationForest 
was fitted with feature names
  "X does not have valid feature names, but"
```

```
anomaly_score = model.decision_function(train_X)
predictions = model.predict(train_X)
```

```
anomaly_score[:5]
```

```
array([0.12114711, 0.01284614, 0.06780871, 0.11218362, 0.09971792])
```

```
print(np.unique(predictions, return_counts=True))
```

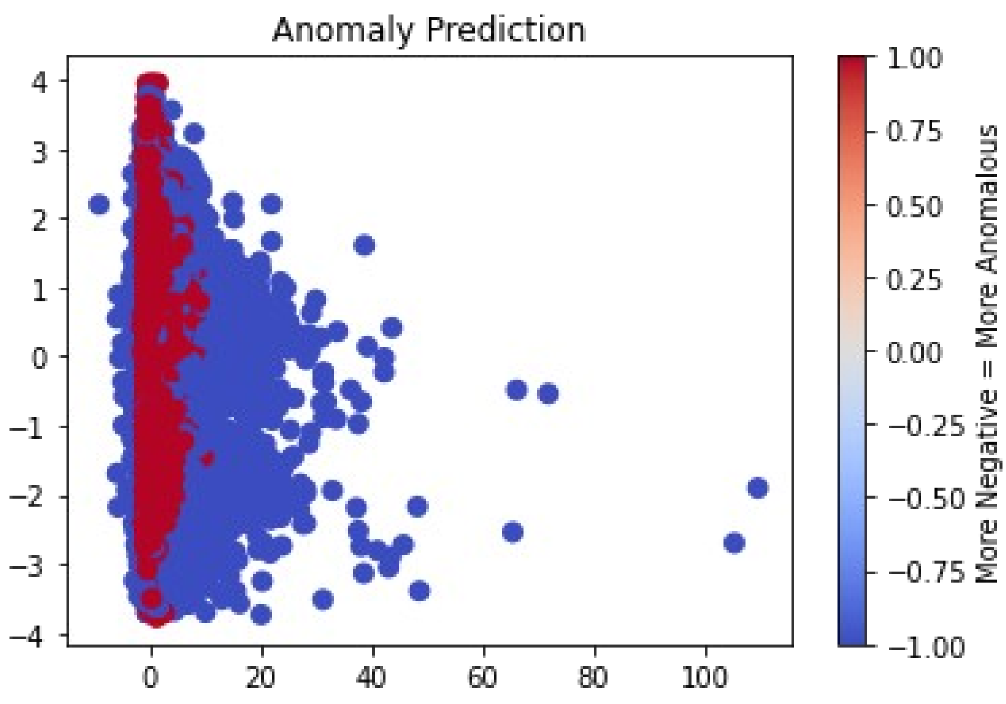
```
(array([-1,  1]), array([ 11318, 215060]))
```

```
anomaly_score_test = model.decision_function(test_X)
```

The finance data got fit with the model for anomaly detection. Here we got the scores and the labels of anomaly (-1,1)

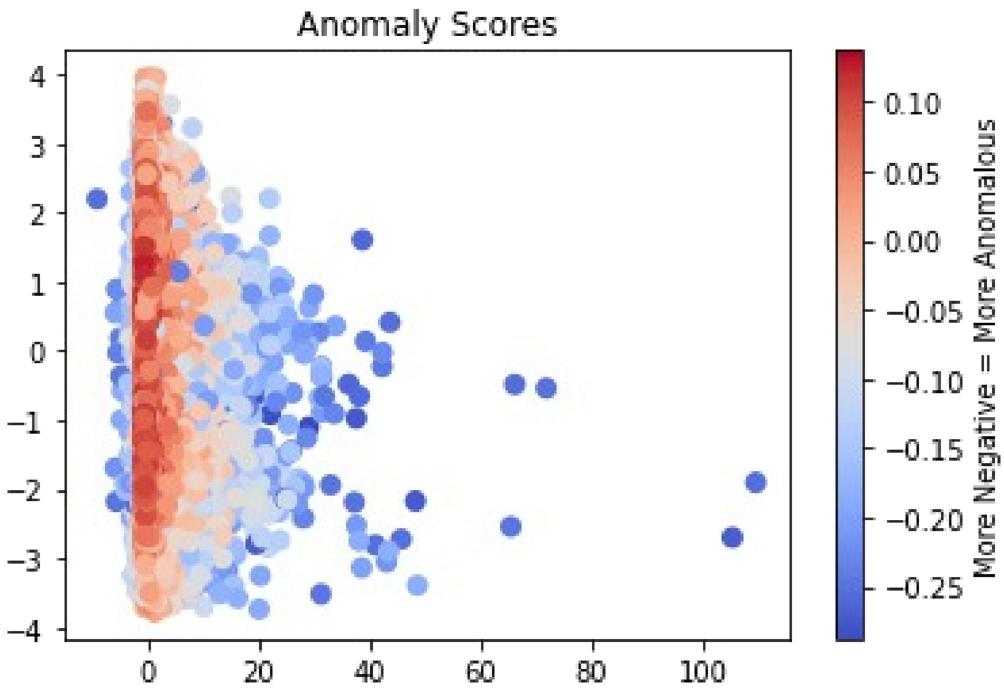
Now we can visualize the data points with the score values and the predictions.

