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
```

```
C:\ProgramData\Anaconda3\lib\site-packages\sklearn\ensemble\weight_boosting.py:
29: DeprecationWarning: numpy.core.umath_tests is an internal NumPy module and
should not be imported. It will be removed in a future NumPy release.
  from numpy.core.umath_tests import inner1d
```

In [0]:
```
#reading
from pandas import read_hdf
df_final_train = read_hdf('data/fea_sample/storage_sample_stage4.h5', 'train
df_final_test = read_hdf('data/fea_sample/storage_sample_stage4.h5', 'test_d
```

In [0]:
```
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')
```

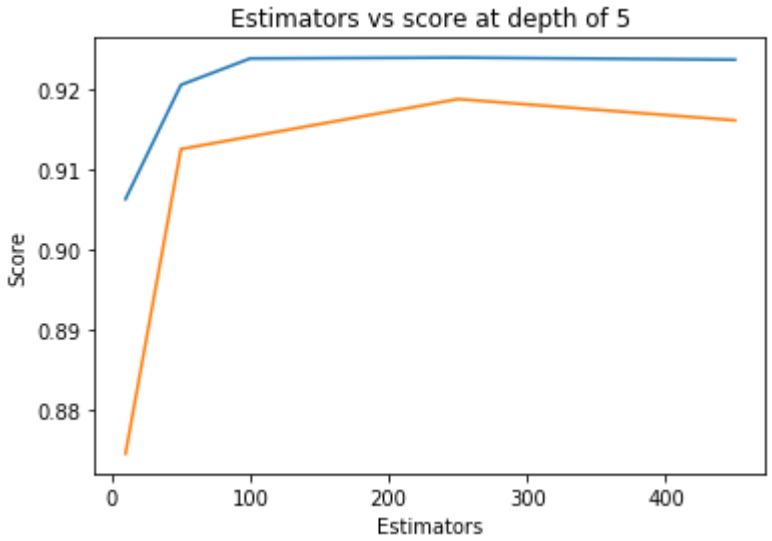
In [0]:
```
y_train = df_final_train.indicator_link
y_test = df_final_test.indicator_link
```

In [0]:
```
df_final_train.drop(['source_node', 'destination_node','indicator_link'],axi
df_final_test.drop(['source_node', 'destination_node','indicator_link'],axis
```

In [0]:
```
estimators = [10,50,100,250,450]
train_scores = []
test_scores = []
for i in estimators:
    clf = RandomForestClassifier(bootstrap=True, class_weight=None, criterio
            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_s
    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')
```

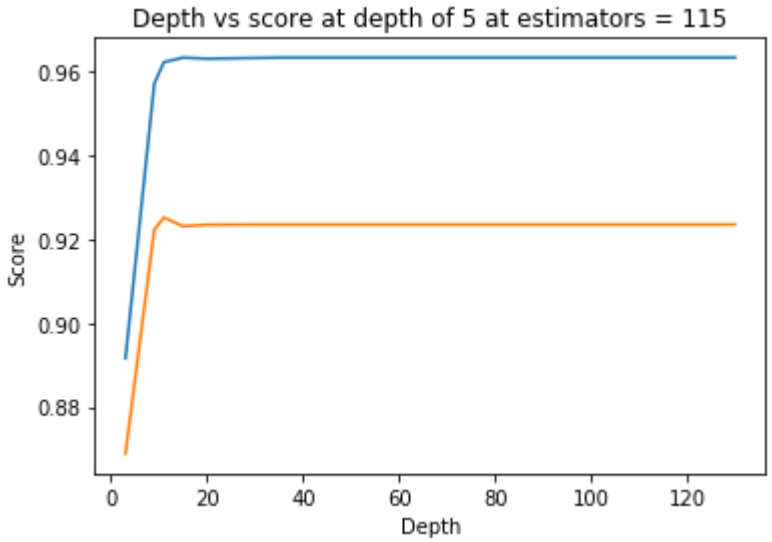
```
Estimators =  10 Train Score 0.9063252121775113 test Score 0.8745605278006858
Estimators =  50 Train Score 0.9205725512208812 test Score 0.9125653355634538
Estimators =  100 Train Score 0.9238690848446947 test Score 0.9141199714153599
Estimators =  250 Train Score 0.9239789348046863 test Score 0.9188007232664732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

Out[6]: Text(0.5,1,'Estimators vs score at depth of 5')



In [0]:
```
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, criterio
            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
    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 [0]:
```
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=

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 [0]:
```
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 [0]:
```
clf = RandomForestClassifier(bootstrap=True, class_weight=None, criterion='g
            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 [0]:
```
clf.fit(df_final_train,y_train)
y_train_pred = clf.predict(df_final_train)
y_test_pred = clf.predict(df_final_test)
```

In [0]:
```
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))
```

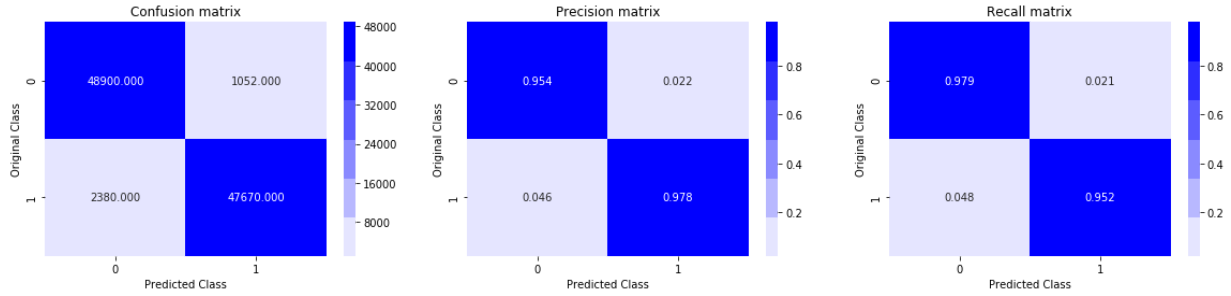
```
Train f1 score 0.9652533106548414
Test f1 score 0.9241678239279553
```

In [61]:

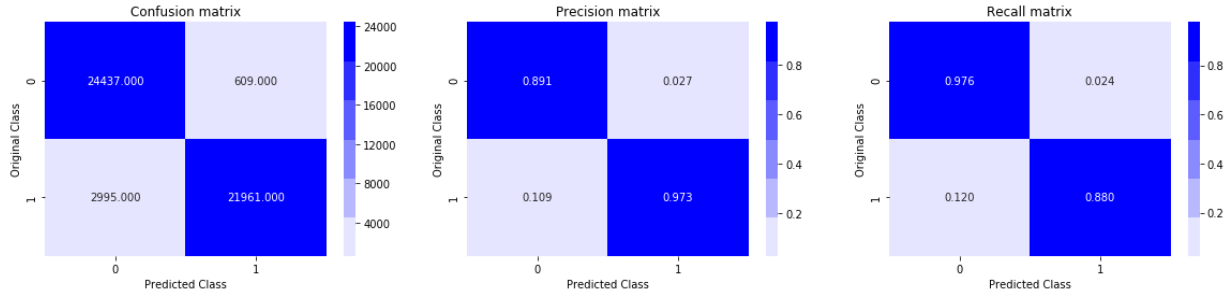
```
from sklearn.metrics import confusion_matrix
def plot_confusion_matrix(test_y, predict_y):
    C = confusion_matrix(test_y, predict_y)

    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, yti
    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, yti
    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, yti
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Recall matrix")

    plt.show()
```

In [0]:
```
print('Train confusion_matrix')
plot_confusion_matrix(y_train,y_train_pred)
print('Test confusion_matrix')
plot_confusion_matrix(y_test,y_test_pred)
```

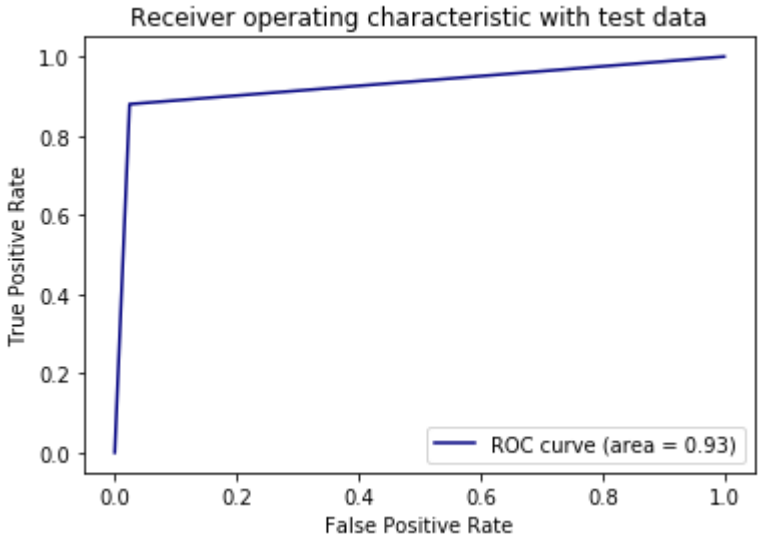
Train confusion_matrix



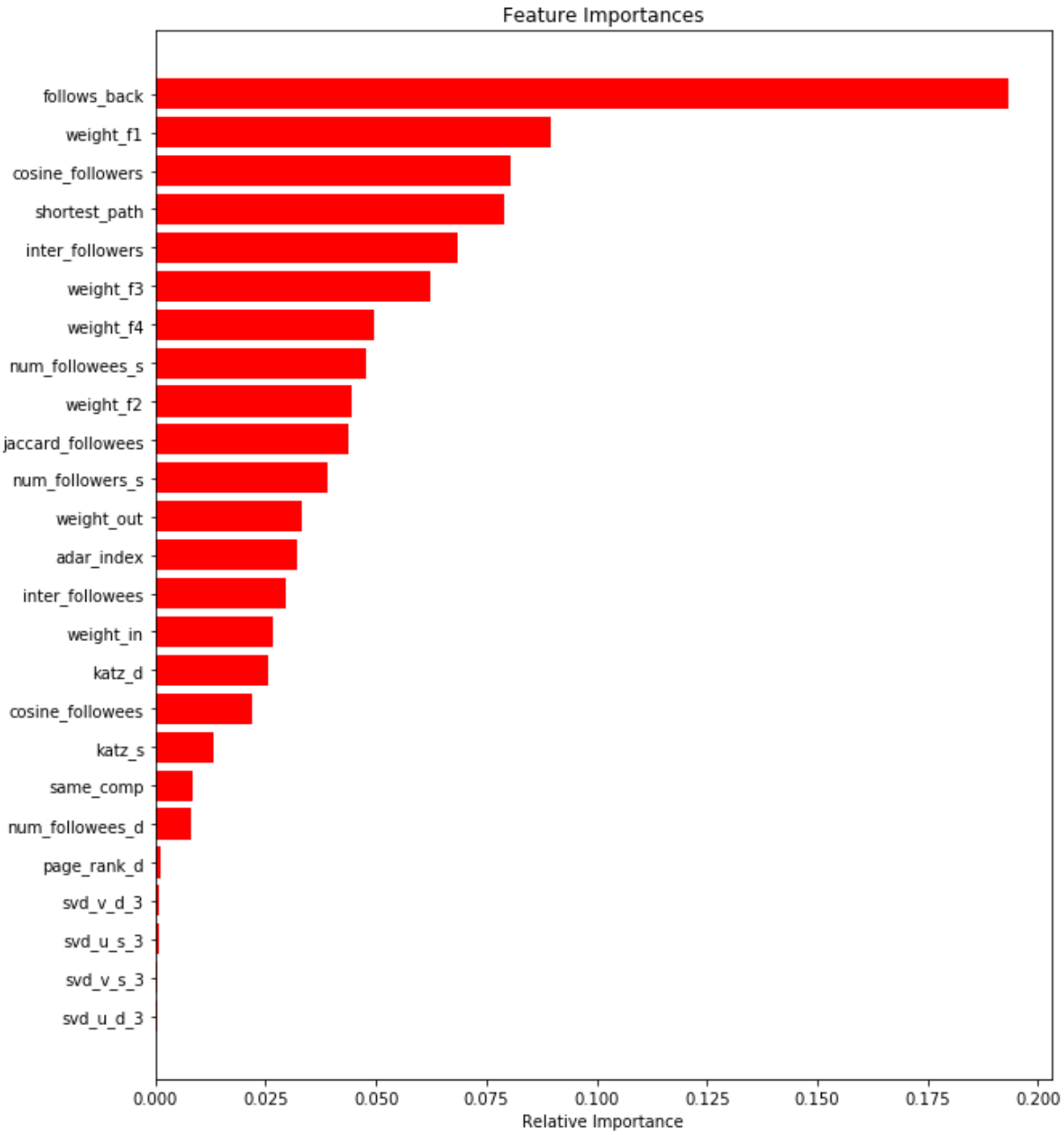
Test confusion_matrix



In [0]:
```
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 [0]:
```
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/ (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 (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.

In [31]:
```
#reading
from pandas import read_hdf
X_train = read_hdf('data/fea_sample/storage_sample_stage5.h5', 'train_df',mo
X_test = read_hdf('data/fea_sample/storage_sample_stage5.h5', 'test_df',mode
```

In [32]:
```
Y_train = X_train.indicator_link
Y_test = X_test.indicator_link
X_train.drop(['source_node', 'destination_node','indicator_link'],axis=1,inp
X_test.drop(['source_node', 'destination_node','indicator_link'],axis=1,inpl
predictors = X_train.columns
```

In [55]:
```
predictors = [str(x) for x in X_train.columns]
```

In [33]:
```
X_train.columns
```

Out[33]:
```
Index(['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',
       'svd_dot_U_U', 'svd_dot_U_V', 'svd_dot_V_V',
       'preferential_attachment_followers',
       'preferential_attachment_followees'],
      dtype='object')
```

In [34]:
```
1 X_test.columns
```

Out[34]:
```
Index(['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',
       'svd_dot_U_U', 'svd_dot_U_V', 'svd_dot_V_V',
       'preferential_attachment_followers',
       'preferential_attachment_followees'],
      dtype='object')
```

In [22]:
```
1  import xgboost
2  from xgboost import XGBClassifier
3  from sklearn import metrics
4  from xgboost import plot_importance
5
6  def plot_features(booster, figsize):
7      fig, ax = plt.subplots(1,1,figsize=figsize)
8
9      return plot_importance(booster=booster, ax=ax, max_num_features=40)
10
11 def xgb_model(model,train_, test_):
12     xgb_param = model.get_xgb_params()
13     xgtrain = xgboost.DMatrix(train_, label = Y_train)
14     cv_result = xgboost.cv(xgb_param, xgtrain,
15                            num_boost_round=model.get_params()['n_estimators'
16                            metrics= 'auc',
17                            early_stopping_rounds=50)
18     model.set_params(n_estimators =cv_result.shape[0])
19     model.fit(train_, Y_train, eval_metric='auc')
20     train_predict = model.predict(train_)
21     train_predict_proba = model.predict_proba(train_)[:,-1]
22     print("Train Accuracy : %.4g" % metrics.accuracy_score(Y_train, train_pr
23     print("AUC Score (Train): %f" % metrics.roc_auc_score(Y_train, train_pre
24     print('#'*50)
25     test_predict = model.predict(test_)
26     test_predict_proba = model.predict_proba(test_)[:,-1]
27     print("Test Accuracy : %.4g" % metrics.accuracy_score(Y_test, test_predi
28     print("AUC Score (test): %f" % metrics.roc_auc_score(Y_test, test_predic
29     model.get_booster().feature_names = predictors
30     plot_features(model, (16,27))
31
32
```

In [23]:
```
from sklearn.model_selection import GridSearchCV
param_test1 = {
 'max_depth':range(6,14,2),
 'min_child_weight':range(1,6,2)
}
gsearch1 = GridSearchCV(
    estimator = XGBClassifier(learning_rate =0.1,
                              n_estimators=140,
                              gamma=0,
                              subsample=0.8,
                              colsample_bytree=0.8,
                              objective= 'binary:logistic',
                              nthread=4,
                              scale_pos_weight=1,
                              seed=27),
    param_grid = param_test1,
    scoring='roc_auc',
    n_jobs=3,
    iid=False,
    cv=5)
gsearch1.fit(X_train,Y_train)
# gsearch1.grid_scores_, gsearch1.best_params_, gsearch1.best_score_gb1, (15
```

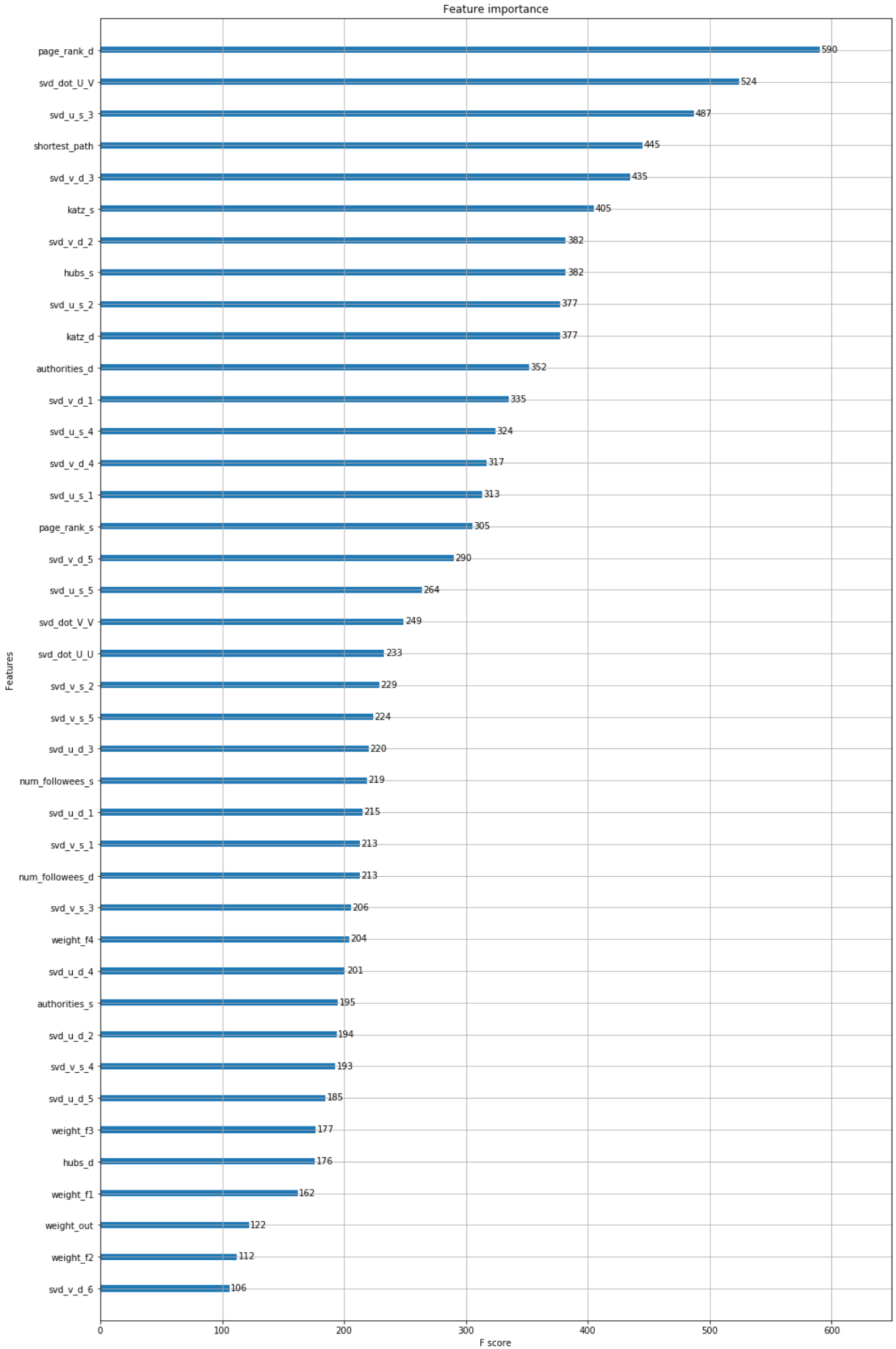
Out[23]:
```
GridSearchCV(cv=5, error_score='raise',
       estimator=XGBClassifier(base_score=0.5, booster='gbtree', colsample_byle
vel=1,
       colsample_bynode=1, colsample_bytree=0.8, gamma=0,
       learning_rate=0.1, max_delta_step=0, max_depth=5,
       min_child_weight=1, missing=None, n_estimators=140, n_jobs=1,
       nthread=4, objective='binary:logistic', random_state=0, reg_alpha=0,
       reg_lambda=1, scale_pos_weight=1, seed=27, silent=None,
       subsample=0.8, verbosity=1),
       fit_params=None, iid=False, n_jobs=3,
       param_grid={'max_depth': range(6, 14, 2), 'min_child_weight': range(1,
6, 2)},
       pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
       scoring='roc_auc', verbose=0)
```

In [24]:
```
gsearch1.best_params_
```

Out[24]:
```
{'max_depth': 12, 'min_child_weight': 5}
```

In [59]:
```
xgb1 = XGBClassifier(learning_rate =0.1,
                                n_estimators=140,
                                max_depth=12,
                                min_child_weight=5,
                                gamma=0,
                                subsample=0.8,
                                colsample_bytree=0.8,
                                objective= 'binary:logistic',
                                nthread=4,
                                scale_pos_weight=1,
                                seed=27)
xgb_model(xgb1,X_train,X_test)
```

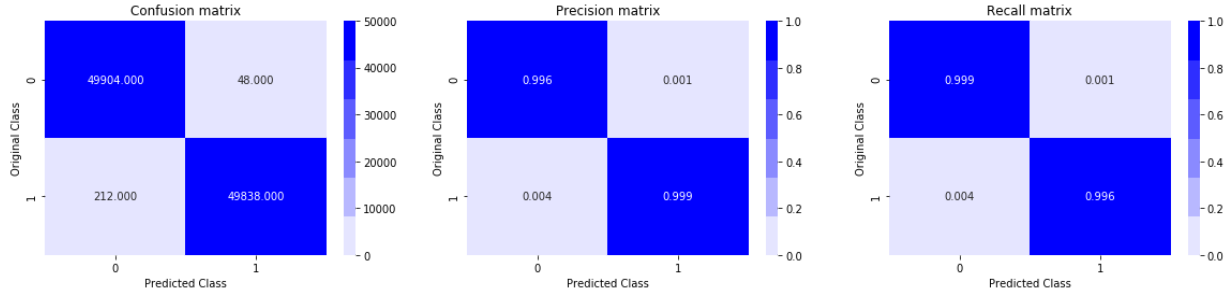
```
C:\ProgramData\Anaconda3\lib\site-packages\sklearn\preprocessing\label.py:151:
DeprecationWarning: The truth value of an empty array is ambiguous. Returning F
alse, but in future this will result in an error. Use `array.size > 0` to check
that an array is not empty.
  if diff:

Train Accuracy : 0.9974
AUC Score (Train): 0.999981
#################################################

C:\ProgramData\Anaconda3\lib\site-packages\sklearn\preprocessing\label.py:151:
DeprecationWarning: The truth value of an empty array is ambiguous. Returning F
alse, but in future this will result in an error. Use `array.size > 0` to check
that an array is not empty.
  if diff:

Test Accuracy : 0.933
AUC Score (test): 0.948747
```


Feature importance
page_rank_d 590
svd_dot_U_V 524
svd_u_s_3 487
shortest_path 445
svd_v_d_3 435
katz_s 405
svd_v_d_2 382
hubs_s 382
svd_u_s_2 377
katz_d 377
authorities_d 352
svd_v_d_1 335
svd_u_s_4 324
svd_v_d_4 317
svd_u_s_1 313
page_rank_s 305
svd_v_d_5 290
svd_u_s_5 264
svd_dot_V_V 249
svd_dot_U_U 233
svd_v_s_2 229
svd_v_s_5 224
svd_u_d_3 220
num_followees_s 219
svd_u_d_1 215
svd_v_s_1 213
num_followees_d 213
svd_v_s_3 206
weight_f4 204
svd_u_d_4 201
authorities_s 195
svd_u_d_2 194
svd_v_s_4 193
svd_u_d_5 185
weight_f3 177
hubs_d 176
weight_f1 162
weight_out 122
weight_f2 112
svd_v_d_6 106
Features
0
100
200
300
400
500
600
F score

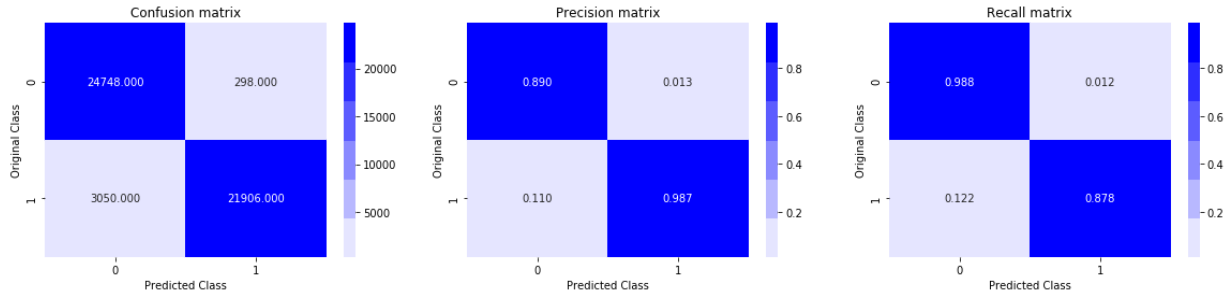
In [63]:
```
y_train_pred = xgb1.predict(X_train)
y_test_pred = xgb1.predict(X_test)
print('Train confusion_matrix')
plot_confusion_matrix(Y_train,y_train_pred)
print('Test confusion_matrix')
plot_confusion_matrix(Y_test,y_test_pred)
```

```
C:\ProgramData\Anaconda3\lib\site-packages\sklearn\preprocessing\label.py:151:
DeprecationWarning: The truth value of an empty array is ambiguous. Returning F
alse, but in future this will result in an error. Use `array.size > 0` to check
that an array is not empty.
  if diff:
C:\ProgramData\Anaconda3\lib\site-packages\sklearn\preprocessing\label.py:151:
DeprecationWarning: The truth value of an empty array is ambiguous. Returning F
alse, but in future this will result in an error. Use `array.size > 0` to check
that an array is not empty.
  if diff:
```

```
Train confusion_matrix
```




```
Test confusion_matrix
```



In [ ]:
```
1
```

In [ ]:
```
1
```

In [ ]:
```
1
```

In [ ]:
```
1
```

In [ ]:
```
1
```