Social network Graph Link Prediction - Facebook Challenge

In [1]:
```python
#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 [ ]:
```python
#!wget --header="Host: doc-0o-bk-docs.googleusercontent.com" --header="User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Ge
```

In [2]:
```python
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

In [3]:
```python
hdf_path = r'/content/drive/MyDrive/AAIML/17_fb_link_pred/data/fea_sample'
```

In [4]:
```python
#reading
from pandas import read_hdf
df_final_train = read_hdf(fr'{hdf_path}/storage_sample_stage4.h5', 'train_df',mode='r')
df_final_test = read_hdf(fr'{hdf_path}/storage_sample_stage4.h5', 'test_df',mode='r')
```

In [ ]:

In [ ]:
```python
# #reading
# from pandas import read_hdf
# df_final_train = read_hdf('storage_sample_stage4.h5', 'train_df',mode='r')
# df_final_test = read_hdf('storage_sample_stage4.h5', 'test_df',mode='r')
```

In [5]:
```python
df_final_train.columns
```

Out[5]:
```
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')
```

NOTE :
As followers for d is missing so we will find them first

In [6]:
```python
eda_path = r'/content/drive/MyDrive/AAIML/17_fb_link_pred/data/after_eda'
```

Here as Negative Points means missing links between pair of users
So we will considered Graph structure for positive data points because negative & positive samples will have same unique vertex
& Info such as OutDegree & Indegree can be obtained solely from Connected Graph (ie Positive Samples from Data where edge is present)
So in this case negative samples are no use for getting followers & followees info

Hence we are using `train_pos_after_eda.csv` to represent the entire train_graph instead of considering `train_after_eda` for train graph

In [7]:
```python
train_graph=nx.read_edgelist(fr'{eda_path}/train_pos_after_eda.csv',delimiter=',',create_using=nx.DiGraph(),nodetype=int)
```

In [ ]:
```python
# Add new column derived from existing column
# ref : https://sparkbyexamples.com/pandas/pandas-add-column-based-on-another-column/

# Below is not working as some destinatio_node are missing in train_Graph (Try runninng below line & you will get idea)
#new_col = df_final_train['destination_node'].apply(train_graph.predecessors)
```

In [8]:
```python
# https://www.statology.org/pandas-select-rows-based-on-column-values/

df_final_train.loc[df_final_train['destination_node']==94679]
```

Out[8]:

	source_node	destination_node	indicator_link	jaccard_followers	jaccard_followees	cosine_followers	cosine_followees	num_followers_s	num_followees_s	num_followees_d	...	svd_v_s_3	s
50072	854725	94679	0	0	0.0	0.0	0.0	0	0	0	...	-2.015384e-22	-1

1 rows × 54 columns

In [9]:
```python
94679 in train_graph  # Even Though the 94679 is present in dataset its missing in Positive Point Train-Graph Hence its the Person only in Negative Samples
```

Out[9]:
```
False
```

Why `94679` Destination Node is Missing in Graph is Questionable because train_graph must include all nodes

(One of the reason may be that because link is missing
hence it is from negative samples & negative samples may contains some nodes that are not present in positive samples at all)

In [10]:
```python
def nFollowers(nodeId):
  '''Followers := InComing Links to a node '''
  if nodeId not in train_graph:
    return 0
  return train_graph.in_degree[nodeId]

def nFollowers2(nodeId):
  '''Followers := InComing Links to a node '''
  if nodeId not in train_graph:
    return 0
  return len(set(train_graph.predecessors(nodeId)))
```

In [11]:
```python
# FOR CHECKING & TESTING PURPOSE
t1 = df_final_train['destination_node'].apply(nFollowers)
t2 = df_final_train['destination_node'].apply(nFollowers2)

(t1 == t2).all()
```

Out[11]:
```
True
```

In [12]:
```python
# # FOR CHECKING & TESTING PURPOSE
t1.count() == df_final_train['destination_node'].count()
```

Out[12]:
```
True
```

In [13]:
```python
# Add new column (Followers for Dstination) derived from existing column
# ref : https://sparkbyexamples.com/pandas/pandas-add-column-based-on-another-column

df_final_train['num_followers_d'] = df_final_train['destination_node'].apply(nFollowers)
```

