spamdetection

March 31, 2019

1 [1]. Reading Data

In [181]:
```
%matplotlib inline
import warnings
warnings.filterwarnings("ignore")


import sqlite3
import pandas as pd
import numpy as np
import nltk
import string
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.feature_extraction.text import TfidfTransformer
from sklearn.feature_extraction.text import TfidfVectorizer

from sklearn.feature_extraction.text import CountVectorizer
from sklearn.metrics import confusion_matrix
from sklearn import metrics
from sklearn.metrics import roc_curve, auc
from nltk.stem.porter import PorterStemmer

import re
# Tutorial about Python regular expressions: https://pymotw.com/2/re/
import string
from nltk.corpus import stopwords
from nltk.stem import PorterStemmer
from nltk.stem.wordnet import WordNetLemmatizer

from gensim.models import Word2Vec
from gensim.models import KeyedVectors
import pickle

from tqdm import tqdm
import os
```

```
In [182]: final=pd.read_csv("emails.csv", skiprows=1,names=["Text","Score"])
          message=final['Text'].tolist()
          print(message[0])
```

```
Subject: naturally irresistible your corporate identity  lt is really hard to recollect a compa
```

2 [3] Preprocessing

2.1 [3.1]. Preprocessing Review Text

Now that we have finished deduplication our data requires some preprocessing before we go on further with analysis and making the prediction model.

Hence in the Preprocessing phase we do the following in the order below:-

1. Begin by removing the html tags
2. Remove any punctuations or limited set of special characters like , or . or # etc.
3. Check if the word is made up of english letters and is not alpha-numeric
4. Check to see if the length of the word is greater than 2 (as it was researched that there is no adjective in 2-letters)
5. Convert the word to lowercase
6. Remove Stopwords
7. Finally Snowball Stemming the word (it was obsereved to be better than Porter Stemming)

After which we collect the words used to describe positive and negative reviews

```
In [183]: # printing some random reviews
          sent_0 = final['Text'].values[0]
          print(sent_0)
          print("="*50)

          sent_1000 = final['Text'].values[1000]
          print(sent_1000)
          print("="*50)

          sent_1500 = final['Text'].values[1500]
          print(sent_1500)
          print("="*50)

          sent_4900 = final['Text'].values[4900]
          print(sent_4900)
          print("="*50)
```

```
Subject: naturally irresistible your corporate identity  lt is really hard to recollect a compa
==================================================
Subject: save your money buy getting this thing here  you have not tried cialls yet ?  than you
==================================================
Subject: hello all  update :  preparations for the upcoming texas finance festival iii are abou
==================================================
```

```
Subject: credit business plan  hi jeff ,  my research colleagues and i are working on a documer
==================================================
```

```
In [184]: # remove urls from text python: https://stackoverflow.com/a/40823105/4084039
          sent_0 = re.sub(r"http\S+", "", sent_0)
          sent_1000 = re.sub(r"http\S+", "", sent_1000)
          sent_150 = re.sub(r"http\S+", "", sent_1500)
          sent_4900 = re.sub(r"http\S+", "", sent_4900)

          print(sent_0)
```

```
Subject: naturally irresistible your corporate identity  lt is really hard to recollect a compa
```

```
In [185]: # https://stackoverflow.com/questions/16206380/python-beautifulsoup-how-to-remove-al
          from bs4 import BeautifulSoup

          soup = BeautifulSoup(sent_0, 'lxml')
          text = soup.get_text()
          print(text)
          print("="*50)

          soup = BeautifulSoup(sent_1000, 'lxml')
          text = soup.get_text()
          print(text)
          print("="*50)

          soup = BeautifulSoup(sent_1500, 'lxml')
          text = soup.get_text()
          print(text)
          print("="*50)

          soup = BeautifulSoup(sent_4900, 'lxml')
          text = soup.get_text()
          print(text)
```

```
Subject: naturally irresistible your corporate identity  lt is really hard to recollect a compa
==================================================
Subject: save your money buy getting this thing here  you have not tried cialls yet ?  than you
==================================================
Subject: hello all  update :  preparations for the upcoming texas finance festival iii are abou
==================================================
Subject: credit business plan  hi jeff ,  my research colleagues and i are working on a documer
```

```
In [186]: # https://stackoverflow.com/a/47091490/4084039
          import re
```

```
        def decontracted(phrase):
            # specific
            phrase = re.sub(r"won't", "will not", phrase)
            phrase = re.sub(r"can\'t", "can not", phrase)

            # general
            phrase = re.sub(r"n\'t", " not", phrase)
            phrase = re.sub(r"\'re", " are", phrase)
            phrase = re.sub(r"\'s", " is", phrase)
            phrase = re.sub(r"\'d", " would", phrase)
            phrase = re.sub(r"\'ll", " will", phrase)
            phrase = re.sub(r"\'t", " not", phrase)
            phrase = re.sub(r"\'ve", " have", phrase)
            phrase = re.sub(r"\'m", " am", phrase)
            return phrase
```

```
In [187]: sent_1500 = decontracted(sent_1500)
          print(sent_1500)
          print("="*50)
```

```
Subject: hello all  update :  preparations for the upcoming texas finance festival iii are abou
==================================================
```

```
In [188]: #remove words with numbers python: https://stackoverflow.com/a/18082370/4084039
          sent_0 = re.sub("\S*\d\S*", "", sent_0).strip()
          print(sent_0)
```

```
Subject: naturally irresistible your corporate identity  lt is really hard to recollect a compa
```

```
In [189]: #remove spacial character: https://stackoverflow.com/a/5843547/4084039
          sent_1500 = re.sub('[^A-Za-z0-9]+', ' ', sent_1500)
          print(sent_1500)
```

```
Subject hello all update preparations for the upcoming texas finance festival iii are about co
```

```
In [190]: # https://gist.github.com/sebleier/554280
          # we are removing the words from the stop words list: 'no', 'nor', 'not'
          # <br /><br /> ==> after the above steps, we are getting "br br"
          # we are including them into stop words list
          # instead of <br /> if we have <br/> these tags would have revmoved in the 1st step

          stopwords= set(['br', 'the', 'i', 'me', 'my', 'myself', 'we', 'our', 'ours', 'oursel
                      "you'll", "you'd", 'your', 'yours', 'yourself', 'yourselves', 'he', 'him
                      'she', "she's", 'her', 'hers', 'herself', 'it', "it's", 'its', 'itself',
                      'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'that',
                      'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'has',
```

```
                    'did', 'doing', 'a', 'an', 'the', 'and', 'but', 'if', 'or', 'because', 'a
                    'at', 'by', 'for', 'with', 'about', 'against', 'between', 'into', 'throug
                    'above', 'below', 'to', 'from', 'up', 'down', 'in', 'out', 'on', 'off',
                    'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'all', 'a
                    'most', 'other', 'some', 'such', 'only', 'own', 'same', 'so', 'than', 'to
                    's', 't', 'can', 'will', 'just', 'don', "don't", 'should', "should've",
                    've', 'y', 'ain', 'aren', "aren't", 'couldn', "couldn't", 'didn', "didn't
                    "hadn't", 'hasn', "hasn't", 'haven', "haven't", 'isn', "isn't", 'ma', 'mi
                    "mustn't", 'needn', "needn't", 'shan', "shan't", 'shouldn', "shouldn't",
                    'won', "won't", 'wouldn', "wouldn't"])
```