```
X_pca = PCA(n_components=2,
random_state=42).fit_transform(train_X.values)
s = plt.scatter(X_pca[:,0], X_pca[:,1], c=predictions,
cmap='coolwarm', linewidths=2)
plt.colorbar(s, label = 'More Negative = More Anomalous')
plt.title('Anomaly Prediction')
plt.show()
```




```
X_pca = PCA(n_components=2,
random_state=42).fit_transform(train_X.values)
s = plt.scatter(X_pca[:,0], X_pca[:,1], c=anomaly_score,
cmap='coolwarm', linewidths=2)
```

```
plt.colorbar(s, label = 'More Negative = More Anomalous')
plt.title('Anomaly Scores')
plt.show()
```

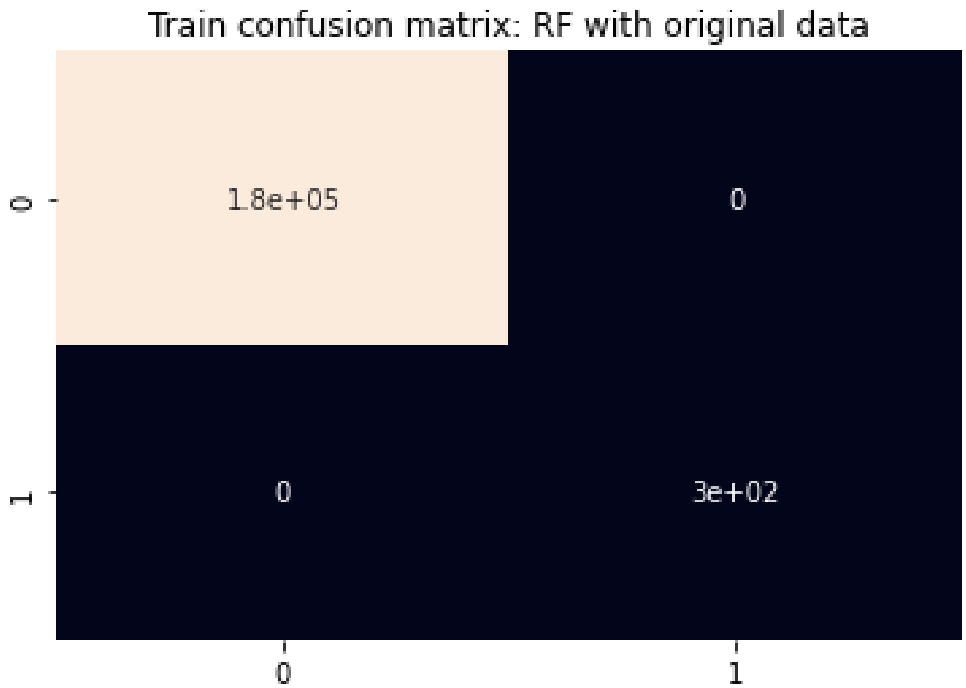


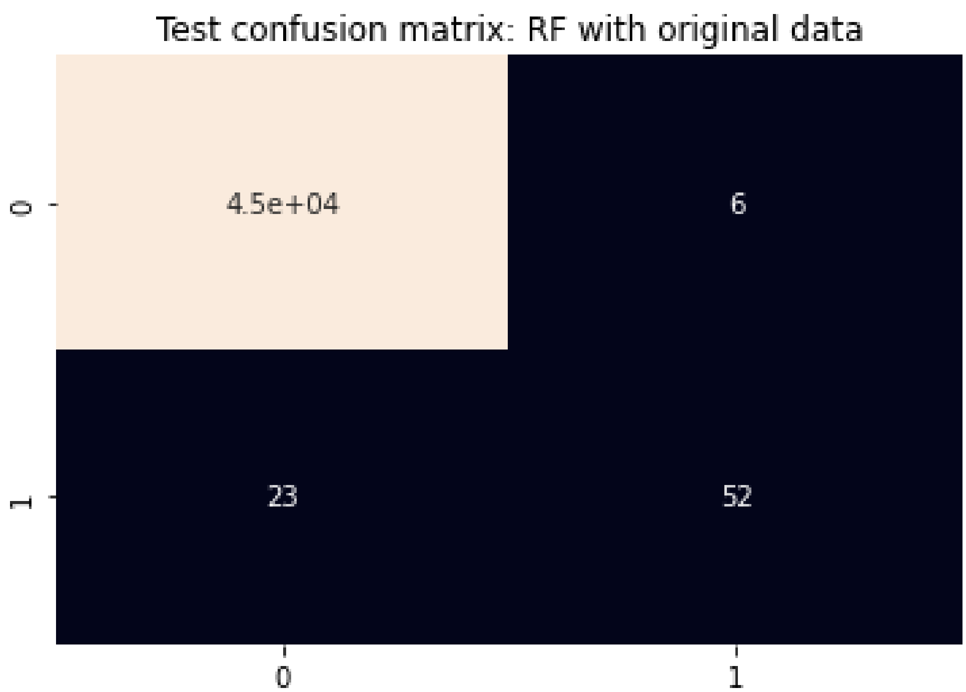
Now lets try to add this anomaly scores to our input data as a feature and check the performance.

Before that, we need to fit a model (Random Forest) with the original data.

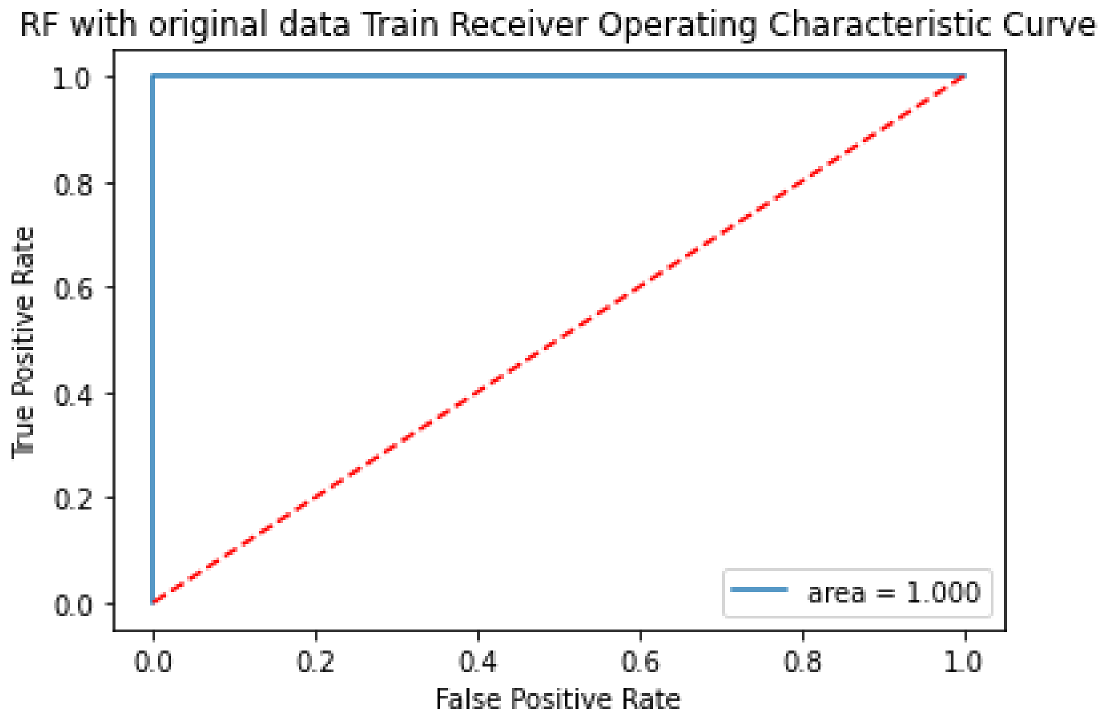
```
x_train, x_test, y_train, y_test = train_test_split(train_X, train_y,

stratify= train_y,

test_size= 0.2, random_state= 0)

rf = RandomForestClassifier(class_weight='balanced')

rf.fit(x_train, y_train)
y_train_pred = rf.predict(x_train)
y_test_pred = rf.predict(x_test)
getPerformance(y_train, y_train_pred, y_test, y_test_pred, 'RF with
original data')
test_y_pred = rf.predict(test_X)
print('\nTest accuracy score {} \n'.format(accuracy_score(test_y,
test_y_pred)))
print('Classification report\n')
print(classification_report(test_y, test_y_pred))
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:1:
DataConversionWarning: A column-vector y was passed when a 1d array
was expected. Please change the shape of y to (n_samples,), for
example using ravel().
  """Entry point for launching an IPython kernel.


Model performance RF with original data

accuracy score train 1.0
accuracy score test 0.9993594840533616

Train classification report: RF with original data

              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       1.00      1.00      1.00       302

    accuracy                           1.00    181102
   macro avg       1.00      1.00      1.00    181102
weighted avg       1.00      1.00      1.00    181102


Test classification report: RF with original data

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       0.90      0.69      0.78        75

    accuracy                           1.00     45276
   macro avg       0.95      0.85      0.89     45276
weighted avg       1.00      1.00      1.00     45276
```






```
roc auc score train 1.0
```




```
roc auc score test 0.8466002964536182
```


```
Test accuracy score 0.9994557775359011
```

```
Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.95      0.72      0.82        98

    accuracy                           1.00     56962
   macro avg       0.97      0.86      0.91     56962
weighted avg       1.00      1.00      1.00     56962
```

Random forest with original data gave a good performance with f-score macro as 0.91.

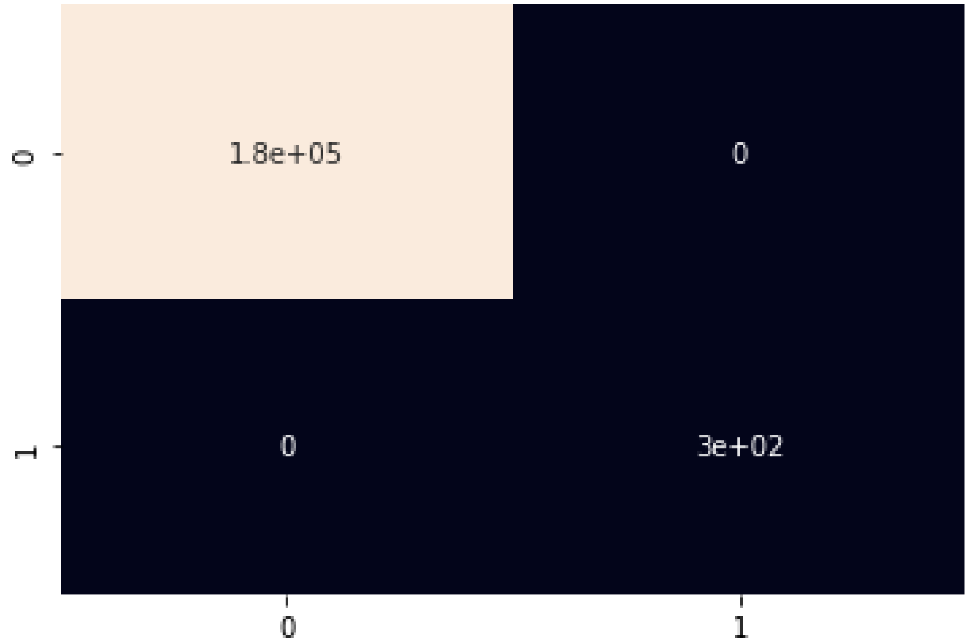
Now we can add the anomaly scores to the input and fit a new model.

```
train_X['Anomaly Score'] = anomaly_score
test_X['Anomaly Score'] = anomaly_score_test

x_train, x_test, y_train, y_test = train_test_split(train_X, train_y,

stratify= train_y,

test_size= 0.2, random_state= 0)

print(x_train.shape)
print(y_train.shape)
print(x_test.shape)
print(y_test.shape)
print(test_X.shape)
print(test_y.shape)

(181102, 31)
(181102, 1)
(45276, 31)
(45276, 1)
(56962, 31)
(56962, 1)

rf_anmly = RandomForestClassifier(class_weight='balanced')

rf_anmly.fit(x_train, y_train)
y_train_pred = rf_anmly.predict(x_train)
y_test_pred = rf_anmly.predict(x_test)
getPerformance(y_train, y_train_pred, y_test, y_test_pred, 'RF with 
original data and anomaly score')
test_y_pred = rf_anmly.predict(test_X)
print('\nTest accuracy score {} \n'.format(accuracy_score(test_y, 
test_y_pred)))
```

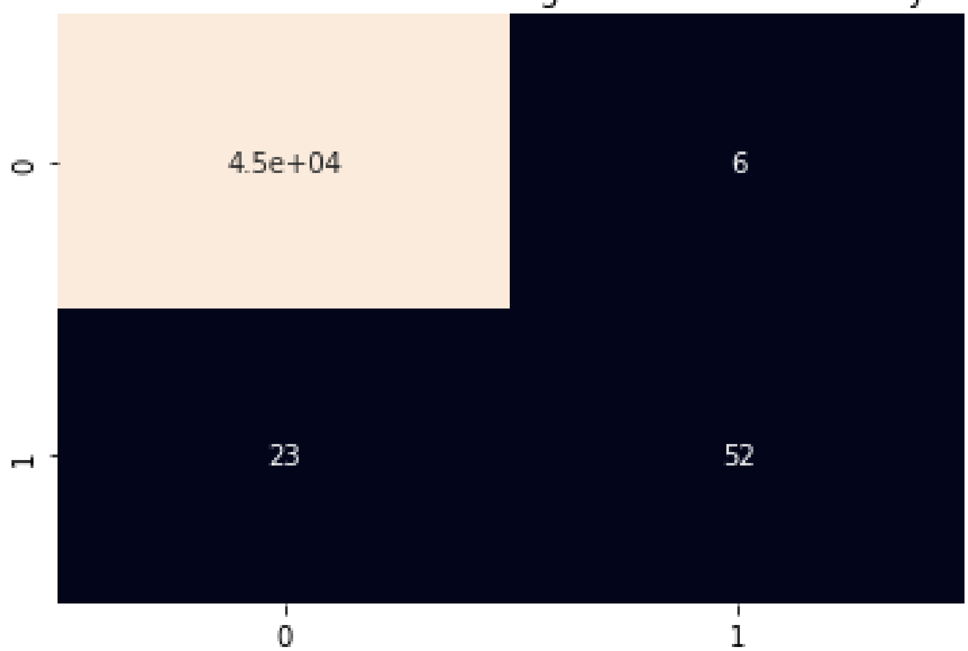
```python
print('Classification report\n')
print(classification_report(test_y, test_y_pred))
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:1:
DataConversionWarning: A column-vector y was passed when a 1d array
was expected. Please change the shape of y to (n_samples,), for
example using ravel().
  """Entry point for launching an IPython kernel.


Model performance RF with original data and anomaly score

accuracy score train 1.0
accuracy score test 0.9993594840533616

Train classification report: RF with original data and anomaly score

              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       1.00      1.00      1.00       302

    accuracy                           1.00    181102
   macro avg       1.00      1.00      1.00    181102
weighted avg       1.00      1.00      1.00    181102


Test classification report: RF with original data and anomaly score

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       0.90      0.69      0.78        75

    accuracy                           1.00     45276
   macro avg       0.95      0.85      0.89     45276
weighted avg       1.00      1.00      1.00     45276
```

Train confusion matrix: RF with original data and anomaly score

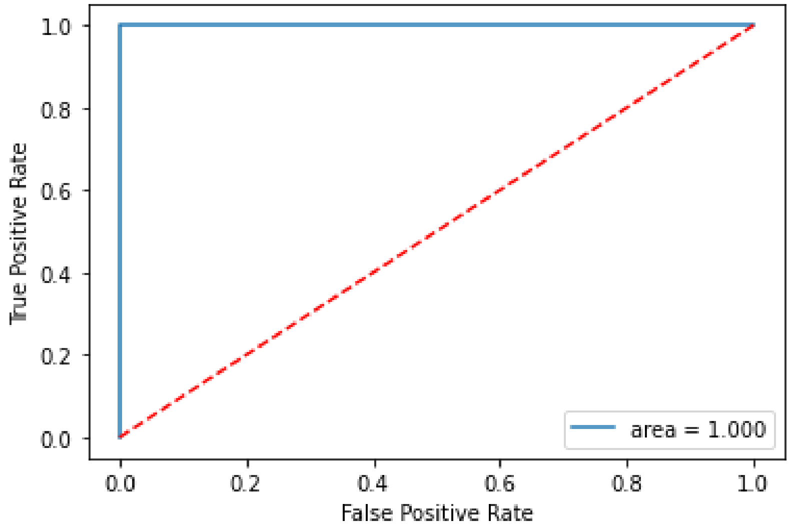


Test confusion matrix: RF with original data and anomaly score



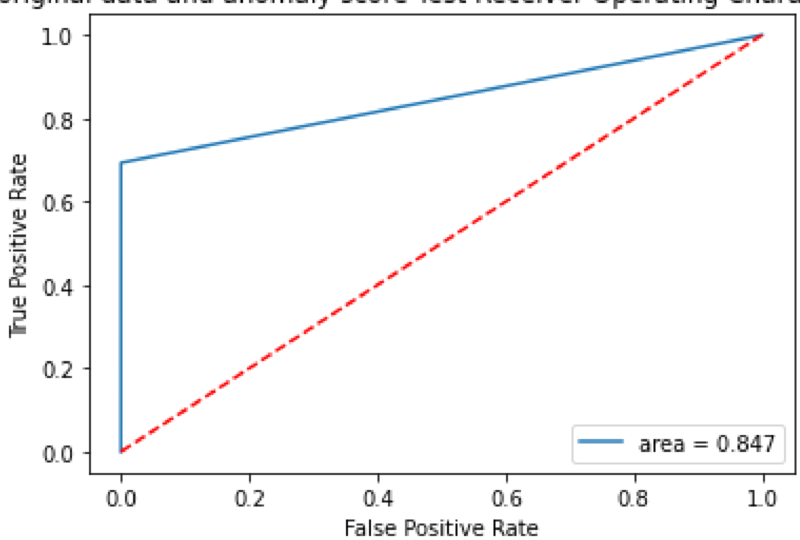

```
roc auc score train 1.0
```

RF with original data and anomaly score Train Receiver Operating Characteristic Curve




```
roc auc score test 0.8466002964536182
```

RF with original data and anomaly score Test Receiver Operating Characteristic Curve




```
Test accuracy score 0.9994557775359011

Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.96      0.71      0.82        98

    accuracy                           1.00     56962
```

```
   macro avg       0.98      0.86      0.91     56962
weighted avg       1.00      1.00      1.00     56962
```

Random forest model trained with original data and the anomaly score gave very good performance (f1-score macro= 0.91) same as the previous model.

So yes, we can use the anomaly score as a new feature, but it would be optional as we didnt see much difference in the two performances.

We didnt see much difference in f1-score is may be because the score we got is not a useful feature to detect froudulent transacations, as the anolamaly model detects the anomaly based on selected features, so there is guarentee that the anomaly data points will be the froud transaction.

Threshold for label prediction

From all the ML model we have, we got the highest score (f-score macro= 0.92) in random forest with oversampled.

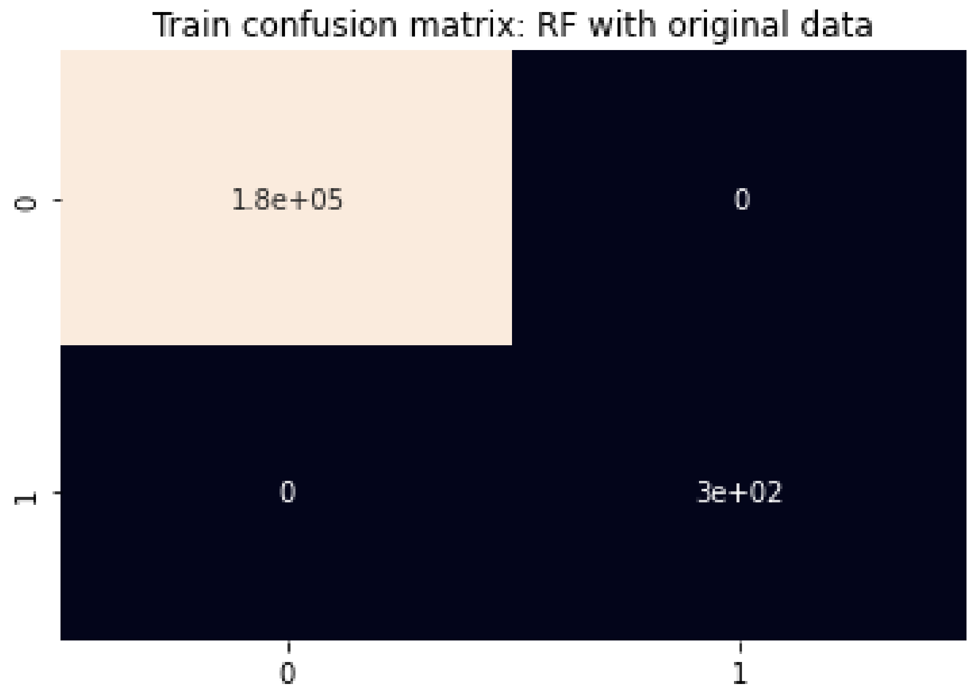
Now we can consider the random forest model with oversampled data as final model.

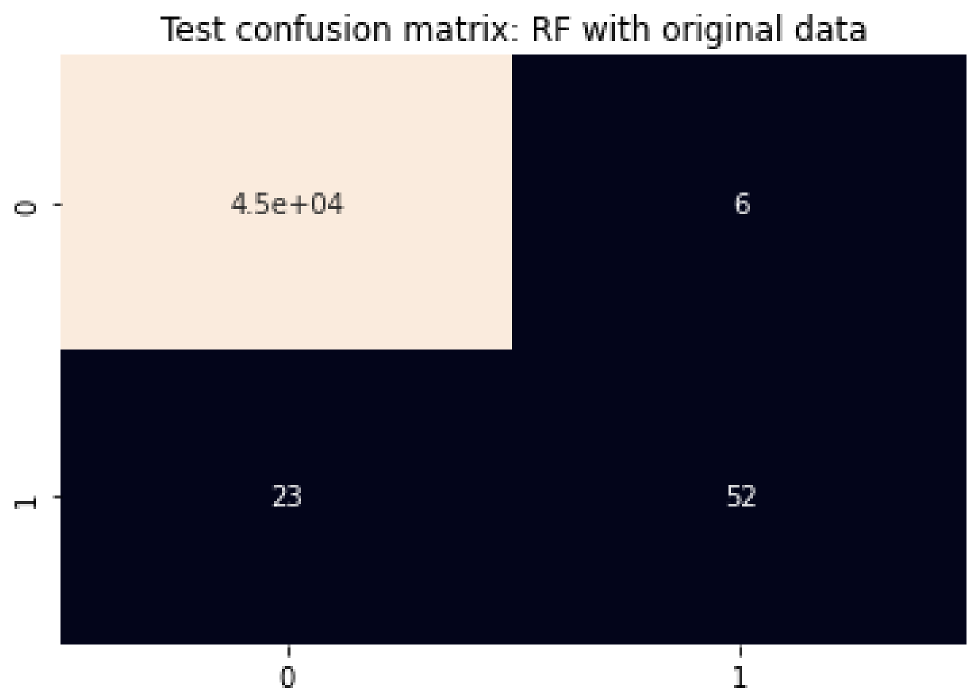
But for thresholding, we can use the random forest model with original data.

```
finance_train = pd.read_pickle('finance_train.pkl')
finance_test = pd.read_pickle('finance_test.pkl')

train_X = finance_train.drop(['Class'], axis=1)
train_y = finance_train[['Class']]

test_X = finance_test.drop(['Class'], axis=1)
test_y = finance_test[['Class']]

x_train, x_test, y_train, y_test = train_test_split(train_X, train_y,

stratify= train_y,

test_size= 0.2, random_state= 0)

print(x_train.shape)
print(y_train.shape)
print(x_test.shape)
print(y_test.shape)
print(test_X.shape)
print(test_y.shape)

(181102, 30)
(181102, 1)
(45276, 30)
(45276, 1)
(56962, 30)
(56962, 1)
```

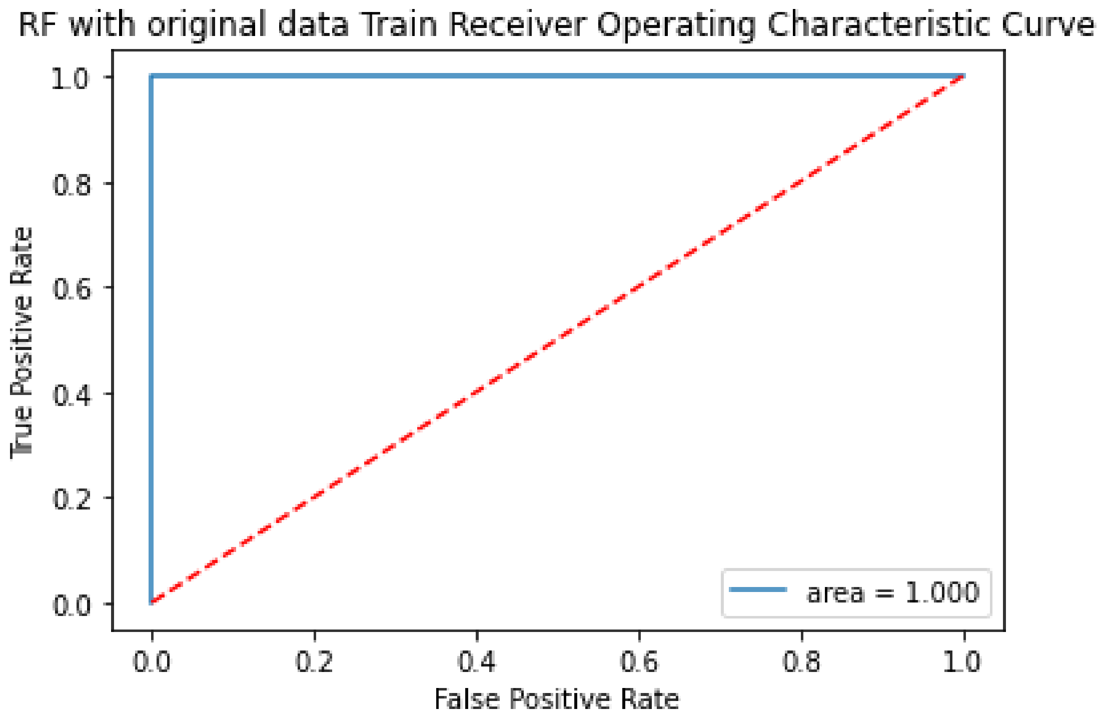
```python
y_train_pred = rf.predict(x_train)
y_test_pred = rf.predict(x_test)
test_y_pred = rf.predict(test_X)
getPerformance(y_train, y_train_pred, y_test, y_test_pred, 'RF with
original data')
print('\nTest accuracy score {} \n'.format(accuracy_score(test_y,
test_y_pred)))
print('Classification report\n')
print(classification_report(test_y, test_y_pred))
```

```
Model performance RF with original data

accuracy score train 1.0
accuracy score test 0.9993594840533616

Train classification report: RF with original data

              precision    recall  f1-score   support

           0       1.00      1.00      1.00    180800
           1       1.00      1.00      1.00       302

    accuracy                           1.00    181102
   macro avg       1.00      1.00      1.00    181102
weighted avg       1.00      1.00      1.00    181102


Test classification report: RF with original data

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     45201
           1       0.90      0.69      0.78        75

    accuracy                           1.00     45276
   macro avg       0.95      0.85      0.89     45276
weighted avg       1.00      1.00      1.00     45276
```






```
roc auc score train 1.0
```



roc auc score test 0.8466002964536182

Test accuracy score 0.9994557775359011

```
Classification report

              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.95      0.72      0.82        98

    accuracy                           1.00     56962
   macro avg       0.97      0.86      0.91     56962
weighted avg       1.00      1.00      1.00     56962
```

```
y_train_pred_proba = rf.predict_proba(x_train)[:, 1]
y_test_pred_proba = rf.predict_proba(x_test)[:, 1]
test_y_pred_proba = rf.predict_proba(test_X)[:, 1]

fpr, tpr, th = roc_curve(y_train, y_train_pred)

f1_scores = []
cur_th = None
def setClass(val):
  if val > cur_th:
    return 1
  else:
    return 0

for t in th:
  cur_th = t
  y_train_pred = np.array(list(map(setClass, y_train_pred_proba)))
  score = f1_score(y_train, y_train_pred, average= 'macro')
  f1_scores.append(score)

f1_scores = np.array(f1_scores)
max_idx = np.argmax(f1_scores)
final_th = th[max_idx]
final_th
```

```
0
```

```
cur_th = final_th
y_train_pred = np.array(list(map(setClass, y_train_pred_proba)))
score = f1_score(y_train, y_train_pred, average= 'macro')
score
```

```
0.6474639191293603
```

```
test_y_pred = np.array(list(map(setClass, test_y_pred_proba)))
score = f1_score(test_y, test_y_pred, average= 'macro')
score
```

```
0.5646132750465037
```

We can take 0 as final threshold value to predict the class labels.

But still without doing thresholding manually, we get much higher f1-score (0.92) directly with the oversampled random forest model.