NOTE
We are using `train_graph` only for test nodes as well because

- Test Data may contains some nodes which are new
- We have knowledge & access about train data only (ie info about social connections)

In [14]:
```python
df_final_test['num_followers_d'] = df_final_test['destination_node'].apply(nFollowers)
```

NOTE :
Here the svd featurization should be interpreted as follow :-
svd_u_s_6 // 6th-dimen val for item's (Source s) repr from Left Singular Matrix (u)

In [15]:
```python
# FOR TESTING PURPOSE ONLY
d1 = len(df_final_train[df_final_train['num_followers_d'] != df_final_train['num_followers_s']])
print('Pair having Different Followers for Source & Destination ', d1)
```

```
Pair having Different Followers for Source & Destination  0
```

In [16]:
```python
# # FOR TESTING PURPOSE ONLY
d2 = len(df_final_train[df_final_train['num_followees_d'] != df_final_train['num_followees_s']])
print('Pair having Different Followees for Source & Destination ', d2)
```

```
Pair having Different Followees for Source & Destination  90260
```

NOTE (OBSERVANCE)
It seems that Followers count for Source & Destination for each pair is same but Followees Count is different in few of them

In [17]:
```python
y_train = df_final_train.indicator_link
y_test = df_final_test.indicator_link
```

In [18]:
```python
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)
```

New Feature 1 (Preferential Attachment)

Val := Connection(Source) * Connection(Destination)

Preferential Attachment

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/

In [19]:
```python
feat_name = 'preferential_attachment'
```

In [20]:
```python
df_final_train[feat_name] = df_final_train['num_followees_s'] * df_final_train['num_followees_d']

df_final_train[[feat_name]].head(3)
```

Out[20]:

	preferential_attachment
0	120
1	8662
2	902

In [21]:
```python
df_final_test[feat_name] = df_final_test['num_followees_s'] * df_final_test['num_followees_d']
```

New Feature 2 (SVD_DOT)

Each Row is a Pair of 2 Person (follower, followee)

Now If we build Adjacency Matrix for each Person considering if edge present or not, then we will get a sparse vector for eahc person where size of the vector would be = #unique persons in the graph

Now We can use SVD technique (for given Adj Matrix) to reduce the dimen of the above vector for each person retaining most info as max as possible

This way let say if we define k=6 then we will get two 6-dimen vector for each person i.e (6+6 = 12) vals as info for each person

Lets understand this briefly :

- 6-dimen from Left Singular Matrix of SVD (ie Matrix Factoriation)
- 6-dimen from Right Singular Matrix of SVD (ie Matrix Factorization)

Notation Understanding

U *S* V = SVD(Adj-Matrix)

U -> Left Singular Matrix
V -> Right Singular Matrix

In our Dataframe, we already have these values computed

Column Name Decoding

svd_u_s_5 := **5th**-dimen val of 6-dimen vector for `source_node` from Left Singular Matrix `U`
svd_v_d_3 := **3rd**-dimen val of 6-dimen vector for `destination_node` from Right Singular Matrix `V`

PLAYGROUND
To test Dot Product of multiple columns at once for SVD-Dot

In [22]:
```python
# FOR TESTING/CHECKING PURPOSE ONLY
d1 = pd.DataFrame({'c1': [1,2], 'c2': [10, 20], 'c3':[100, 200], 'c4': [50, 500]})
d1
```

Out[22]:

	c1	c2	c3	c4
0	1	10	100	50
1	2	20	200	500

In [23]:
```python
# # FOR TESTING/CHECKING PURPOSE ONLY
s1 = d1.loc[0][['c1', 'c2']]
s1.shape
```

Out[23]:
```
(2,)
```

In [24]:
```python
# FOR TESTING/CHECKING PURPOSE ONLY
s2 = d1.loc[0][['c3', 'c4']]
type(s2)
```

Out[24]:
```
pandas.core.series.Series
```

In [25]:
```python
# FOR TESTING/CHECKING PURPOSE ONLY
np.dot(s1, s2)
```

Out[25]:
```
600
```

In [26]:
```python
# FOR TESTING/CHECKING PURPOSE ONLY
def f(row):
  return np.dot(row[['c1', 'c2']], row[['c3', 'c4']])

d1['c5'] = d1.apply(f, axis=1)
d1
```

Out[26]:

	c1	c2	c3	c4	c5
0	1	10	100	50	600
1	2	20	200	500	10400

SVD-Dot Feature

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

We get 2 representations for each person

In [27]:
```python
feat_name = 'svd_dot'
```

In [28]:
```python
def calc_svd_dot(row):

  src_v1 = [f'svd_u_s_{i}' for i in range(1, 7)] # 6-dimen vector from Left Singular Matrix U
  src_v2 = [f'svd_v_s_{i}' for i in range(1, 7)] # 6-dimen vector from right Singular Matrix V

  src_v = [*src_v1, *src_v2]

  dst_v1 = [f'svd_u_d_{i}' for i in range(1, 7)] # 6-dimen vector from Left Singular Matrix U
  dst_v2 = [f'svd_v_d_{i}' for i in range(1, 7)] # 6-dimen vector from right Singular Matrix V

  dst_v = [*dst_v1, *dst_v2]

  return np.dot(row[src_v], row[dst_v])
```

In [29]:
```python
# https://sparkbyexamples.com/pandas/pandas-add-column-based-on-another-column/
df_final_train[feat_name] = df_final_train.apply(calc_svd_dot, axis=1)

df_final_train[[feat_name]].head(3)
```

Out[29]:

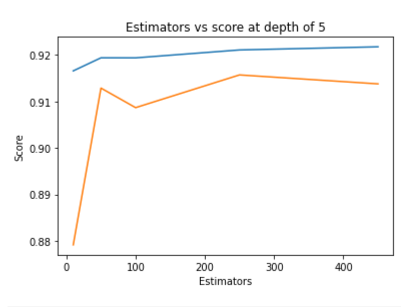
	svd_dot
0	1.338835e-11
1	4.099684e-03
2	2.034290e-35

In [30]:
```python
df_final_test[feat_name] = df_final_test.apply(calc_svd_dot, axis=1)
```

In [31]:
```python
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')
```

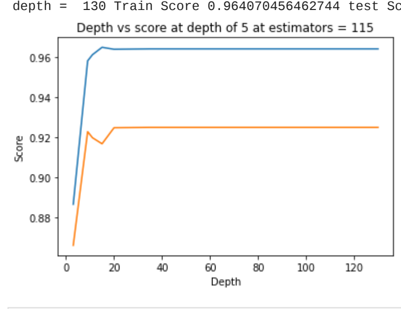
```
Estimators =  10 Train Score 0.916574881203386 test Score 0.8791390009981339
Estimators =  50 Train Score 0.919380817906077 test Score 0.9128689988444164
Estimators =  100 Train Score 0.9193735438237229 test Score 0.9086616496975063
Estimators =  250 Train Score 0.9210740779437886 test Score 0.9157020634121791
Estimators =  450 Train Score 0.921750039203387 test Score 0.9137760575527463
```

Out[31]:
```
Text(0.5, 1.0, 'Estimators vs score at depth of 5')
```



In [33]:
```python
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,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 = 115')
plt.show()
```

```
depth =  3 Train Score 0.8866686956247967 test Score 0.8662080164088539
depth =  9 Train Score 0.9581065765425418 test Score 0.9228265922826593
depth =  11 Train Score 0.9611498505763485 test Score 0.9198155122075065
depth =  15 Train Score 0.9648505259740918 test Score 0.9167782666921752
depth =  20 Train Score 0.963869617771638 test Score 0.9247920273637095
depth =  35 Train Score 0.964070456462744 test Score 0.9249456051036143
depth =  50 Train Score 0.964070456462744 test Score 0.9249456051036143
depth =  70 Train Score 0.964070456462744 test Score 0.9249456051036143
depth =  130 Train Score 0.964070456462744 test Score 0.9249456051036143
```



In [35]:
```python
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=True
                                  )

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 [0.96228784 0.96165159 0.96020582 0.96195035 0.96384623]
mean train scores [0.96302613 0.96249264 0.96086972 0.96267275 0.9648021 ]
```

In [36]:
```python
print(rf_random.best_estimator_)
```

```
RandomForestClassifier(max_depth=14, min_samples_leaf=28, min_samples_split=111,
                       n_estimators=121, n_jobs=-1, random_state=25)
```

In [38]:
```python
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 [39]:
```python
clf.fit(df_final_train,y_train)
y_train_pred = clf.predict(df_final_train)
y_test_pred = clf.predict(df_final_test)
```

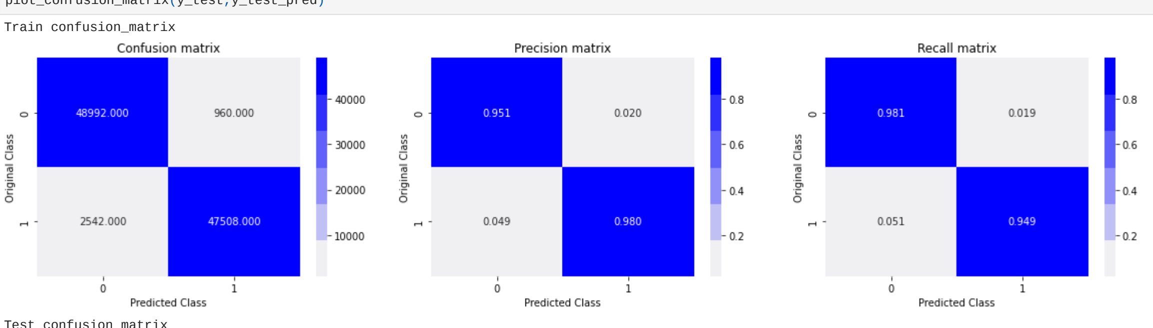
In [40]:
```python
from sklearn.metrics import f1_score
print('Train f1 score',f1_score(y_train,y_train_pred))
print('Test f1 score',f1_score(y_test,y_test_pred))
```

```
Train f1 score 0.9644531963702064
Test f1 score 0.9129052222720191
```

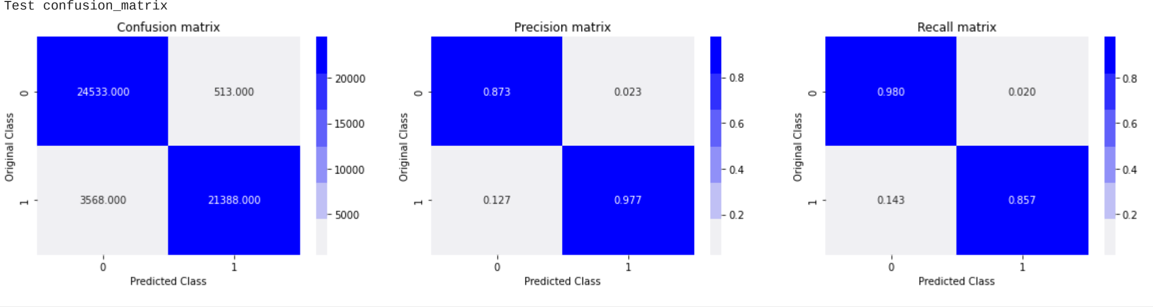
In [41]:
```python
from sklearn.metrics import confusion_matrix
def plot_confusion_matrix(test_y, predict_y):
    C = confusion_matrix(test_y, predict_y)

    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 [42]:
```python
print('Train confusion_matrix')
plot_confusion_matrix(y_train,y_train_pred)
print('Test confusion_matrix')
plot_confusion_matrix(y_test,y_test_pred)
```

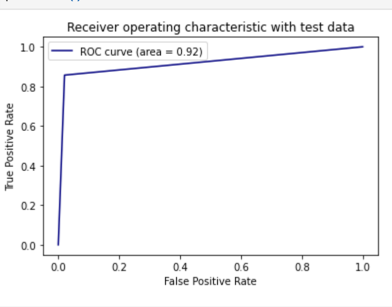
```
Train confusion_matrix
```




```
Test confusion_matrix
```



In [43]:
```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 [44]:
```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()
```