In [191]:
```
# Combining all the above stundents
from tqdm import tqdm
preprocessed_emails = []
# tqdm is for printing the status bar
for sentance in tqdm(final['Text'].values):
    sentance = re.sub(r"http\S+", "", sentance)
    sentance = BeautifulSoup(sentance, 'lxml').get_text()
    sentance = decontracted(sentance)
    sentance = re.sub("\S*\d\S*", "", sentance).strip()
    sentance = re.sub('[^A-Za-z]+', ' ', sentance)
    # https://gist.github.com/sebleier/554280
    sentance = ' '.join(e.lower() for e in sentance.split() if e.lower() not in stopw
    preprocessed_emails.append(sentance.strip())
```

```
100%|| 5728/5728 [00:04<00:00, 1317.84it/s]
```

In [192]:
```
print(preprocessed_emails[0])
len(preprocessed_emails)
```

```
subject naturally irresistible corporate identity lt really hard recollect company market full
```

Out[192]:
```
5728
```

3 [4] Featurization

Splitting the dataset into train, test and cv We are taking 100000 points in total , 33 % of which is kept as dtest

In [193]:
```
from sklearn.model_selection import train_test_split
```

```
# X_train, X_test, y_train, y_test = train_test_split(X, Y, test_size=0.33, shuffle=
X=np.asarray(preprocessed_reviews[:5728])
Y=final['Score'].values
#print(X.shape," ",Y.shape)
```

```
X_train, X_test, y_train, y_test = train_test_split(X, Y[:5728], test_size=0.33) # t
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train, test_size=0.33) #

print(X_train.shape)
print(type(X_train))
```

```
(2570,)
<class 'numpy.ndarray'>
```

3.1 [4.1] BAG OF WORDS

```
In [194]: #BoW
          count_vect = CountVectorizer() #in scikit-learn
          count_vect.fit(X_train)
          print("some feature names ", count_vect.get_feature_names()[:10])
          print('='*50)

          final_countsXtrain = count_vect.transform(X_train)
          final_countsXtest = count_vect.transform(X_test)
          final_countsXcv = count_vect.transform(X_cv)

          print("the shape of out text BOW vectorizer xtrain ",final_countsXtrain.get_shape())
          print("the shape of out text BOW vectorizer xtest ",final_countsXtest.get_shape())
          print("the shape of out text BOW vectorizer xcv ",final_countsXcv.get_shape())


          #print("the number of unique words ", final_counts.get_shape()[1])
```

```
some feature names  ['aa', 'aaa', 'aaldous', 'aaliyah', 'aall', 'aaron', 'aawesome', 'ab', 'aba
==================================================
the shape of out text BOW vectorizer xtrain  (2570, 23005)
the shape of out text BOW vectorizer xtest  (1891, 23005)
the shape of out text BOW vectorizer xcv  (1267, 23005)
```

bow vectors with added feature of review length

```
In [195]: from scipy.sparse import coo_matrix, hstack
          xtrain_len=[]
          xtest_len=[]
          xcv_len=[]
          for i in X_train:
              xtrain_len.append(len(i))

          for i in X_test:
              xtest_len.append(len(i))

          for i in X_cv:
```

```
        xcv_len.append(len(i))
    xtrain_len=coo_matrix(np.reshape(np.array(xtrain_len),(-1,1)))
    xtest_len=coo_matrix(np.reshape(np.array(xtest_len),(-1,1)))
    xcv_len=coo_matrix(np.reshape(np.array(xcv_len),(-1,1)))
    bowtrain=coo_matrix(final_countsXtrain)
    bowtest=coo_matrix(final_countsXtest)
    bowcv=coo_matrix(final_countsXcv)
    bowtrain=hstack([final_countsXtrain,xtrain_len])
    bowtest=hstack([final_countsXtest,xtest_len])
    bowcv=hstack([final_countsXcv,xcv_len])
    print(bowtrain.shape)
    print(bowtest.shape)
    print(bowcv.shape)
```

```
(2570, 23006)
(1891, 23006)
(1267, 23006)
```

3.2 [4.3] TF-IDF

```
In [196]: tf_idf_vect = TfidfVectorizer(ngram_range=(1,2), min_df=10)
          tf_idf_vect.fit(X_train)
          print("some sample features(unique words in the corpus)",tf_idf_vect.get_feature_name
          print('='*50)

          final_tf_idfXtrain = tf_idf_vect.transform(X_train)
          final_tf_idfXtest = tf_idf_vect.transform(X_test)
          final_tf_idfXcv = tf_idf_vect.transform(X_cv)
          #print("the type of count vectorizer ",type(final_tf_idf))
          print("the shape of out text TFIDF vectorizer xtrain ",final_tf_idfXtrain.get_shape()
          print("the shape of out text TFIDF vectorizer xtest ",final_tf_idfXtest.get_shape())
          print("the shape of out text TFIDF vectorizer xcv ",final_tf_idfXcv.get_shape())
          #print("the number of unique words including both unigrams and bigrams ", final_tf_i
```

```
some sample features(unique words in the corpus) ['aa', 'ability', 'able', 'able deliver', 'abl
==================================================
the shape of out text TFIDF vectorizer xtrain  (2570, 5729)
the shape of out text TFIDF vectorizer xtest  (1891, 5729)
the shape of out text TFIDF vectorizer xcv  (1267, 5729)
```

tfidf vectors with added feature of review length

```
In [197]: tfidftrain=coo_matrix(final_tf_idfXtrain)
          tfidftest=coo_matrix(final_tf_idfXtest)
          tfidfcv=coo_matrix(final_tf_idfXcv)
          tfidftrain=hstack([final_tf_idfXtrain,xtrain_len])
          tfidftest=hstack([final_tf_idfXtest,xtest_len])
```

```
        tfidfcv=hstack([final_tf_idfXcv,xcv_len])
        print(tfidftrain.shape)
        print(tfidftest.shape)
        print(tfidfcv.shape)
```

```
(2570, 5730)
(1891, 5730)
(1267, 5730)
```

4 [5] Assignment 4: Apply Naive Bayes

```
<li><strong>Apply Multinomial NaiveBayes on these feature sets</strong>
    <ul>
        <li><font color='red'>SET 1:</font>Review text, preprocessed one converted into vectors
        <li><font color='red'>SET 2:</font>Review text, preprocessed one converted into vectors
    </ul>
</li>
<br>
<li><strong>The hyper paramter tuning(find best Alpha)</strong>
    <ul>
<li>Find the best hyper parameter which will give the maximum <a href='https://www.appliedaicou
<li>Consider a wide range of alpha values for hyperparameter tuning, start as low as 0.00001</l
<li>Find the best hyper paramter using k-fold cross validation or simple cross validation data
<li>Use gridsearch cv or randomsearch cv or you can also write your own for loops to do this ta
    </ul>
</li>
<br>
<li><strong>Feature importance</strong>
    <ul>
<li>Find the top 10 features of positive class and top 10 features of negative class for both
    </ul>
</li>
<br>
<li><strong>Feature engineering</strong>
    <ul>
<li>To increase the performance of your model, you can also experiment with with feature engine
        <ul>
        <li>Taking length of reviews as another feature.</li>
        <li>Considering some features from review summary as well.</li>
    </ul>
    </ul>
</li>
<br>
<li><strong>Representation of results</strong>
    <ul>
<li>You need to plot the performance of model both on train data and cross validation data for
```

```
<img src='train_cv_auc.JPG' width=300px></li>
<li>Once after you found the best hyper parameter, you need to train your model with it, and fi
<img src='train_test_auc.JPG' width=300px></li>
<li>Along with plotting ROC curve, you need to print the <a href='https://www.appliedaicourse.c
<img src='confusion_matrix.png' width=300px></li>
    </ul>
</li>
<br>
<li><strong>Conclusion</strong>
    <ul>
<li>You need to summarize the results at the end of the notebook, summarize it in the table fo
    <img src='summary.JPG' width=400px>
</li>
    </ul>
```

Note: Data Leakage

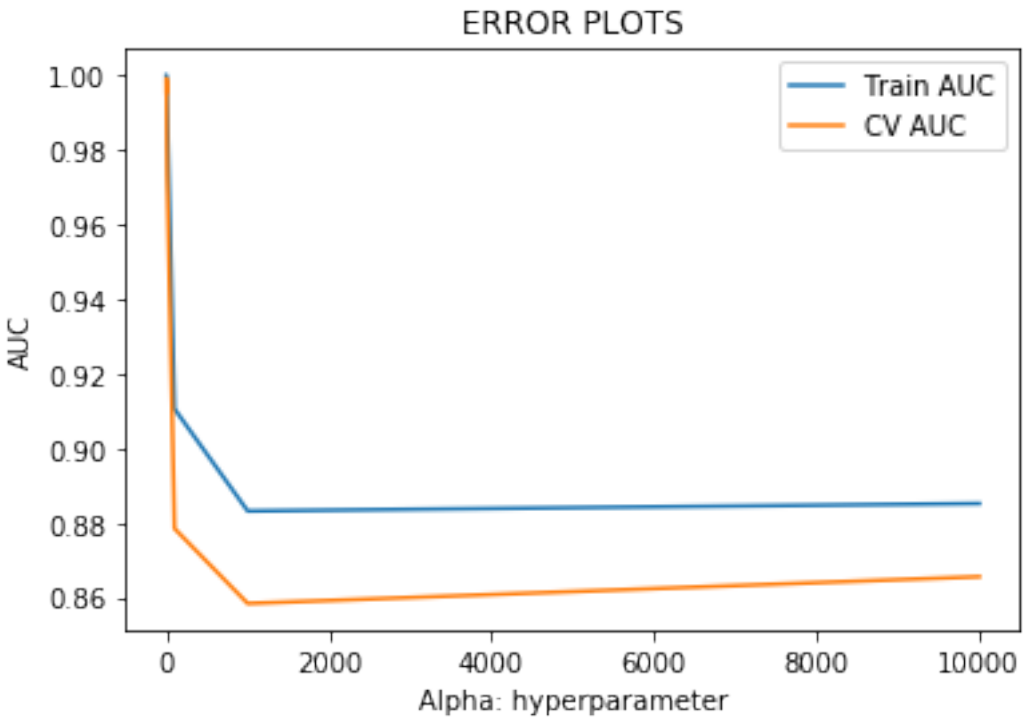
1. There will be an issue of data-leakage if you vectorize the entire data and then split it into train/cv/test.
2. To avoid the issue of data-leakag, make sure to split your data first and then vectorize it.
3. While vectorizing your data, apply the method fit_transform() on you train data, and apply the method transform() on cv/test data.
4. For more details please go through this link.

5 Applying Multinomial Naive Bayes

5.1 [5.1] Applying Naive Bayes on BOW, SET 1

In [198]:
```
# Please write all the code with proper documentation
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import roc_auc_score
import matplotlib.pyplot as plt
from sklearn.preprocessing import StandardScaler

x_train=final_countsXtrain
x_test=final_countsXtest
x_cv=final_countsXcv
"""
y_true : array, shape = [n_samples] or [n_samples, n_classes]
True binary labels or binary label indicators.

y_score : array, shape = [n_samples] or [n_samples, n_classes]
Target scores, can either be probability estimates of the positive class, confidence
decisions (as returned by decision_function on some classifiers).
For binary y_true, y_score is supposed to be the score of the class with greater lab

"""
#print(final_countsXtrain.toarray().shape)
```

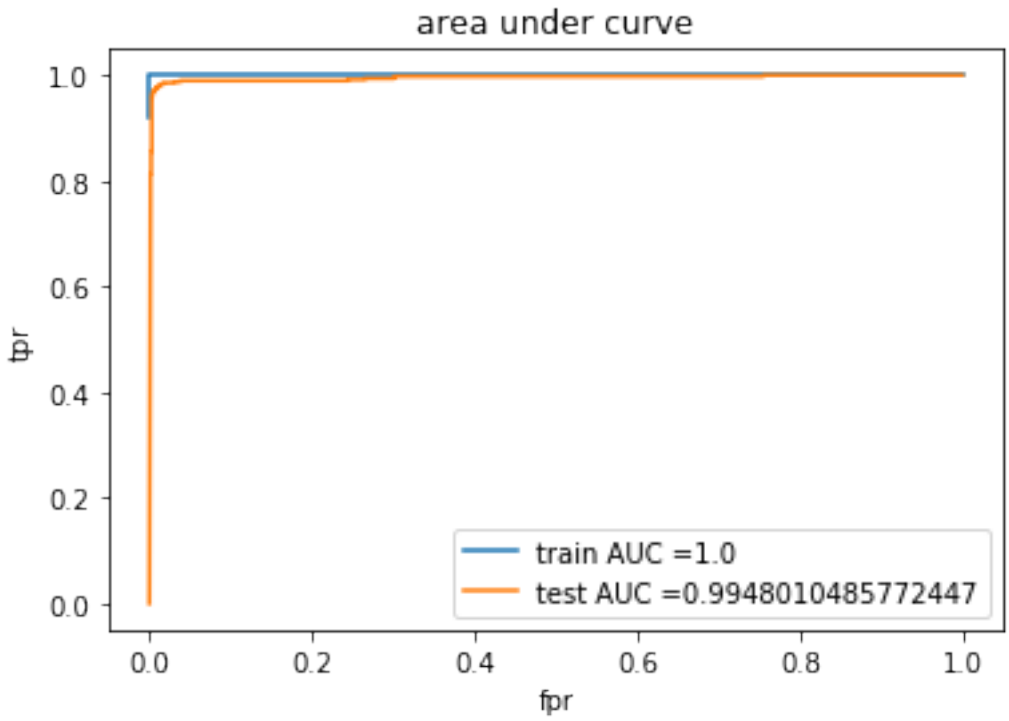
```
train_auc = []
cv_auc = []
A = [0.000001,0.00001,0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 1000,10000]
for i in A:
    model1 = MultinomialNB(alpha=i)
    model1.fit(x_train, y_train)
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimat
    # not the predicted outputs
    y_train_pred =  model1.predict_proba(x_train)[:,1]
    y_cv_pred =  model1.predict_proba(x_cv)[:,1]

    train_auc.append(roc_auc_score(y_train,y_train_pred))
    cv_auc.append(roc_auc_score(y_cv, y_cv_pred))

plt.plot(A, train_auc, label='Train AUC')
plt.plot(A, cv_auc, label='CV AUC')
plt.legend()
plt.xlabel("Alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.show()
```



In [199]:
```
from sklearn.metrics import roc_curve, auc
```

```
best_a = A[cv_auc.index(max(cv_auc))]
print(best_a)
model1 = MultinomialNB(alpha=best_a)
model1.fit(x_train, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates o
# not the predicted outputs

train_fpr, train_tpr, thresholds = roc_curve(y_train, model1.predict_proba(x_train)[
test_fpr, test_tpr, thresholds = roc_curve(y_test, model1.predict_proba(x_test)[:,1])

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("fpr")
plt.ylabel("tpr")
plt.title("area under curve")
plt.show()

print("="*100)

from sklearn.metrics import confusion_matrix
print("Train confusion matrix")
print(confusion_matrix(y_train, model1.predict(x_train)))
print("Test confusion matrix")
print(confusion_matrix(y_test, model1.predict(x_test)))
```

```
0.01
```




```
==========================================================================================
Train confusion matrix
[[1991    0]
 [   0  579]]
Test confusion matrix
[[1401    4]
 [  26  460]]
```

5.1.1 [5.1.1] Top 10 important features of positive class from SET 1

```
In [200]: # Please write all the code with proper documentation
          fi=np.array(model1.feature_log_prob_)
          print(fi.shape)
          top=np.array(sorted(fi[1,:]))
          toppos=top[len(top)-10:]
          top_pos_index=[]
          top_pos_feat=[]
          for i in toppos:
              top_pos_feat.append(count_vect.get_feature_names()[fi[1,:].tolist().index(i)])
              top_pos_index.append(fi[1,:].tolist().index(i))
          print(top_pos_index)
          print("Top 10 important features of positive class are")
          print(top_pos_feat)
```

```
(2, 23005)
[13155, 9539, 13794, 6493, 10071, 2677, 3856, 3764, 13885, 19733]
Top 10 important features of positive class are
['money', 'http', 'no', 'email', 'information', 'business', 'company', 'com', 'not', 'subject']
```

[5.1.2] Top 10 important features of negative class from SET 1

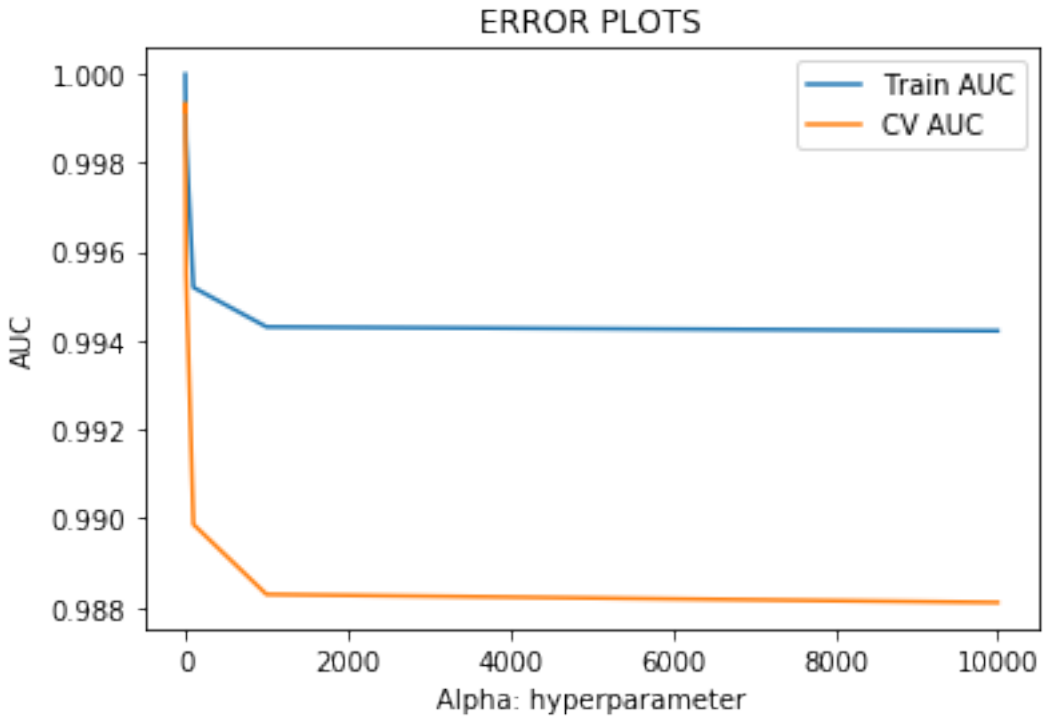
```
In [203]: # Please write all the code with proper documentation
          fi=np.array(model1.feature_log_prob_)
          print(fi.shape)
          top=np.array(sorted(fi[0,:]))
          topneg=top[len(top)-10:]
          top_neg_index=[]
          top_neg_feat=[]
          for i in topneg:
              top_neg_feat.append(count_vect.get_feature_names()[fi[0,:].tolist().index(i)])
              top_neg_index.append(fi[0,:].tolist().index(i))
          print(top_neg_index)
          print("Top 10 important features of negative class are")

          print(top_neg_feat)
```

```
(2, 23005)
[3084, 22605, 15382, 3764, 10966, 9499, 21857, 19733, 6269, 6723]
Top 10 important features of negative class are
['cc', 'would', 'please', 'com', 'kaminski', 'hou', 'vince', 'subject', 'ect', 'enron']
```

5.2 [5.2] Applying Naive Bayes on TFIDF, SET 2

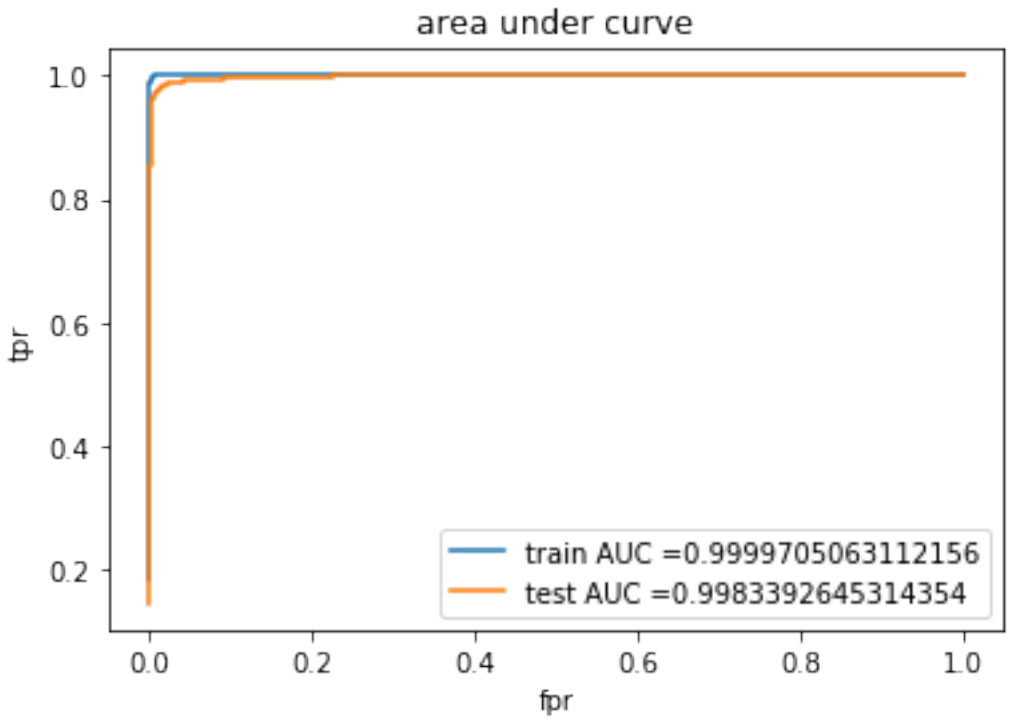
```
In [204]: # Please write all the code with proper documentation
          from sklearn.neighbors import KNeighborsClassifier
          from sklearn.metrics import roc_auc_score
          import matplotlib.pyplot as plt
          from sklearn.preprocessing import StandardScaler

          x_train=final_tf_idfXtrain
          x_test=final_tf_idfXtest
          x_cv=final_tf_idfXcv
          """
          y_true : array, shape = [n_samples] or [n_samples, n_classes]
          True binary labels or binary label indicators.

          y_score : array, shape = [n_samples] or [n_samples, n_classes]
          Target scores, can either be probability estimates of the positive class, confidence
          decisions (as returned by decision_function on some classifiers).
          For binary y_true, y_score is supposed to be the score of the class with greater lab
```

```
"""
#print(final_countsXtrain.toarray().shape)
train_auc = []
cv_auc = []
A = [0.000001,0.00001,0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 1000,10000]
for i in A:
    model2 = MultinomialNB(alpha=i)
    model2.fit(x_train, y_train)
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimat
    # not the predicted outputs
    y_train_pred =  model2.predict_proba(x_train)[:,1]
    y_cv_pred =  model2.predict_proba(x_cv)[:,1]

    train_auc.append(roc_auc_score(y_train,y_train_pred))
    cv_auc.append(roc_auc_score(y_cv, y_cv_pred))

plt.plot(A, train_auc, label='Train AUC')
plt.plot(A, cv_auc, label='CV AUC')
plt.legend()
plt.xlabel("Alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.show()
```



In [205]:
```
from sklearn.metrics import roc_curve, auc

best_a = A[cv_auc.index(max(cv_auc))]
print(best_a)
model2 = MultinomialNB(alpha=best_a)
model2.fit(x_train, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates o
# not the predicted outputs

train_fpr, train_tpr, thresholds = roc_curve(y_train, model2.predict_proba(x_train)[
test_fpr, test_tpr, thresholds = roc_curve(y_test, model2.predict_proba(x_test)[:,1]

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("fpr")
plt.ylabel("tpr")
plt.title("area under curve")
plt.show()

print("="*100)

from sklearn.metrics import confusion_matrix
print("Train confusion matrix")
print(confusion_matrix(y_train, model2.predict(x_train)))
print("Test confusion matrix")
print(confusion_matrix(y_test, model2.predict(x_test)))
```

```
0.001
```




```
==========================================================================================
Train confusion matrix
[[1990    1]
 [  11  568]]
Test confusion matrix
[[1404    1]
 [  44  442]]
```

5.2.1 [5.2.1] Top 10 important features of positive class from SET 2

```
In [206]: # Please write all the code with proper documentation
          fi=np.array(model2.feature_log_prob_)
          print(fi.shape)
          top=np.array(sorted(fi[1,:]))
          toppos=top[len(top)-10:]
          top_pos_index=[]
          top_pos_feat=[]
          for i in toppos:
              top_pos_feat.append(tf_idf_vect.get_feature_names()[fi[1,:].tolist().index(i)])
              top_pos_index.append(fi[1,:].tolist().index(i))
          print(top_pos_index)
          print("Top 10 important features of positive class are")
          print(top_pos_feat)
```

```
(2, 5729)
[3496, 3226, 5556, 4464, 2314, 4704, 770, 807, 3381, 4894]
Top 10 important features of positive class are
['online', 'money', 'website', 'save', 'http', 'software', 'click', 'com', 'not', 'subject']
```

5.2.2 [5.2.2] Top 10 important features of negative class from SET 2

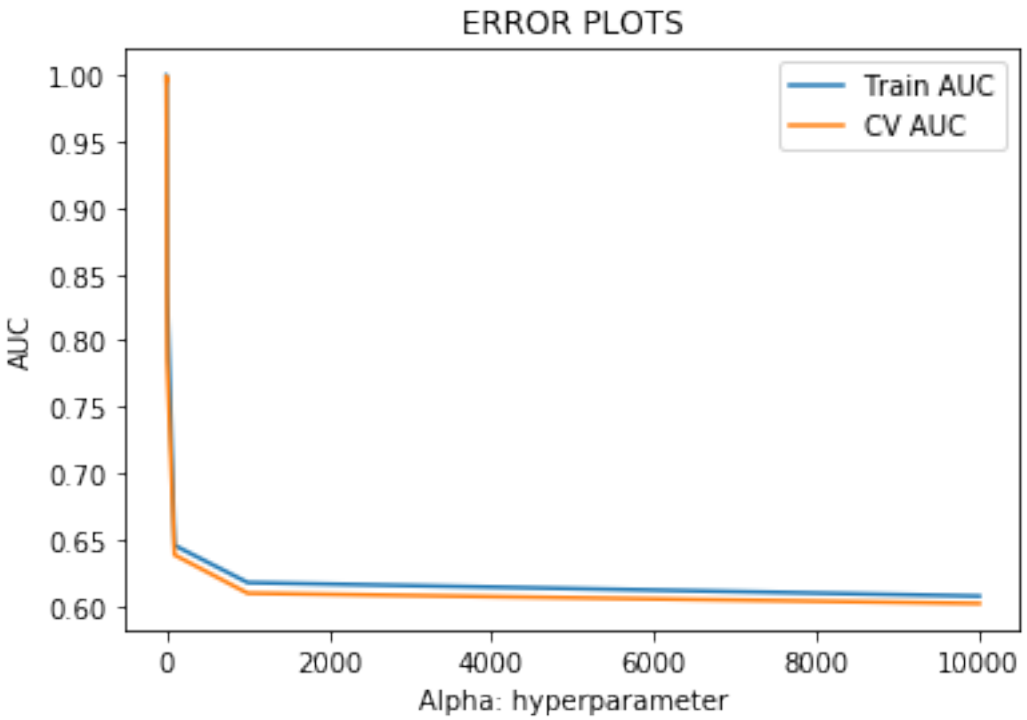
```
In [209]: # Please write all the code with proper documentation
          fi=np.array(model2.feature_log_prob_)
          print(fi.shape)
          top=np.array(sorted(fi[0,:]))
          topneg=top[len(top)-10:]
          top_neg_index=[]
          top_neg_feat=[]
          for i in topneg:
              top_neg_feat.append(tf_idf_vect.get_feature_names()[fi[0,:].tolist().index(i)])
              top_neg_index.append(fi[0,:].tolist().index(i))
          print(top_neg_index)
          print("Top 10 important features of negitive class are")
          print(top_neg_feat)
```

```
(2, 5729)
[807, 3760, 1422, 2627, 2286, 2285, 4894, 5445, 1568, 1416]
Top 10 important features of negitive class are
['com', 'please', 'ect ect', 'kaminski', 'hou ect', 'hou', 'subject', 'vince', 'enron', 'ect']
```

Applying Naive Bayes on BOW after adding feature

```
In [210]: from sklearn.naive_bayes import MultinomialNB
          from sklearn.metrics import roc_auc_score
          import matplotlib.pyplot as plt
          from sklearn.preprocessing import StandardScaler

          x_train=bowtrain
          x_test=bowtest
          x_cv=bowcv
          """
          y_true : array, shape = [n_samples] or [n_samples, n_classes]
          True binary labels or binary label indicators.

          y_score : array, shape = [n_samples] or [n_samples, n_classes]
          Target scores, can either be probability estimates of the positive class, confidence
          decisions (as returned by decision_function on some classifiers).
          For binary y_true, y_score is supposed to be the score of the class with greater lab

          """
          #print(final_countsXtrain.toarray().shape)
```

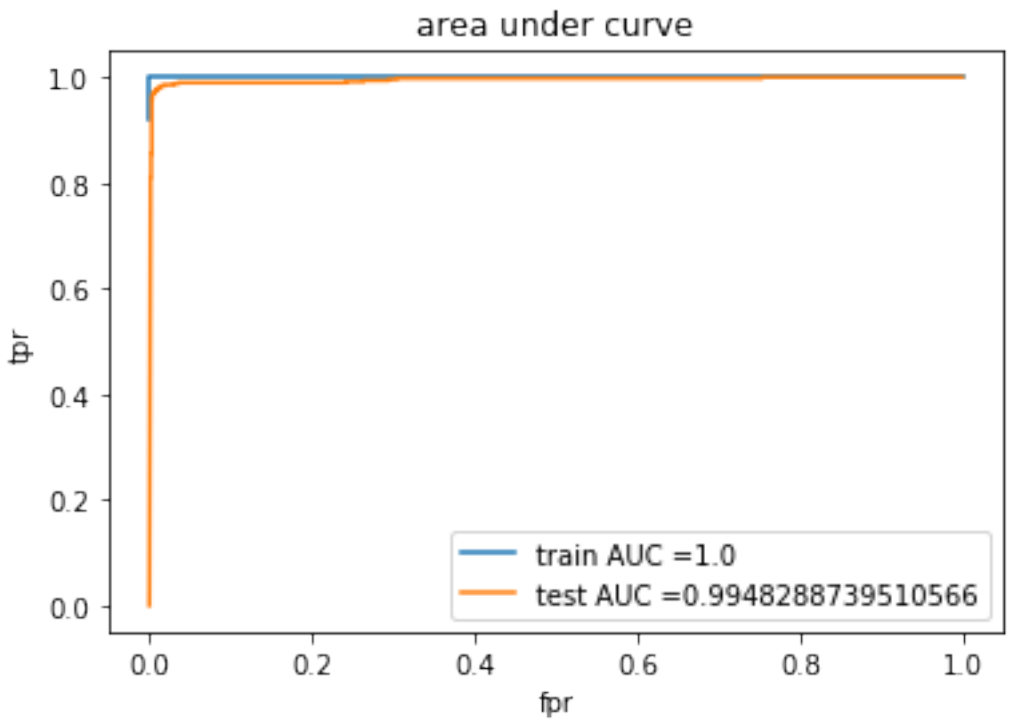
```
train_auc = []
cv_auc = []
A = [0.000001,0.00001,0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 1000,10000]
for i in A:
    model3 = MultinomialNB(alpha=i)
    model3.fit(x_train, y_train)
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimat
    # not the predicted outputs
    y_train_pred =  model3.predict_proba(x_train)[:,1]
    y_cv_pred =  model3.predict_proba(x_cv)[:,1]

    train_auc.append(roc_auc_score(y_train,y_train_pred))
    cv_auc.append(roc_auc_score(y_cv, y_cv_pred))

plt.plot(A, train_auc, label='Train AUC')
plt.plot(A, cv_auc, label='CV AUC')
plt.legend()
plt.xlabel("Alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.show()
```



In [211]: `from sklearn.metrics import roc_curve, auc`

```
best_a = A[cv_auc.index(max(cv_auc))]
print(best_a)
model3 = MultinomialNB(alpha=best_a)
model3.fit(x_train, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates o
# not the predicted outputs

train_fpr, train_tpr, thresholds = roc_curve(y_train, model3.predict_proba(x_train)[
test_fpr, test_tpr, thresholds = roc_curve(y_test, model3.predict_proba(x_test)[:,1])

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("fpr")
plt.ylabel("tpr")
plt.title("area under curve")
plt.show()

print("="*100)

from sklearn.metrics import confusion_matrix
print("Train confusion matrix")
print(confusion_matrix(y_train, model3.predict(x_train)))
print("Test confusion matrix")
print(confusion_matrix(y_test, model3.predict(x_test)))
```

```
0.01
```

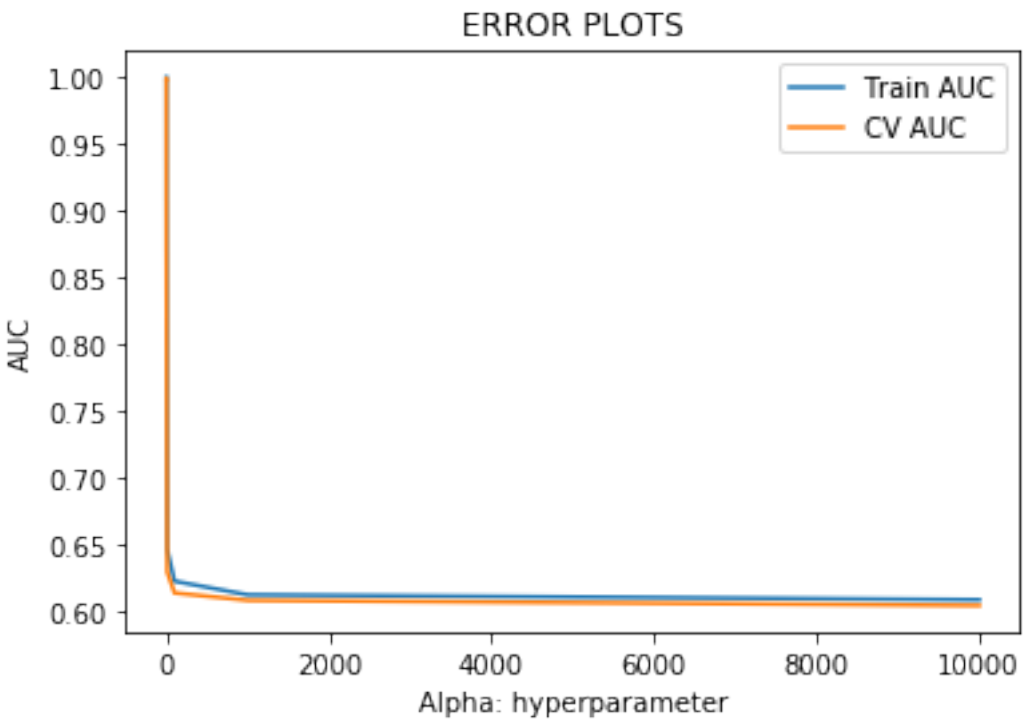



```
================================================================================================
Train confusion matrix
[[1991    0]
 [   0  579]]
Test confusion matrix
[[1401    4]
 [  25  461]]
```

Applying Naive Bayes on TFIDF after adding feature

```
In [212]: from sklearn.neighbors import KNeighborsClassifier
          from sklearn.metrics import roc_auc_score
          import matplotlib.pyplot as plt
          from sklearn.preprocessing import StandardScaler

          x_train=tfidftrain
          x_test=tfidftest
          x_cv=tfidfcv
          """
          y_true : array, shape = [n_samples] or [n_samples, n_classes]
          True binary labels or binary label indicators.

          y_score : array, shape = [n_samples] or [n_samples, n_classes]
```

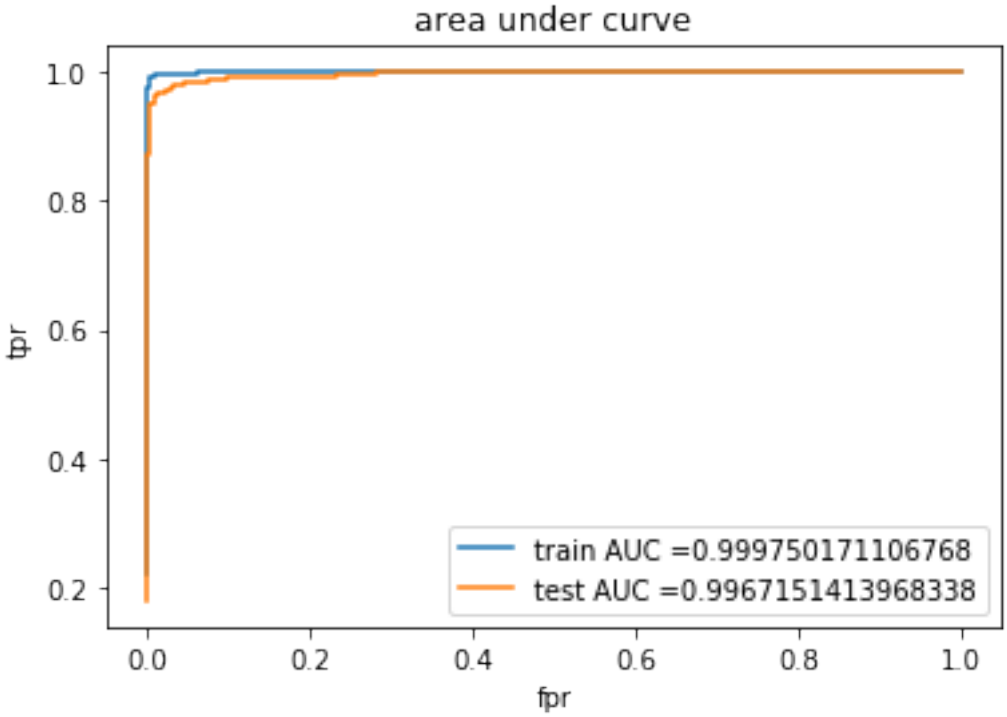
```
Target scores, can either be probability estimates of the positive class, confidence
decisions (as returned by decision_function on some classifiers).
For binary y_true, y_score is supposed to be the score of the class with greater lab

"""
#print(final_countsXtrain.toarray().shape)
train_auc = []
cv_auc = []
A = [0.000001,0.00001,0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 1000,10000]
for i in A:
    model = MultinomialNB(alpha=i)
    model.fit(x_train, y_train)
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimat
    # not the predicted outputs
    y_train_pred =  model.predict_proba(x_train)[:,1]
    y_cv_pred =  model.predict_proba(x_cv)[:,1]

    train_auc.append(roc_auc_score(y_train,y_train_pred))
    cv_auc.append(roc_auc_score(y_cv, y_cv_pred))

plt.plot(A, train_auc, label='Train AUC')
plt.plot(A, cv_auc, label='CV AUC')
plt.legend()
plt.xlabel("Alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.show()
```



In [213]:
```
from sklearn.metrics import roc_curve, auc

best_a = A[cv_auc.index(max(cv_auc))]
print(best_a)
model4 = MultinomialNB(alpha=best_a)
model4.fit(x_train, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates o
# not the predicted outputs

train_fpr, train_tpr, thresholds = roc_curve(y_train, model4.predict_proba(x_train)[
test_fpr, test_tpr, thresholds = roc_curve(y_test, model4.predict_proba(x_test)[:,1]]

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("fpr")
plt.ylabel("tpr")
plt.title("area under curve")
plt.show()

print("="*100)

from sklearn.metrics import confusion_matrix
print("Train confusion matrix")
```

```
print(confusion_matrix(y_train, model4.predict(x_train)))
print("Test confusion matrix")
print(confusion_matrix(y_test, model4.predict(x_test)))
```

```
0.0001
```




```
==========================================================================================
Train confusion matrix
[[1990    1]
 [  19  560]]
Test confusion matrix
[[1404    1]
 [  57  429]]
```

6 [6] Conclusions

```
In [214]: from prettytable import PrettyTable

          x = PrettyTable()

          x.field_names = ["Vectorizer", "Model", "Hyperparameter -alpha ", "AUC"]
```

```
x.add_row(["BOW", "Multinomial NaiveBayes", 1, 0.998])
x.add_row(["TFIDF", "Multinomial NaiveBayes", 0.01, 0.999])
x.add_row(["BOW with feature eng ", "Multinomial NaiveBayes", 0.1, 0.998])
x.add_row(["TFIDF with feature eng  ","Multinomial NaiveBayes", 0.001, 0.998])

print(x)
```

```
+--------------------------+-----------------------+-------------------------+-------+
|        Vectorizer        |         Model         | Hyperparameter -alpha   |  AUC  |
+--------------------------+-----------------------+-------------------------+-------+
|           BOW            | Multinomial NaiveBayes |           1            | 0.998 |
|          TFIDF           | Multinomial NaiveBayes |          0.01          | 0.999 |
|  BOW with feature eng    | Multinomial NaiveBayes |          0.1           | 0.998 |
| TFIDF with feature eng   | Multinomial NaiveBayes |         0.001          | 0.998 |
+--------------------------+-----------------------+-------------------------+-------+
```

In [215]:
```
def preprocess(sentance):
    preprocessed_email=[]
    sentance = re.sub(r"http\S+", "", sentance)
    sentance = BeautifulSoup(sentance, 'lxml').get_text()
    sentance = decontracted(sentance)
    sentance = re.sub("\S*\d\S*", "", sentance).strip()
    sentance = re.sub('[^A-Za-z]+', ' ', sentance)
    # https://gist.github.com/sebleier/554280
    sentance = ' '.join(e.lower() for e in sentance.split() if e.lower() not in stopw
    preprocessed_email.append(sentance.strip())
    return preprocessed_email
def findclass(x):
    x=preprocess(x)
    x=np.asarray(x)
    l = tf_idf_vect.transform(x)
    c=model2.predict(l)
    return c[0]
```

In [216]:
```
x=input("Enter the message")
print()
print()
print()
print("-----------------------------------------------")
c=findclass(x)
if c==1:
    print("The message is not a spam")
elif c==0:
    print("The message is a spam")
```

```
Enter the message"Subject: news : aurora 5 . 2 update  aurora version 5 . 2  - the fastest mode
```

```
---------------------------------------------
The message is a spam
```

In [ ]: