# Social network Graph Link Prediction - Facebook Challenge

In [1]:

```
#Importing Libraries
# please do go through this python notebook:
import warnings
warnings.filterwarnings("ignore")

import csv
import pandas as pd#pandas to create small dataframes
import datetime #Convert to unix time
import time #Convert to unix time
# if numpy is not installed already : pip3 install numpy
import numpy as np#Do aritmetic operations on arrays
# matplotlib: used to plot graphs
import matplotlib
import matplotlib.pylab as plt
import seaborn as sns#Plots
from matplotlib import rcParams#Size of plots
from sklearn.cluster import MiniBatchKMeans, KMeans#Clustering
import math
import pickle
import os
# to install xgboost: pip3 install xgboost
import xgboost as xgb

import warnings
import networkx as nx
import pdb
import pickle
from pandas import HDFStore,DataFrame
from pandas import read_hdf
from scipy.sparse.linalg import svds, eigs
import gc
from tqdm import tqdm
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import f1_score
```

In [2]:

```
#reading
from pandas import read_hdf
df_final_train = read_hdf('data/fea_sample/storage_sample_stage4.h5', 'train_df',mode='r')
df_final_test = read_hdf('data/fea_sample/storage_sample_stage4.h5', 'test_df',mode='r')
```

In [3]:

```
df_final_train.columns
```

Out[3]:

```
Index(['source_node', 'destination_node', 'indicator_link',
       'jaccard_followers', 'jaccard_followees', 'cosine_followers',
       'cosine_followees', 'num_followers_s', 'num_followees_s',
       'num_followees_d', 'inter_followers', 'inter_followees', 'adar_index',
       'follows_back', 'same_comp', 'shortest_path', 'weight_in', 'weight_out',
       'weight_f1', 'weight_f2', 'weight_f3', 'weight_f4', 'page_rank_s',
       'page_rank_d', 'katz_s', 'katz_d', 'hubs_s', 'hubs_d', 'authorities_s',
       'authorities_d', 'svd_u_s_1', 'svd_u_s_2', 'svd_u_s_3', 'svd_u_s_4',
       'svd_u_s_5', 'svd_u_s_6', 'svd_u_d_1', 'svd_u_d_2', 'svd_u_d_3',
       'svd_u_d_4', 'svd_u_d_5', 'svd_u_d_6', 'svd_v_s_1', 'svd_v_s_2',
       'svd_v_s_3', 'svd_v_s_4', 'svd_v_s_5', 'svd_v_s_6', 'svd_v_d_1',
       'svd_v_d_2', 'svd_v_d_3', 'svd_v_d_4', 'svd_v_d_5', 'svd_v_d_6'],
      dtype='object')
```

In [4]:

```
y_train = df_final_train.indicator_link
```

```
y_test = df_final_test.indicator_link
```

In [5]:

```
df_final_train.drop(['source_node', 'destination_node','indicator_link'],axis=1,inplace=True)
df_final_test.drop(['source_node', 'destination_node','indicator_link'],axis=1,inplace=True)
```

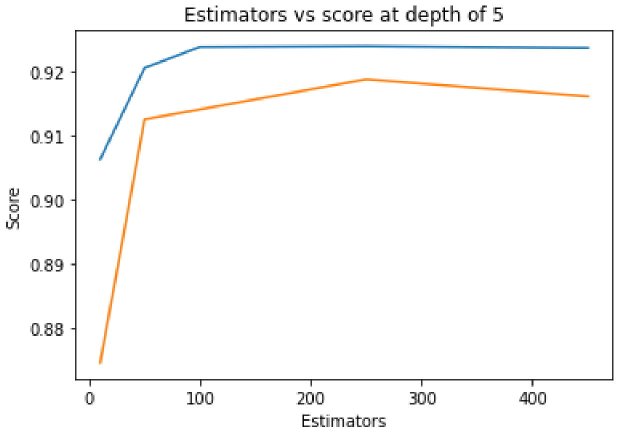
In [6]:

```
estimators = [10,50,100,250,450]
train_scores = []
test_scores = []
for i in estimators:
    clf = RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
            max_depth=5, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=52, min_samples_split=120,
            min_weight_fraction_leaf=0.0, n_estimators=i, n_jobs=-1,random_state=25,verbose=0,warm_
start=False)
    clf.fit(df_final_train,y_train)
    train_sc = f1_score(y_train,clf.predict(df_final_train))
    test_sc = f1_score(y_test,clf.predict(df_final_test))
    test_scores.append(test_sc)
    train_scores.append(train_sc)
    print('Estimators = ',i,'Train Score',train_sc,'test Score',test_sc)
plt.plot(estimators,train_scores,label='Train Score')
plt.plot(estimators,test_scores,label='Test Score')
plt.xlabel('Estimators')
plt.ylabel('Score')
plt.title('Estimators vs score at depth of 5')
```

```
Estimators =  10 Train Score 0.9063252121775113 test Score 0.8745605278006858
Estimators =  50 Train Score 0.9205725512208812 test Score 0.9125653355634538
Estimators =  100 Train Score 0.9238690848446947 test Score 0.9141199714153599
Estimators =  250 Train Score 0.9239789348046863 test Score 0.9188007232664732
Estimators =  450 Train Score 0.9237190618658074 test Score 0.9161507685828595
```

Out[6]:

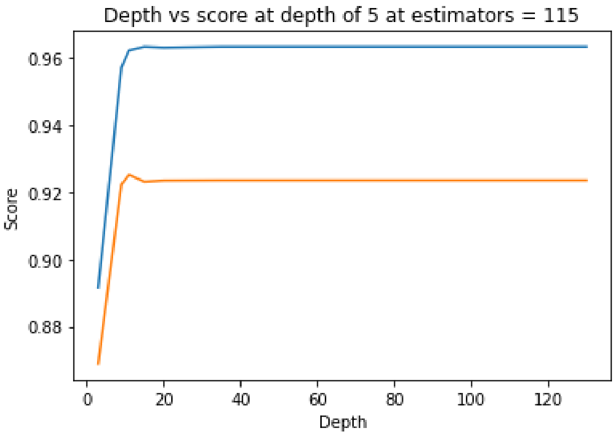
```
Text(0.5, 1.0, 'Estimators vs score at depth of 5')
```



In [7]:

```
depths = [3,9,11,15,20,35,50,70,130]
train_scores = []
test_scores = []
for i in depths:
    clf = RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
            max_depth=i, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=52, min_samples_split=120,
            min_weight_fraction_leaf=0.0, n_estimators=115, n_jobs=-1,random_state=25,verbose=0,war
m_start=False)
    clf.fit(df_final_train,y_train)
    train_sc = f1_score(y_train,clf.predict(df_final_train))
    test_sc = f1_score(y_test,clf.predict(df_final_test))
    test_scores.append(test_sc)
    train_scores.append(train_sc)
    print('depth = ',i,'Train Score',train_sc,'test Score',test_sc)
plt.plot(depths,train_scores,label='Train Score')
plt.plot(depths,test_scores,label='Test Score')
plt.xlabel('Depth')
plt.ylabel('Score')
plt.title('Depth vs score at depth of 5 at estimators = 115')
plt.show()
```

```
depth =  3 Train Score 0.8916120853581238 test Score 0.8687934859875491
depth =  9 Train Score 0.9572226298198419 test Score 0.9222953031452904
depth =  11 Train Score 0.9623451340902863 test Score 0.9252318758281279
depth =  15 Train Score 0.9634267621927706 test Score 0.9231288356496615
depth =  20 Train Score 0.9631629153051491 test Score 0.9235051024711141
depth =  35 Train Score 0.9634333127085721 test Score 0.9235601652753184
depth =  50 Train Score 0.9634333127085721 test Score 0.9235601652753184
depth =  70 Train Score 0.9634333127085721 test Score 0.9235601652753184
depth =  130 Train Score 0.9634333127085721 test Score 0.9235601652753184
```



In [10]:

```
from sklearn.metrics import f1_score
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import f1_score
from sklearn.model_selection import RandomizedSearchCV
from scipy.stats import randint as sp_randint
from scipy.stats import uniform

param_dist = {"n_estimators":sp_randint(105,125),
              "max_depth": sp_randint(10,15),
              "min_samples_split": sp_randint(110,190),
              "min_samples_leaf": sp_randint(25,65)}

clf = RandomForestClassifier(random_state=25,n_jobs=-1)

rf_random = RandomizedSearchCV(clf, param_distributions=param_dist,
                                   n_iter=5,cv=10,scoring='f1',random_state=25, return_train_score=
rue)

rf_random.fit(df_final_train,y_train)
print('mean test scores',rf_random.cv_results_['mean_test_score'])
print('mean train scores',rf_random.cv_results_['mean_train_score'])
```

```
mean test scores [0.96225043 0.96215493 0.96057081 0.96194015 0.96330005]
mean train scores [0.96294922 0.96266735 0.96115674 0.96263457 0.96430539]
```

In [11]:

```
print(rf_random.best_estimator_)
```

```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
                       max_depth=14, max_features='auto', max_leaf_nodes=None,
                       min_impurity_decrease=0.0, min_impurity_split=None,
                       min_samples_leaf=28, min_samples_split=111,
                       min_weight_fraction_leaf=0.0, n_estimators=121,
                       n_jobs=-1, oob_score=False, random_state=25, verbose=0,
                       warm_start=False)
```

In [12]:

```
clf = RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
            max_depth=14, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=28, min_samples_split=111,
            min_weight_fraction_leaf=0.0, n_estimators=121, n_jobs=-1,
            oob_score=False, random_state=25, verbose=0, warm_start=False)
```

In [13]:

```
clf.fit(df_final_train,y_train)
y_train_pred = clf.predict(df_final_train)
y_test_pred = clf.predict(df_final_test)
```

In [14]:

```
from sklearn.metrics import f1_score
print('Train f1 score',f1_score(y_train,y_train_pred))
print('Test f1 score',f1_score(y_test,y_test_pred))
```

```
Train f1 score 0.9652533106548414
Test f1 score 0.9241678239279553
```

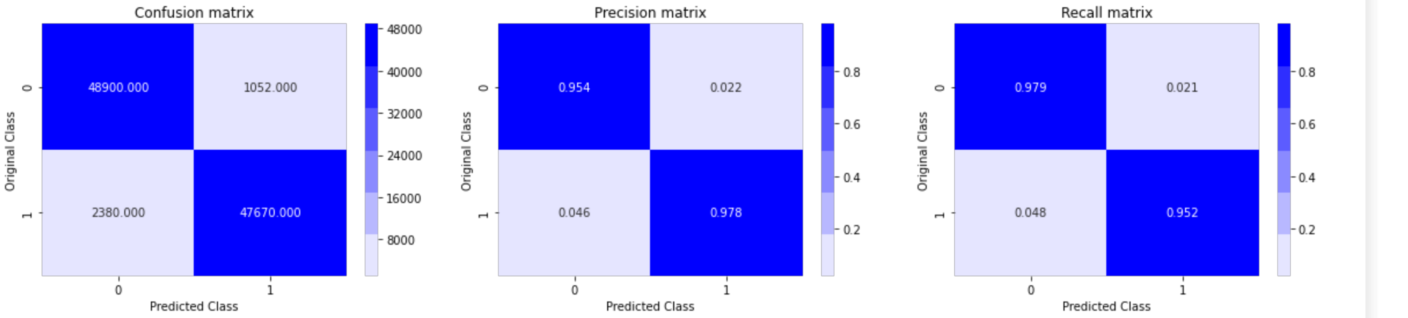
In [15]:

```
from sklearn.metrics import confusion_matrix
def plot_confusion_matrix(test_y, predict_y):
    C = confusion_matrix(test_y, predict_y)

    A =(((C.T)/(C.sum(axis=1))).T)

    B =(C/C.sum(axis=0))
    plt.figure(figsize=(20,4))

    labels = [0,1]
    # representing A in heatmap format
    cmap=sns.light_palette("blue")
    plt.subplot(1, 3, 1)
    sns.heatmap(C, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Confusion matrix")

    plt.subplot(1, 3, 2)
    sns.heatmap(B, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Precision matrix")

    plt.subplot(1, 3, 3)
    # representing B in heatmap format
    sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Recall matrix")

    plt.show()
```

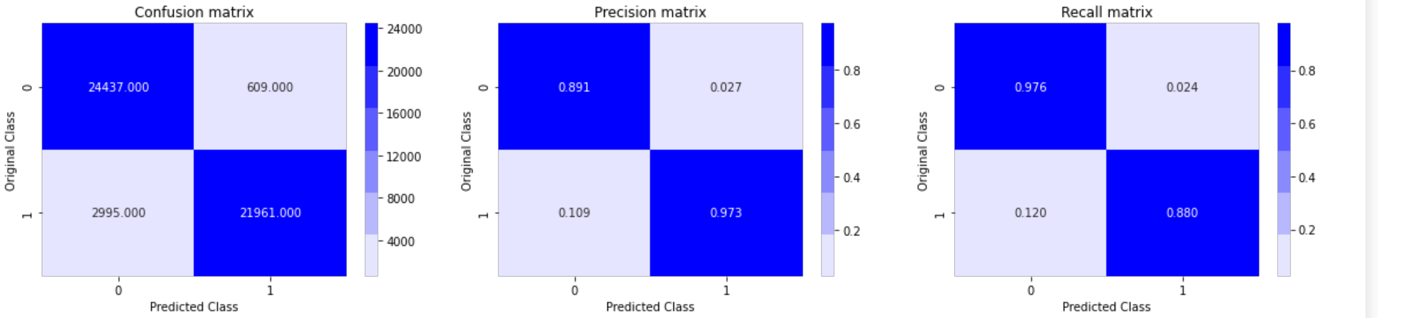
In [16]:

```
print('Train confusion_matrix')
plot_confusion_matrix(y_train,y_train_pred)
print('Test confusion_matrix')
plot_confusion_matrix(y_test,y_test_pred)
```

```
Train confusion_matrix
```

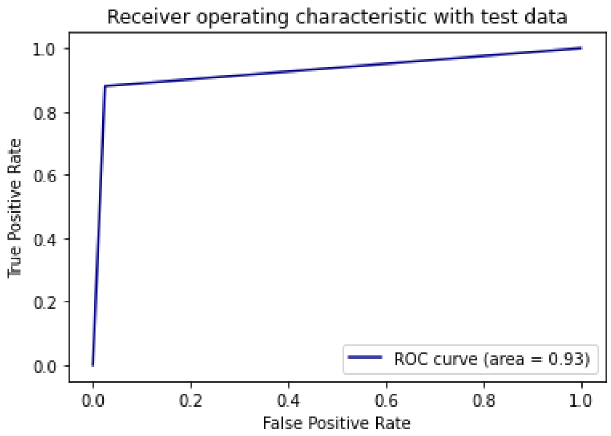


```
Test confusion_matrix
```



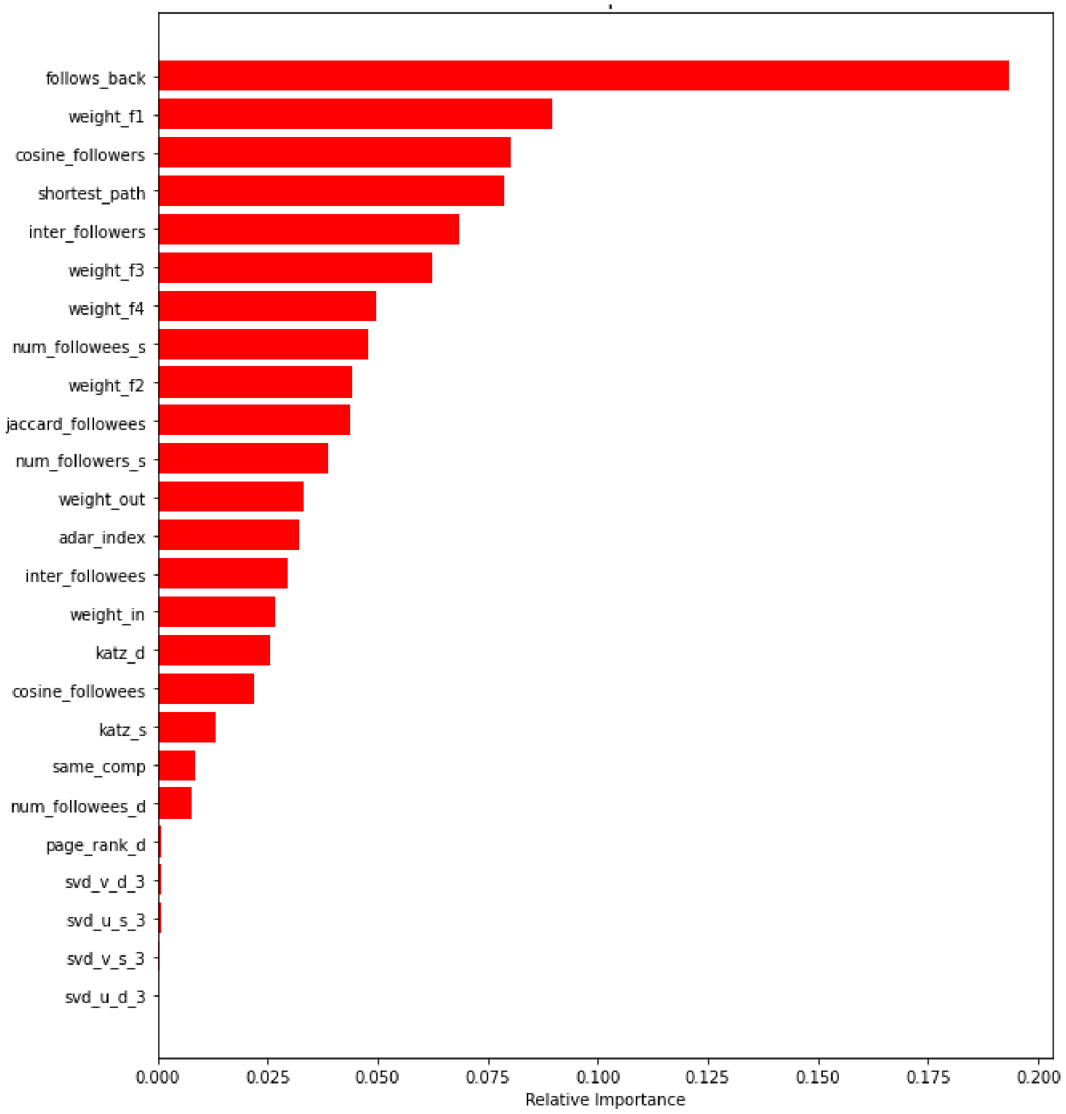
In [17]:

```python
from sklearn.metrics import roc_curve, auc
fpr,tpr,ths = roc_curve(y_test,y_test_pred)
auc_sc = auc(fpr, tpr)
plt.plot(fpr, tpr, color='navy',label='ROC curve (area = %0.2f)' % auc_sc)
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver operating characteristic with test data')
plt.legend()
plt.show()
```



In [18]:

```python
features = df_final_train.columns
importances = clf.feature_importances_
indices = (np.argsort(importances))[-25:]
plt.figure(figsize=(10,12))
plt.title('Feature Importances')
plt.barh(range(len(indices)), importances[indices], color='r', align='center')
plt.yticks(range(len(indices)), [features[i] for i in indices])
plt.xlabel('Relative Importance')
plt.show()
```



# Assignments:

1. Add another feature called Preferential Attachment with followers and followees data of vertex. you can check about Preferential Attachment in below link http://be.amazd.com/link-prediction/
2. Add feature called svd_dot. you can calculate svd_dot as Dot product between sourse node svd and destination node svd features. you can read about this in below pdf https://storage.googleapis.com/kaggle-forum-message-attachments/2594/supervised_link_prediction.pdf
3. Tune hyperparameters for XG boost with all these features and check the error metric.

## Preferential Attachment

### Preferential Attachement for followers

In [27]:

```
#for train dataset

train_followers_s = np.array(df_final_train['num_followers_s'])
train_followers_d = np.array(df_final_train['num_followees_d'])
preferential_followers=[]
for i in range(len(train_followers_s)):
    preferential_followers.append(train_followers_d[i]*train_followers_s[i])
df_final_train['preferential_followers']= preferential_followers
df_final_train.head()
```

Out[27]:

|  | jaccard_followers | jaccard_followees | cosine_followers | cosine_followees | num_followers_s | num_followees_s | num_followees_d | inter |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0.000000 | 0.000000 | 0.000000 | 6 | 15 | 8 |  |
| 1 | 0 | 0.187135 | 0.028382 | 0.343828 | 94 | 61 | 142 |  |
| 2 | 0 | 0.369565 | 0.156957 | 0.566038 | 28 | 41 | 22 |  |
| 3 | 0 | 0.000000 | 0.000000 | 0.000000 | 11 | 5 | 7 |  |
| 4 | 0 | 0.000000 | 0.000000 | 0.000000 | 1 | 11 | 3 |  |

5 rows × 54 columns

In [28]:

```
# for test dataset

test_followers_s = np.array(df_final_test['num_followers_s'])
test_followers_d = np.array(df_final_test['num_followees_d'])
preferential_followers=[]
for i in range(len(test_followers_s)):
    preferential_followers.append(test_followers_d[i]*test_followers_s[i])
df_final_test['preferential_followers']= preferential_followers
df_final_test.head()
```

Out[28]:

|  | jaccard_followers | jaccard_followees | cosine_followers | cosine_followees | num_followers_s | num_followees_s | num_followees_d | inter |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0.0 | 0.029161 | 0.000000 | 14 | 6 | 9 |  |
| 1 | 0 | 0.0 | 0.000000 | 0.000000 | 17 | 1 | 19 |  |
| 2 | 0 | 0.0 | 0.000000 | 0.000000 | 10 | 16 | 9 |  |
| 3 | 0 | 0.0 | 0.000000 | 0.000000 | 37 | 10 | 34 |  |
| 4 | 0 | 0.2 | 0.042767 | 0.347833 | 27 | 15 | 27 |  |

5 rows × 54 columns

### Preferential Attachement for followees

In [29]:

```
#for train dataset

train_followees_s = np.array(df_final_train['num_followees_s'])
train_followees_d = np.array(df_final_train['num_followees_d'])
preferential_followees=[]
for i in range(len(train_followees_s)):
    preferential_followees.append(train_followees_d[i]*train_followees_s[i])
df_final_train['preferential_followees']= preferential_followees
df_final_train.head()
```

Out[29]:

|  | jaccard_followers | jaccard_followees | cosine_followers | cosine_followees | num_followers_s | num_followees_s | num_followees_d | inter |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0.000000 | 0.000000 | 0.000000 | 6 | 15 | 8 |  |

|  | jaccard_followers | jaccard_followees | cosine_followers | cosine_followees | num_followers_s | num_followees_s | num_followees_d | inter |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.187135 | 0.028382 | 0.343828 | 94 | 61 | 142 |  |
| 2 | 0 | 0.369565 | 0.156957 | 0.566038 | 28 | 41 | 22 |  |
| 3 | 0 | 0.000000 | 0.000000 | 0.000000 | 11 | 5 | 7 |  |
| 4 | 0 | 0.000000 | 0.000000 | 0.000000 | 1 | 11 | 3 |  |

5 rows × 54 columns

In [30]:

```
#for test dataset

test_followees_s = np.array(df_final_test['num_followees_s'])
test_followees_d = np.array(df_final_test['num_followees_d'])
preferential_followees=[]
for i in range(len(test_followees_s)):
    preferential_followees.append(test_followees_d[i]*test_followees_s[i])
df_final_test['preferential_followees']= preferential_followees
df_final_test.head()
```

Out[30]:

|  | jaccard_followers | jaccard_followees | cosine_followers | cosine_followees | num_followers_s | num_followees_s | num_followees_d | inter |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0.0 | 0.029161 | 0.000000 | 14 | 6 | 9 |  |
| 1 | 0 | 0.0 | 0.000000 | 0.000000 | 17 | 1 | 19 |  |
| 2 | 0 | 0.0 | 0.000000 | 0.000000 | 10 | 16 | 9 |  |
| 3 | 0 | 0.0 | 0.000000 | 0.000000 | 37 | 10 | 34 |  |
| 4 | 0 | 0.2 | 0.042767 | 0.347833 | 27 | 15 | 27 |  |

5 rows × 54 columns

### SVD_dot

In [31]:

```
#for train datasets
su1,su2,su3,su4,su5,su6=df_final_train['svd_u_s_1'],df_final_train['svd_u_s_2'],df_final_train['svd_u_s_3'],df_final_train['svd_u_s_4'],df_final_train['svd_u_s_5'],df_final_train['svd_u_s_6']
sv1,sv2,sv3,sv4,sv5,sv6=df_final_train['svd_v_s_1'],df_final_train['svd_v_s_2'],df_final_train['svd_v_s_3'],df_final_train['svd_v_s_4'],df_final_train['svd_v_s_5'],df_final_train['svd_v_s_6']

du1,du2,du3,du4,du5,du6=df_final_train['svd_u_d_1'],df_final_train['svd_u_d_2'],df_final_train['svd_u_d_3'],df_final_train['svd_u_d_4'],df_final_train['svd_u_d_5'],df_final_train['svd_u_d_6']
dv1,dv2,dv3,dv4,dv5,dv6=df_final_train['svd_v_d_1'],df_final_train['svd_v_d_2'],df_final_train['svd_v_d_3'],df_final_train['svd_v_d_4'],df_final_train['svd_v_d_5'],df_final_train['svd_v_d_6']
```

In [32]:

```
su = np.array([su1,su2,su3,su4,su5,su6]).T
sv = np.array([sv1,sv2,sv3,sv4,sv5,sv6]).T
print(su.shape)
print(sv.shape)
```

```
(100002, 6)
(100002, 6)
```

In [33]:

```
du = np.array([du1,du2,du3,du4,du5,du6]).T
dv = np.array([dv1,dv2,dv3,dv4,dv5,dv6]).T
print(du.shape)
print(dv.shape)
```

```
(100002, 6)
(100002, 6)
```

In [34]:

```
u_dot = []
v_dot = []
for ea in range(su.shape[0]):
    u_dot.append(np.dot(su[ea],du[ea]))
    v_dot.append(np.dot(sv[ea],dv[ea]))
df_final_train['ud_dot']=u_dot
df_final_train['vd_dot']=v_dot
```

In [35]:

```
#for test datasets
su1,su2,su3,su4,su5,su6=df_final_test['svd_u_s_1'],df_final_test['svd_u_s_2'],df_final_test['svd_u_
s_3'],df_final_test['svd_u_s_4'],df_final_test['svd_u_s_5'],df_final_test['svd_u_s_6']
sv1,sv2,sv3,sv4,sv5,sv6=df_final_test['svd_v_s_1'],df_final_test['svd_v_s_2'],df_final_test['svd_v_
s_3'],df_final_test['svd_v_s_4'],df_final_test['svd_v_s_5'],df_final_test['svd_v_s_6']

du1,du2,du3,du4,du5,du6=df_final_test['svd_u_d_1'],df_final_test['svd_u_d_2'],df_final_test['svd_u_
d_3'],df_final_test['svd_u_d_4'],df_final_test['svd_u_d_5'],df_final_test['svd_u_d_6']
dv1,dv2,dv3,dv4,dv5,dv6=df_final_test['svd_v_d_1'],df_final_test['svd_v_d_2'],df_final_test['svd_v_
d_3'],df_final_test['svd_v_d_4'],df_final_test['svd_v_d_5'],df_final_test['svd_v_d_6']
```

In [36]:

```
su = np.array([su1,su2,su3,su4,su5,su6]).T
sv = np.array([sv1,sv2,sv3,sv4,sv5,sv6]).T
print(su.shape)
print(sv.shape)

du = np.array([du1,du2,du3,du4,du5,du6]).T
dv = np.array([dv1,dv2,dv3,dv4,dv5,dv6]).T
print(du.shape)
print(dv.shape)
```

```
(50002, 6)
(50002, 6)
(50002, 6)
(50002, 6)
```

In [37]:

```
u_dot = []
v_dot = []
for ea in range(su.shape[0]):
    u_dot.append(np.dot(su[ea],du[ea]))
    v_dot.append(np.dot(sv[ea],dv[ea]))
df_final_test['ud_dot']=u_dot
df_final_test['vd_dot']=v_dot
```

In [38]:

```
hdf = HDFStore('storage_sample_stage4.h5')
hdf.put('train_df',df_final_train, format='table', data_columns=True)
hdf.put('test_df',df_final_test, format='table', data_columns=True)
hdf.close()
```

## Models

In [39]:

```
#reading
from pandas import read_hdf
df_final_train = read_hdf('data/fea_sample/storage_sample_stage4.h5', 'train_df',mode='r')
df_final_test = read_hdf('data/fea_sample/storage_sample_stage4.h5', 'test_df',mode='r')
```

In [40]:

```
y_train = df_final_train.indicator_link
y_test = df_final_test.indicator_link
```

In [41]:

```
df_final_train.drop(['source_node', 'destination_node','indicator_link'],axis=1,inplace=True)
df_final_test.drop(['source_node', 'destination_node','indicator_link'],axis=1,inplace=True)
```

## Random Forest

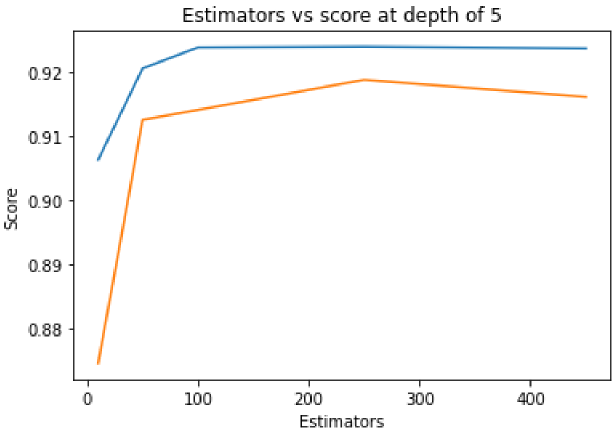
In [43]:

```
estimators = [10,50,100,250,450]
train_scores = []
test_scores = []
for i in estimators:
    clf = RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
            max_depth=5, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=52, min_samples_split=120,
            min_weight_fraction_leaf=0.0, n_estimators=i, n_jobs=-1,random_state=25,verbose=0,warm_
start=False)
    clf.fit(df_final_train,y_train)
    train_sc = f1_score(y_train,clf.predict(df_final_train))
    test_sc = f1_score(y_test,clf.predict(df_final_test))
    test_scores.append(test_sc)
    train_scores.append(train_sc)
    print('Estimators = ',i,'Train Score',train_sc,'test Score',test_sc)
plt.plot(estimators,train_scores,label='Train Score')
plt.plot(estimators,test_scores,label='Test Score')
plt.xlabel('Estimators')
plt.ylabel('Score')
plt.title('Estimators vs score at depth of 5')
```

```
Estimators =  10 Train Score 0.9063252121775113 test Score 0.8745605278006858
Estimators =  50 Train Score 0.9205725512208812 test Score 0.9125653355634538
Estimators =  100 Train Score 0.9238690848446947 test Score 0.9141199714153599
Estimators =  250 Train Score 0.9239789348046863 test Score 0.9188007232664732
Estimators =  450 Train Score 0.9237190618658074 test Score 0.9161507685828595
```

Out[43]:

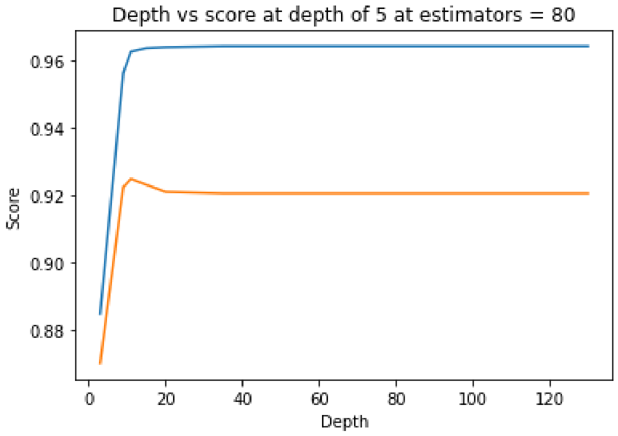
```
Text(0.5, 1.0, 'Estimators vs score at depth of 5')
```



In [44]:

```
depths = [3,9,11,15,20,35,50,70,130]
train_scores = []
test_scores = []
for i in depths:
    clf = RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
            max_depth=i, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=52, min_samples_split=120,
            min_weight_fraction_leaf=0.0, n_estimators=80, n_jobs=-1,random_state=25,verbose=0,warm
_start=False)
    clf.fit(df_final_train,y_train)
    train_sc = f1_score(y_train,clf.predict(df_final_train))
    test_sc = f1_score(y_test,clf.predict(df_final_test))
    test_scores.append(test_sc)
    train_scores.append(train_sc)
    print('depth = ',i,'Train Score',train_sc,'test Score',test_sc)
plt.plot(depths,train_scores,label='Train Score')
plt.plot(depths,test_scores,label='Test Score')
plt.xlabel('Depth')
plt.ylabel('Score')
plt.title('Depth vs score at depth of 5 at estimators = 80')
plt.show()
```

```
depth =  3 Train Score 0.8849759014352744 test Score 0.8702997392634731
depth =  9 Train Score 0.9562150923396796 test Score 0.9224417575936302
depth =  11 Train Score 0.9625550214000284 test Score 0.9248817407757806
depth =  15 Train Score 0.9635776387421792 test Score 0.9231678486997635
depth =  20 Train Score 0.9638512691590301 test Score 0.9210487397798577
depth =  35 Train Score 0.9641481901828057 test Score 0.9205993617515903
depth =  50 Train Score 0.9641481901828057 test Score 0.9205993617515903
depth =  70 Train Score 0.9641481901828057 test Score 0.9205993617515903
depth =  130 Train Score 0.9641481901828057 test Score 0.9205993617515903
```



In [46]:

```
from sklearn.metrics import f1_score
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import f1_score
from sklearn.model_selection import RandomizedSearchCV
from scipy.stats import randint as sp_randint
from scipy.stats import uniform

param_dist = {"n_estimators":sp_randint(50,100),
              "max_depth": sp_randint(10,20),
              "min_samples_split": sp_randint(110,190),
              "min_samples_leaf": sp_randint(25,65)}

clf = RandomForestClassifier(random_state=25,n_jobs=-1)

rf_random = RandomizedSearchCV(clf, param_distributions=param_dist,
                                   n_iter=5,cv=10,scoring='f1',random_state=25, return_train_score=
rue)
```

```
rf_random.fit(df_final_train,y_train)
print('mean test scores',rf_random.cv_results_['mean_test_score'])
print('mean train scores',rf_random.cv_results_['mean_train_score'])
```

```
mean test scores [0.96265992 0.96158474 0.96200118 0.963598   0.96370982]
mean train scores [0.96314184 0.96238398 0.96263138 0.96481945 0.9645718 ]
```

In [47]:

```
print(rf_random.best_estimator_)
```

```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
                       max_depth=14, max_features='auto', max_leaf_nodes=None,
                       min_impurity_decrease=0.0, min_impurity_split=None,
                       min_samples_leaf=28, min_samples_split=111,
                       min_weight_fraction_leaf=0.0, n_estimators=72, n_jobs=-1,
                       oob_score=False, random_state=25, verbose=0,
                       warm_start=False)
```

## Best Parameters found

max_depth = 14, n_estimators = 72, min_samples_leaf=28, min_samples_split=111

In [49]:

```
clf = RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
            max_depth=14, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=28, min_samples_split=111,
            min_weight_fraction_leaf=0.0, n_estimators=72, n_jobs=-1,
            oob_score=False, random_state=25, verbose=0, warm_start=False)
```

In [50]:

```
clf.fit(df_final_train,y_train)
y_train_pred = clf.predict(df_final_train)
y_test_pred = clf.predict(df_final_test)
```

In [51]:

```
from sklearn.metrics import f1_score
print('Train f1 score',f1_score(y_train,y_train_pred))
print('Test f1 score',f1_score(y_test,y_test_pred))
```

```
Train f1 score 0.9651837915478141
Test f1 score 0.9219529654504495
```

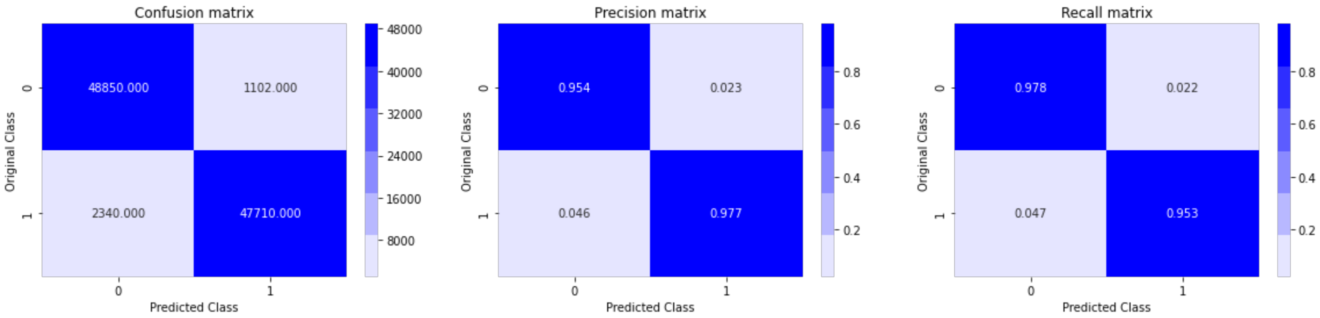
In [52]:

```
from sklearn.metrics import confusion_matrix
def plot_confusion_matrix(test_y, predict_y):
    C = confusion_matrix(test_y, predict_y)

    A =(((C.T)/(C.sum(axis=1))).T)

    B =(C/C.sum(axis=0))
    plt.figure(figsize=(20,4))

    labels = [0,1]
    # representing A in heatmap format
    cmap=sns.light_palette("blue")
    plt.subplot(1, 3, 1)
    sns.heatmap(C, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Confusion matrix")

    plt.subplot(1, 3, 2)
    sns.heatmap(B, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Precision matrix")

    plt.subplot(1, 3, 3)
    # representing B in heatmap format
    sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Recall matrix")

    plt.show()
```

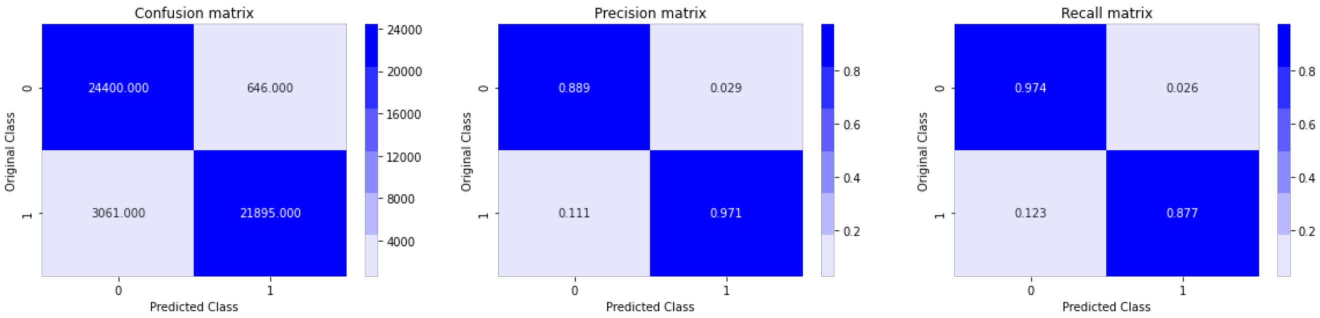
In [53]:

```
print('Train confusion_matrix')
plot_confusion_matrix(y_train,y_train_pred)
print('Test confusion_matrix')
plot_confusion_matrix(y_test,y_test_pred)
```

```
Train confusion_matrix
```

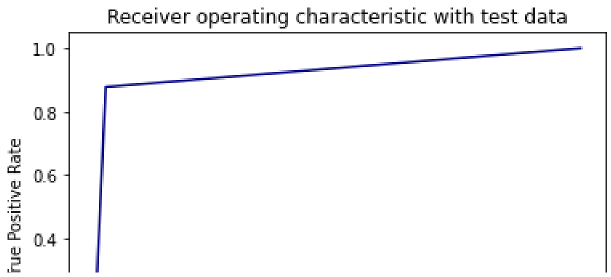


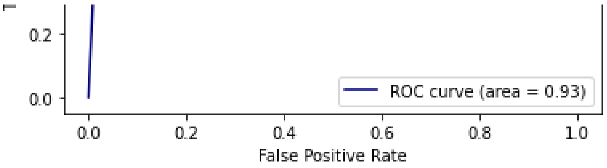
```
Test confusion_matrix
```



In [54]:

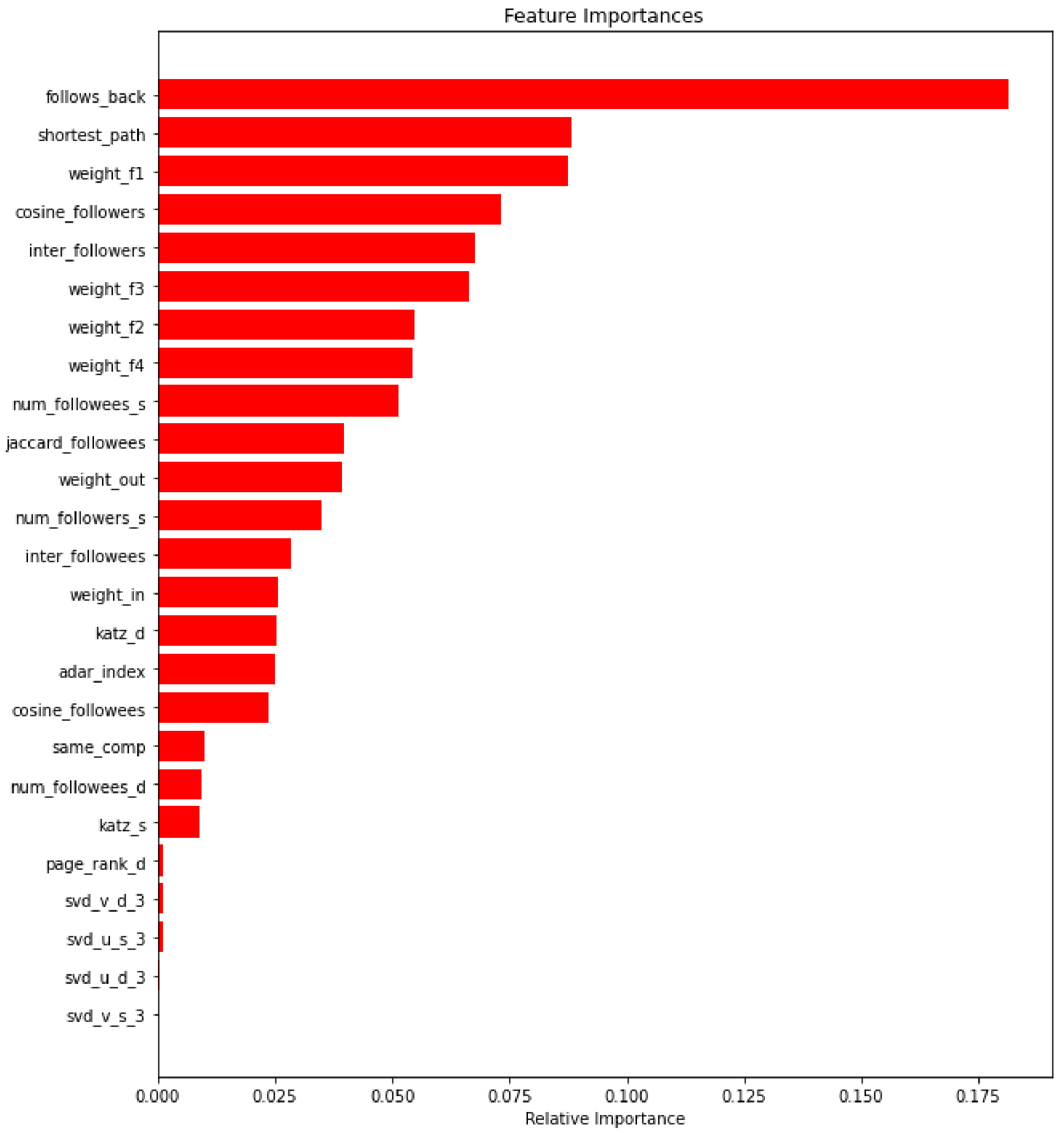
```
from sklearn.metrics import roc_curve, auc
fpr,tpr,ths = roc_curve(y_test,y_test_pred)
auc_sc = auc(fpr, tpr)
plt.plot(fpr, tpr, color='navy',label='ROC curve (area = %0.2f)' % auc_sc)
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver operating characteristic with test data')
plt.legend()
plt.show()
```





In [55]:

```
features = df_final_train.columns
importances = clf.feature_importances_
indices = (np.argsort(importances))[-25:]
plt.figure(figsize=(10,12))
plt.title('Feature Importances')
plt.barh(range(len(indices)), importances[indices], color='r', align='center')
plt.yticks(range(len(indices)), [features[i] for i in indices])
plt.xlabel('Relative Importance')
plt.show()
```



## XGBOOST (Tuning)

In [57]:

```
import xgboost as xgb
clf = xgb.XGBClassifier()
param_dist = {"n_estimators":sp_randint(50,100),
              "max_depth": sp_randint(10,20)
              }
model = RandomizedSearchCV(clf, param_distributions=param_dist,
                                   n_iter=5,cv=3,scoring='f1',random_state=25, return_train_score=T
ue)


model.fit(df_final_train,y_train)
print('mean test scores',model.cv_results_['mean_test_score'])
print('mean train scores',model.cv_results_['mean_train_score'])
```

```
mean test scores [0.97880937 0.9784645  0.97809646 0.97882821 0.97802711]
mean train scores [0.99828396 0.99972021 0.99126111 0.99822881 0.99668854]
```

In [58]:

```
print(model.best_estimator_)
```

```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=1, gamma=0,
              learning_rate=0.1, max_delta_step=0, max_depth=14,
              min_child_weight=1, missing=None, n_estimators=75, n_jobs=1,
              nthread=None, objective='binary:logistic', random_state=0,
              reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
              silent=None, subsample=1, verbosity=1)
```

## Best Parameter found

max_depth = 14, n_estimators = 76

In [60]:

```
clf=xgb.XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=14, min_child_weight=1, missing=None, n_estimators=76,
       n_jobs=1, nthread=None, objective='binary:logistic', random_state=0,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
       silent=True, subsample=1)
```

In [61]:

```
clf.fit(df_final_train,y_train)
y_train_pred = clf.predict(df_final_train)
y_test_pred = clf.predict(df_final_test)
```

In [62]:

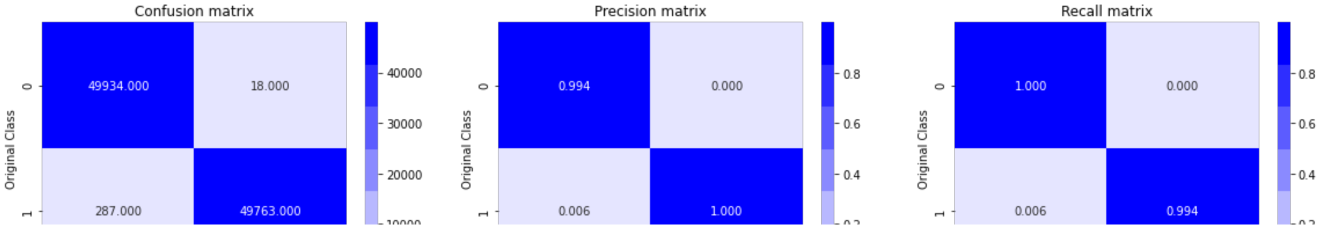
```
from sklearn.metrics import f1_score
print('Train f1 score',f1_score(y_train,y_train_pred))
print('Test f1 score',f1_score(y_test,y_test_pred))
```

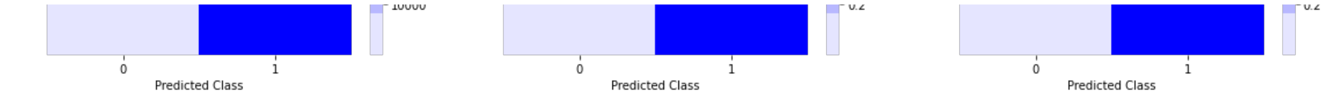
```
Train f1 score 0.9969448367741482
Test f1 score 0.9278612765777033
```

In [63]:

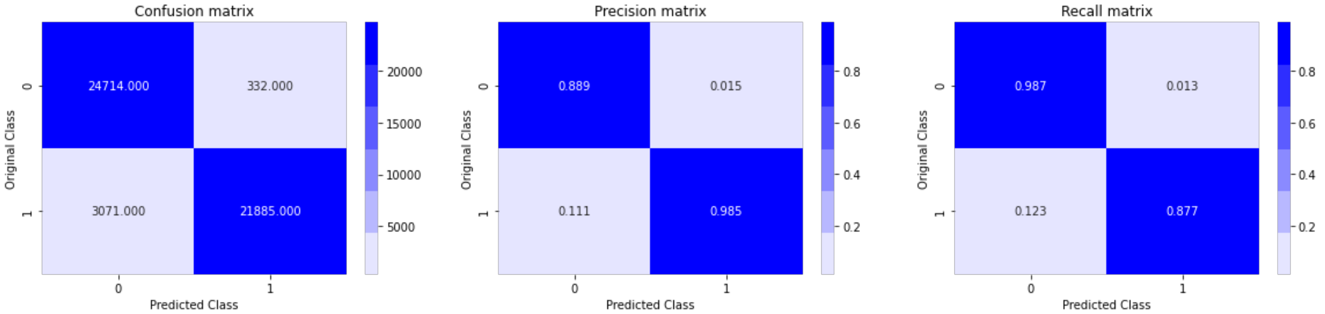
```
print('Train confusion_matrix')
plot_confusion_matrix(y_train,y_train_pred)
print('Test confusion_matrix')
plot_confusion_matrix(y_test,y_test_pred)
```

```
Train confusion_matrix
```



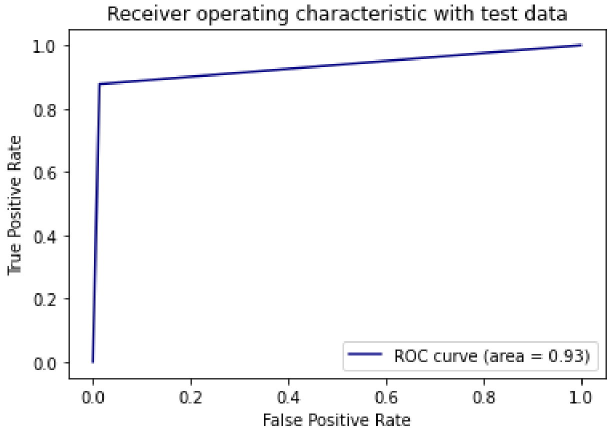


```
Test confusion_matrix
```



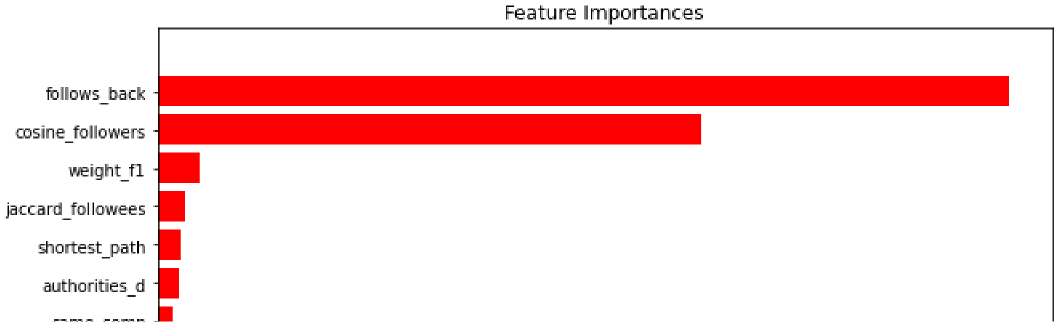
In [64]:

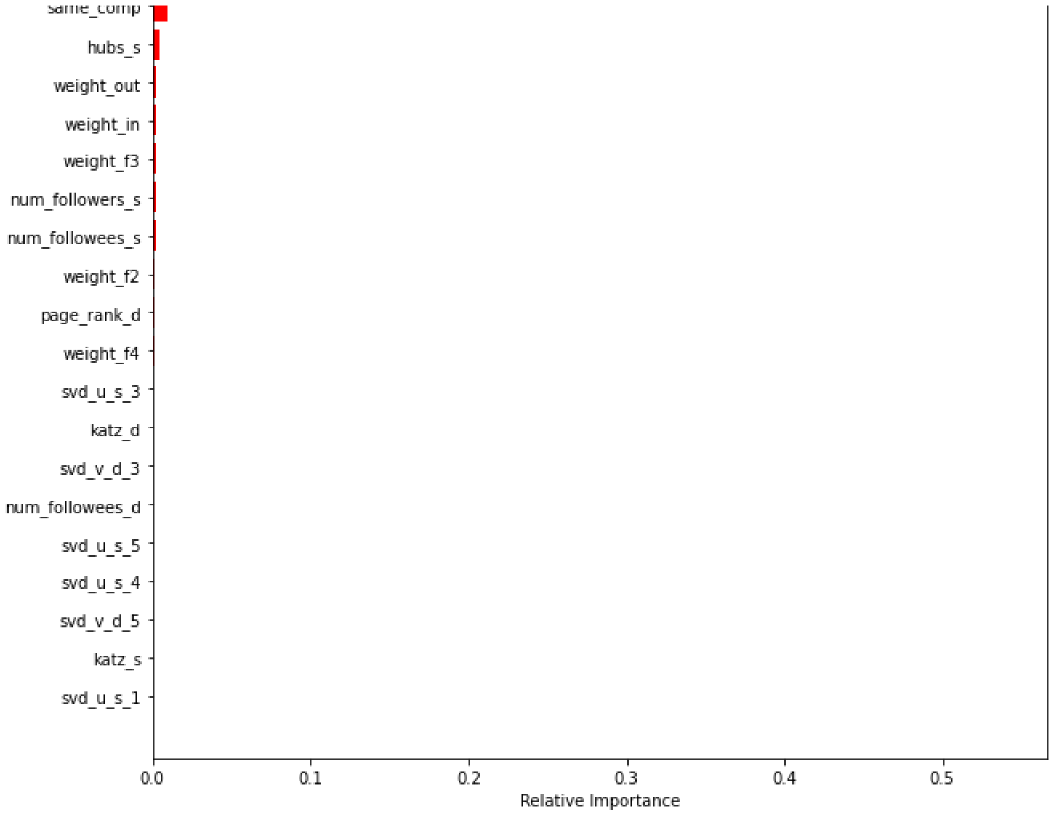
```
from sklearn.metrics import roc_curve, auc
fpr,tpr,ths = roc_curve(y_test,y_test_pred)
auc_sc = auc(fpr, tpr)
plt.plot(fpr, tpr, color='navy',label='ROC curve (area = %0.2f)' % auc_sc)
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver operating characteristic with test data')
plt.legend()
plt.show()
```



In [65]:

```
features = df_final_train.columns
importances = clf.feature_importances_
indices = (np.argsort(importances))[-25:]
plt.figure(figsize=(10,12))
plt.title('Feature Importances')
plt.barh(range(len(indices)), importances[indices], color='r', align='center')
plt.yticks(range(len(indices)), [features[i] for i in indices])
plt.xlabel('Relative Importance')
plt.show()
```





In [66]:

```
from prettytable import PrettyTable
summary = PrettyTable()
summary.field_names = ["Model", "n_estimators", "max_depth", "Train f1-Score","Test f1-Score"]
```

In [67]:

```
summary.add_row(['Random Forest','72','14','0.962','0.926'])
summary.add_row(['XGBOOST','76','14','0.996','0.927'])
print(summary)
```

```
+---------------+--------------+-----------+----------------+---------------+
|     Model     | n_estimators | max_depth | Train f1-Score | Test f1-Score |
+---------------+--------------+-----------+----------------+---------------+
| Random Forest |      72      |     14    |     0.962      |     0.926     |
|    XGBOOST    |      76      |     14    |     0.996      |     0.927     |
+---------------+--------------+-----------+----------------+---------------+
```

In [ ]: