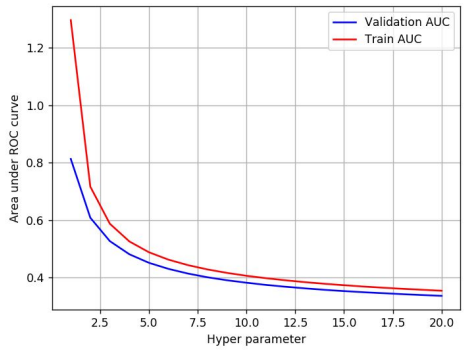
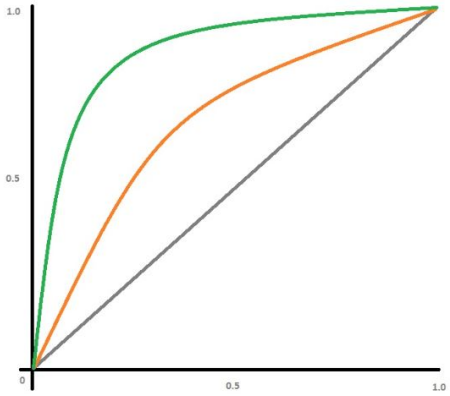
Assignment 6: Apply NB

1. **Apply Multinomial NB on these feature sets**
    - Set 1: categorical, numerical features + preprocessed_eassay (BOW)
    - Set 2: categorical, numerical features + preprocessed_eassay (TFIDF)
2. **The hyper paramter tuning(find best alpha:smoothing parameter)**
    - Find the best hyper parameter which will give the maximum AUC value
    - find the best hyper paramter using k-fold cross validation(use GridsearchCV or RandomsearchCV)/simple cross validation data (write for loop to iterate over hyper parameter values)
    -
3. **Representation of results**
    - You need to plot the performance of model both on train data and cross validation data for each hyper parameter, like shown in the figure



    - Once after you found the best hyper parameter, you need to train your model with it, and find the AUC on test data and plot the ROC curve on both train and test.



    - Along with plotting ROC curve, you need to print the confusion matrix with predicted and original labels of test data points

	Predicted: NO	Predicted: YES
Actual: NO	TN = ??	FP = ??
Actual: YES	FN = ??	TP = ??

4. fine the top 20 features from either from feature Set 1 or feature Set 2 using absolute values of `feature_log_prob_ ` parameter of `MultinomialNB` (https://scikit-learn.org/stable/modules/generated/sklearn.naive_bayes.MultinomialNB.html) and print their corresponding feature names
5. You need to summarize the results at the end of the notebook, summarize it in the table format

Vectorizer	Model	Hyper parameter	AUC
BOW	Brute	7	0.78
TFIDF	Brute	12	0.79
W2V	Brute	10	0.78

TFIDFW2V	Brute	6	0.78

2. Naive Bayes

1.1 Loading Data

In [0]:

```
import pandas as pd
import nltk
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
```

In [0]:

```
data = pd.read_csv('/content/drive/My Drive/AppliedAI/preprocessed_data.csv')
```

In [3]:

```
data.head()
```

Out[3]:

	school_state	teacher_prefix	project_grade_category	teacher_number_of_previously_posted_projects	project_is_approved	clean_cat
0	ca	mrs	grades_prek_2	53	1	math_
1	ut	ms	grades_3_5	4	1	specia
2	ca	mrs	grades_prek_2	10	1	literacy_la
3	ga	mrs	grades_prek_2	2	1	appliedl
4	wa	mrs	grades_3_5	2	1	literacy_la

In [4]:

```
data.columns.values
```

Out[4]:

```
array(['school_state', 'teacher_prefix', 'project_grade_category',
       'teacher_number_of_previously_posted_projects',
```

```
       'project_is_approved', 'clean_categories', 'clean_subcategories',
       'essay', 'price'], dtype=object)
```

For title

Pre-processing project title

In [0]:

```
data1 = pd.read_csv('/content/drive/My Drive/AppliedAI/train_data.csv')
```

In [6]:

```
data1.head()
```

Out[6]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_submitted_datetime	project_grade_c
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs.	IN	2016-12-05 13:43:57	Grades
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr.	FL	2016-10-25 09:22:10	Gra
2	21895	p182444	3465aaf82da834c0582ebd0ef8040ca0	Ms.	AZ	2016-08-31 12:03:56	Gra
3	45	p246581	f3cb9bffbba169bef1a77b243e620b60	Mrs.	KY	2016-10-06 21:16:17	Grades
4	172407	p104768	be1f7507a41f8479dc06f047086a39ec	Mrs.	TX	2016-07-11 01:10:09	Grades

In [0]:

```
project_title = data1['project_title']
```

In [0]:

```
stopwords= ['i', 'me', 'my', 'myself', 'we', 'our', 'ours', 'ourselves', 'you', "you're", "you've",\
            "you'll", "you'd", 'your', 'yours', 'yourself', 'yourselves', 'he', 'him', 'his', 'himself'
, \
            'she', "she's", 'her', 'hers', 'herself', 'it', "it's", 'its', 'itself', 'they', 'them', 't
heir',\
            'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'that', "that'll", 'these',
'those', \
            'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'has', 'had', 'having', 'd
o', 'does', \
            'did', 'doing', 'a', 'an', 'the', 'and', 'but', 'if', 'or', 'because', 'as', 'until', 'whil
e', 'of', \
            'at', 'by', 'for', 'with', 'about', 'against', 'between', 'into', 'through', 'during', 'bef
ore', 'after',\
            'above', 'below', 'to', 'from', 'up', 'down', 'in', 'out', 'on', 'off', 'over', 'under', 'a
gain', 'further',\
            'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'all', 'any', 'both', 'each
', 'few', 'more',\
            'most', 'other', 'some', 'such', 'only', 'own', 'same', 'so', 'than', 'too', 'very', \
            's', 't', 'can', 'will', 'just', 'don', "don't", 'should', "should've", 'now', 'd', 'll', '
m', 'o', 're', \
            've', 'y', 'ain', 'aren', "aren't", 'couldn', "couldn't", 'didn', "didn't", 'doesn', "doesn
```

```
't", 'hadn',\
            "hadn't", 'hasn', "hasn't", 'haven', "haven't", 'isn', "isn't", 'ma', 'mightn', "mightn't",
'mustn',\
            "mustn't", 'needn', "needn't", 'shan', "shan't", 'shouldn', "shouldn't", 'wasn', "wasn't",
'weren', "weren't", \
            'won', "won't", 'wouldn', "wouldn't"]
```

In [9]:

```
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

from tqdm import tqdm
def preprocess_text(text_data):
    preprocessed_text = []
    # tqdm is for printing the status bar
    for sentance in tqdm(text_data):
        sent = decontracted(sentance)
        sent = sent.replace('\\r', ' ')
        sent = sent.replace('\\n', ' ')
        sent = sent.replace('\\"', ' ')
        sent = re.sub('[^A-Za-z0-9]+', ' ', sent)
        # https://gist.github.com/sebleier/554280
        sent = ' '.join(e for e in sent.split() if e.lower() not in stopwords)
        preprocessed_text.append(sent.lower().strip())
    return preprocessed_text


preprocessed_titles = preprocess_text(data1['project_title'].values)
```

```
100%|██████████| 109248/109248 [00:02<00:00, 46574.78it/s]
```

In [10]:

```
#number of project title
len(data)
```

Out[10]:

```
109248
```

In [0]:

```
#Appending preprocessed_title to data
data["project_title"] = preprocessed_titles
```

In [0]:

```
#Seperating class label from features
y = data['project_is_approved'].values
x = data.drop(['project_is_approved'], axis=1)
```

In [0]:

```
# train test split
```

```
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, stratify=y)
x_train, x_cv, y_train, y_cv = train_test_split(x_train, y_train, test_size=0.33, stratify=y_train)
```

In [14]:

```
len(x)
```

Out[14]:

109248

In [0]:

```
#final feature names for picking top 20 features
final_feature_names = []
```

1.1 BoW Implementation

Essay Vectorization

In [16]:

```
print(x_train.shape, y_train.shape)
print(x_cv.shape, y_cv.shape)
print(x_test.shape, y_test.shape)

print("="*100)

vectorizer = CountVectorizer(min_df=10,ngram_range=(1,4),max_features=5000)
vectorizer.fit(x_train['essay'].values) # fit has to happen only on train data

x_train_essay_bow = vectorizer.transform(x_train['essay'].values)
x_cv_essay_bow = vectorizer.transform(x_cv['essay'].values)
x_test_essay_bow = vectorizer.transform(x_test['essay'].values)

final_feature_names +=  vectorizer.get_feature_names()
print(len(final_feature_names))

print("After vectorizations")
print(x_train_essay_bow.shape, y_train.shape)
print(x_cv_essay_bow.shape, y_cv.shape)
print(x_test_essay_bow.shape, y_test.shape)
```

```
(49041, 9) (49041,)
(24155, 9) (24155,)
(36052, 9) (36052,)
====================================================================================================
5000
After vectorizations
(49041, 5000) (49041,)
(24155, 5000) (24155,)
(36052, 5000) (36052,)
```

Project Title Vectorization

In [17]:

```
#project title
print(x_train.shape, y_train.shape)
print(x_cv.shape, y_cv.shape)
print(x_test.shape, y_test.shape)

print("="*100)

vectorizer = CountVectorizer(min_df=10,ngram_range=(1,4),max_features=5000)
vectorizer.fit(x_train['project_title'].values) # fit has to happen only on train data

x_train_project_title_bow = vectorizer.transform(x_train['project_title'].values)
```

```
x_train_project_title_bow = vectorizer.transform(x_train['project_title'].values)
x_cv_project_title_bow = vectorizer.transform(x_cv['project_title'].values)
x_test_project_title_bow = vectorizer.transform(x_test['project_title'].values)
final_feature_names += vectorizer.get_feature_names()
print(len(final_feature_names))


print("After vectorizations")
print(x_train_project_title_bow.shape, y_train.shape)
print(x_cv_project_title_bow.shape, y_cv.shape)
print(x_test_project_title_bow.shape, y_test.shape)
```

```
(49041, 9) (49041,)
(24155, 9) (24155,)
(36052, 9) (36052,)
==================================================================================================
8447
After vectorizations
(49041, 3447) (49041,)
(24155, 3447) (24155,)
(36052, 3447) (36052,)
```

School State Encoding

In [18]:

```
#School state encoding
vectorizer = CountVectorizer()
vectorizer.fit(x_train['school_state'].values) # fit has to happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
x_train_state_ohe = vectorizer.transform(x_train['school_state'].values)
x_cv_state_ohe = vectorizer.transform(x_cv['school_state'].values)
x_test_state_ohe = vectorizer.transform(x_test['school_state'].values)

final_feature_names +=  vectorizer.get_feature_names()
print(len(final_feature_names))



print("After vectorizations")
print(x_train_state_ohe.shape, y_train.shape)
print(x_cv_state_ohe.shape, y_cv.shape)
print(x_test_state_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
8498
After vectorizations
(49041, 51) (49041,)
(24155, 51) (24155,)
(36052, 51) (36052,)
['ak', 'al', 'ar', 'az', 'ca', 'co', 'ct', 'dc', 'de', 'fl', 'ga', 'hi', 'ia', 'id', 'il', 'in', 'ks',
'ky', 'la', 'ma', 'md', 'me', 'mi', 'mn', 'mo', 'ms', 'mt', 'nc', 'nd', 'ne', 'nh', 'nj', 'nm', 'nv', '
ny', 'oh', 'ok', 'or', 'pa', 'ri', 'sc', 'sd', 'tn', 'tx', 'ut', 'va', 'vt', 'wa', 'wi', 'wv', 'wy']
==================================================================================================
```

Teacher Prefix Encoding

In [19]:

```
#Teacher prefix encoding
vectorizer = CountVectorizer()
vectorizer.fit(x_train['teacher_prefix'].values) # fit has to happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
x_train_teacher_ohe = vectorizer.transform(x_train['teacher_prefix'].values)
x_cv_teacher_ohe = vectorizer.transform(x_cv['teacher_prefix'].values)
x_test_teacher_ohe = vectorizer.transform(x_test['teacher_prefix'].values)

final_feature_names +=  vectorizer.get_feature_names()
print(len(final_feature_names))
```

```
print("After vectorizations")
print(x_train_teacher_ohe.shape, y_train.shape)
print(x_cv_teacher_ohe.shape, y_cv.shape)
print(x_test_teacher_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
8503
After vectorizations
(49041, 5) (49041,)
(24155, 5) (24155,)
(36052, 5) (36052,)
['dr', 'mr', 'mrs', 'ms', 'teacher']
====================================================================================================
```

Project Grade Encoding

In [20]:

```
#project grade encoding
vectorizer = CountVectorizer()
vectorizer.fit(x_train['project_grade_category'].values) # fit has to happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
x_train_grade_ohe = vectorizer.transform(x_train['project_grade_category'].values)
x_cv_grade_ohe = vectorizer.transform(x_cv['project_grade_category'].values)
x_test_grade_ohe = vectorizer.transform(x_test['project_grade_category'].values)

final_feature_names +=  vectorizer.get_feature_names()
print(len(final_feature_names))



print("After vectorizations")
print(x_train_grade_ohe.shape, y_train.shape)
print(x_cv_grade_ohe.shape, y_cv.shape)
print(x_test_grade_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
8507
After vectorizations
(49041, 4) (49041,)
(24155, 4) (24155,)
(36052, 4) (36052,)
['grades_3_5', 'grades_6_8', 'grades_9_12', 'grades_prek_2']
====================================================================================================
```

Categories encoding

In [21]:

```
#clean_categories encoding
vectorizer = CountVectorizer()
vectorizer.fit(x_train['clean_categories'].values) # fit has to happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
x_train_clean_cat_ohe = vectorizer.transform(x_train['clean_categories'].values)
x_cv_clean_cat_ohe = vectorizer.transform(x_cv['clean_categories'].values)
x_test_clean_cat_ohe = vectorizer.transform(x_test['clean_categories'].values)

final_feature_names +=  vectorizer.get_feature_names()
print(len(final_feature_names))



print("After vectorizations")
print(x_train_clean_cat_ohe.shape, y_train.shape)
print(x_cv_clean_cat_ohe.shape, y_cv.shape)
print(x_test_clean_cat_ohe.shape, y_test.shape)
```

```
print(x_test_clean_cat_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
8516
After vectorizations
(49041, 9) (49041,)
(24155, 9) (24155,)
(36052, 9) (36052,)
['appliedlearning', 'care_hunger', 'health_sports', 'history_civics', 'literacy_language', 'math_scienc
e', 'music_arts', 'specialneeds', 'warmth']
====================================================================================================
```

Sub-categories encoding

In [22]:

```
#clean_subcategories encoding
vectorizer = CountVectorizer()
vectorizer.fit(x_train['clean_subcategories'].values) # fit has to happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
x_train_subcat_ohe = vectorizer.transform(x_train['clean_subcategories'].values)
x_cv_subcat_ohe = vectorizer.transform(x_cv['clean_subcategories'].values)
x_test_subcat_ohe = vectorizer.transform(x_test['clean_subcategories'].values)

final_feature_names +=  vectorizer.get_feature_names()
print(len(final_feature_names))



print("After vectorizations")
print(x_train_subcat_ohe.shape, y_train.shape)
print(x_cv_subcat_ohe.shape, y_cv.shape)
print(x_test_subcat_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
8546
After vectorizations
(49041, 30) (49041,)
(24155, 30) (24155,)
(36052, 30) (36052,)
['appliedsciences', 'care_hunger', 'charactereducation', 'civics_government', 'college_careerprep', 'co
mmunityservice', 'earlydevelopment', 'economics', 'environmentalscience', 'esl', 'extracurricular', 'fi
nancialliteracy', 'foreignlanguages', 'gym_fitness', 'health_lifescience', 'health_wellness', 'history_
geography', 'literacy', 'literature_writing', 'mathematics', 'music', 'nutritioneducation', 'other', 'p
arentinvolvement', 'performingarts', 'socialsciences', 'specialneeds', 'teamsports', 'visualarts', 'war
mth']
====================================================================================================
```

Prize Normalization

In [23]:

```
from sklearn.preprocessing import Normalizer
normalizer = Normalizer()


normalizer.fit(x_train['price'].values.reshape(-1,1))

x_train_price_norm = normalizer.transform(x_train['price'].values.reshape(-1,1))
x_cv_price_norm = normalizer.transform(x_cv['price'].values.reshape(-1,1))
x_test_price_norm = normalizer.transform(x_test['price'].values.reshape(-1,1))

final_feature_names +=  ['price']
print(len(final_feature_names))




print("After vectorizations")
print(x_train_price_norm.shape, y_train.shape)
```

```
print(x_train_price_norm.shape, y_train.shape)
print(x_cv_price_norm.shape, y_cv.shape)
print(x_test_price_norm.shape, y_test.shape)
print("="*100)
```

```
8547
After vectorizations
(49041, 1) (49041,)
(24155, 1) (24155,)
(36052, 1) (36052,)
====================================================================================================
```

teacher_number_of_previously_posted_projects normalization

In [24]:

```
normalizer = Normalizer()



normalizer.fit(x_train['teacher_number_of_previously_posted_projects'].values.reshape(-1,1))

x_train_teacher_num_norm = normalizer.transform(x_train['teacher_number_of_previously_posted_projects']
.values.reshape(-1,1))
x_cv_teacher_num_norm = normalizer.transform(x_cv['teacher_number_of_previously_posted_projects'].value
s.reshape(-1,1))
x_test_teacher_num_norm = normalizer.transform(x_test['teacher_number_of_previously_posted_projects'].v
alues.reshape(-1,1))

final_feature_names +=  ['teacher_number_of_previously_posted_projects']
print(len(final_feature_names))



print("After vectorizations")
print(x_train_teacher_num_norm.shape, y_train.shape)
print(x_cv_teacher_num_norm.shape, y_cv.shape)
print(x_test_teacher_num_norm.shape, y_test.shape)
print("="*100)
```

```
8548
After vectorizations
(49041, 1) (49041,)
(24155, 1) (24155,)
(36052, 1) (36052,)
====================================================================================================
```

In [25]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039
from scipy.sparse import hstack
x_tr = hstack((x_train_essay_bow,x_train_project_title_bow, x_train_state_ohe, x_train_teacher_ohe, x_t
rain_grade_ohe,x_train_clean_cat_ohe,x_train_subcat_ohe, x_train_price_norm,x_train_teacher_num_norm)).
tocsr()
x_cr = hstack((x_cv_essay_bow,x_cv_project_title_bow, x_cv_state_ohe, x_cv_teacher_ohe, x_cv_grade_ohe,
x_cv_clean_cat_ohe,x_cv_subcat_ohe, x_cv_price_norm,x_cv_teacher_num_norm)).tocsr()
x_te = hstack((x_test_essay_bow,x_test_project_title_bow, x_test_state_ohe, x_test_teacher_ohe, x_test_
grade_ohe,x_test_clean_cat_ohe,x_test_subcat_ohe, x_test_price_norm,x_test_teacher_num_norm)).tocsr()

print("Final Data matrix")
print(x_tr.shape, y_train.shape)
print(x_cr.shape, y_cv.shape)
print(x_te.shape, y_test.shape)
print(len(final_feature_names))
print("="*100)
```

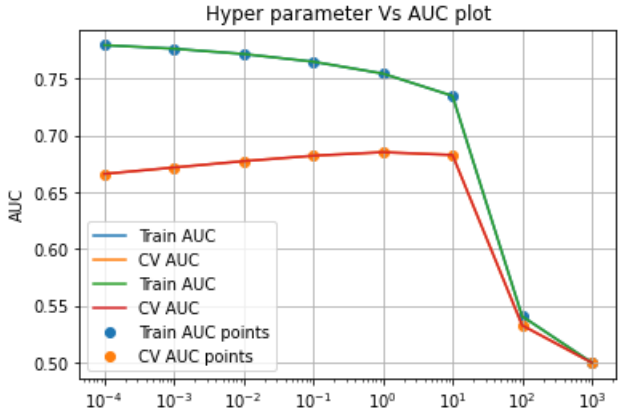
```
Final Data matrix
(49041, 8548) (49041,)
(24155, 8548) (24155,)
(36052, 8548) (36052,)
8548
====================================================================================================
```

Finding best hyper-parameter using RandomizedSearchCV

In [26]:

```
from sklearn.naive_bayes import MultinomialNB
from scipy.stats import randint as sp_randint
from sklearn.model_selection import RandomizedSearchCV
import random
import matplotlib.pyplot as plt


nb_bow = MultinomialNB()

parameters = {'alpha':[0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 1000]}
classifier = RandomizedSearchCV(nb, parameters, cv=3, return_train_score=True,scoring='roc_auc',)

classifier.fit(x_tr,y_train)

results = pd.DataFrame.from_dict(classifier.cv_results_)
results = results.sort_values(['param_alpha'])

train_auc= results['mean_train_score']
train_auc_std= results['std_train_score']
cv_auc = results['mean_test_score']
cv_auc_std= results['std_test_score']
alpha =  results['param_alpha']


plt.plot(alpha, train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
# plt.gca().fill_between(K, train_auc - train_auc_std,train_auc + train_auc_std,alpha=0.2,color='darkbl
ue')

plt.plot(alpha, cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
# plt.gca().fill_between(K, cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.2,color='darkorange')

plt.semilogx(alpha, train_auc, label='Train AUC')
plt.semilogx(alpha, cv_auc, label='CV AUC')

plt.scatter(alpha, train_auc, label='Train AUC points')
plt.scatter(alpha, cv_auc, label='CV AUC points')

plt.legend()
plt.xlabel("alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()

results.head()
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_search.py:281: UserWarning: The total s
pace of parameters 8 is smaller than n_iter=10. Running 8 iterations. For exhaustive searches, use Grid
SearchCV.
  % (grid_size, self.n_iter, grid_size), UserWarning)
```



alpha: hyperparameter

Out[26]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_alpha	params	split0_test_score	split1_test_score	split2_te
0	0.056013	0.000733	0.018101	0.000838	0.0001	{'alpha': 0.0001}	0.669590	0.661500	
1	0.054557	0.001521	0.017326	0.000390	0.001	{'alpha': 0.001}	0.675304	0.667422	
2	0.057896	0.003658	0.018706	0.000777	0.01	{'alpha': 0.01}	0.680640	0.673304	
3	0.056105	0.001750	0.017465	0.000885	0.1	{'alpha': 0.1}	0.685118	0.678218	
4	0.052802	0.000655	0.017159	0.000237	1	{'alpha': 1}	0.687864	0.681428	

In [0]:

```
#Best hyper-parameter
bow_alpha = 10
```

Training Model for best Alpha

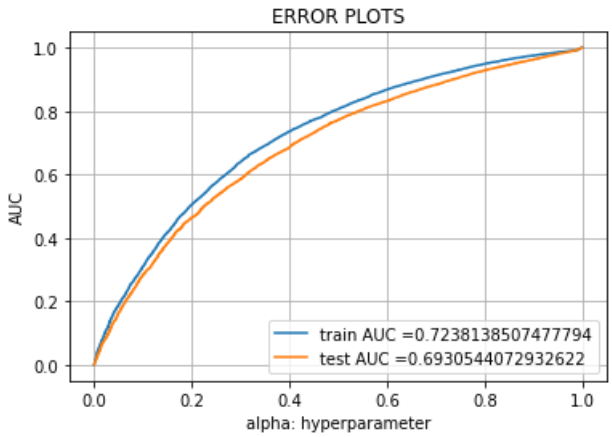
In [0]:

```
def batch_predict(clf, data):
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive
class
    # not the predicted outputs

    y_data_pred = []
    tr_loop = data.shape[0] - data.shape[0]%1000
    # consider you X_tr shape is 49041, then your tr_loop will be 49041 - 49041%1000 = 49000
    # in this for loop we will iterate unti the last 1000 multiplier
    for i in range(0, tr_loop, 1000):
        y_data_pred.extend(clf.predict_proba(data[i:i+1000])[:,1])
    # we will be predicting for the last data points
    if data.shape[0]%1000 !=0:
        y_data_pred.extend(clf.predict_proba(data[tr_loop:])[:,1])

    return y_data_pred
```

In [29]:

```
# https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_
curve
from sklearn.metrics import roc_curve, auc


nb_bow = MultinomialNB(alpha=bow_alpha)
nb_bow.fit(x_tr, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive clas
s
# not the predicted outputs



y_train_pred = batch_predict(nb_bow, x_tr)
y_test_pred = batch_predict(nb_bow, x_te)

train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred)

train_auc_bow = round(auc(train_fpr, train_tpr),2)
test_auc_bow = round(auc(test_fpr, test_tpr),2)

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("alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.grid()
plt.show()
```



In [0]:

```
import numpy as np

def find_best_threshold(threshould, fpr, tpr):
    t = threshould[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for threshold", np.round(t,3))
    return t

def predict_with_best_t(proba, threshould):
    predictions = []
    for i in proba:
        if i>=threshould:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

Confusion Matrix

In [31]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
print(confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t)))
print("Test confusion matrix")
print(confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))
```

```
====================================================================================================
the maximum value of tpr*(1-fpr) 0.4524237234348346 for threshold 0.978
Train confusion matrix
[[ 5054  2372]
 [13951 27664]]
Test confusion matrix
[[ 3437  2022]
 [10353 20240]]
```

1.2 Tf-idf Implementation

In [0]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
```

```
from sklearn.feature_extraction.text import TfidfVectorizer
```

Essay Tf-idf vectorization

In [34]:

```
print(x_train.shape, y_train.shape)
print(x_cv.shape, y_cv.shape)
print(x_test.shape, y_test.shape)

print("="*100)


vectorizer = TfidfVectorizer(min_df=10,ngram_range=(1,4),max_features=5000)
vectorizer.fit(x_train['essay'].values) # fit has to happen only on train data

x_train_essay_tfidf = vectorizer.transform(x_train['essay'].values)
x_cv_essay_tfidf = vectorizer.transform(x_cv['essay'].values)
x_test_essay_tfidf = vectorizer.transform(x_test['essay'].values)


print("After vectorizations")
print(x_train_essay_tfidf.shape, y_train.shape)
print(x_cv_essay_tfidf.shape, y_cv.shape)
print(x_test_essay_tfidf.shape, y_test.shape)
```

```
(49041, 9) (49041,)
(24155, 9) (24155,)
(36052, 9) (36052,)
====================================================================================================
After vectorizations
(49041, 5000) (49041,)
(24155, 5000) (24155,)
(36052, 5000) (36052,)
```

Project Title Tf-idf vectorization

In [35]:

```
#project title
print(x_train.shape, y_train.shape)
print(x_cv.shape, y_cv.shape)
print(x_test.shape, y_test.shape)

print("="*100)

vectorizer = TfidfVectorizer(min_df=10,ngram_range=(1,4),max_features=5000)
vectorizer.fit(x_train['project_title'].values)  # fit has to happen only on train data

x_train_project_title_tfidf = vectorizer.transform(x_train['project_title'].values)
x_cv_project_title_tfidf = vectorizer.transform(x_cv['project_title'].values)
x_test_project_title_tfidf = vectorizer.transform(x_test['project_title'].values)


print("After vectorizations")
print(x_train_project_title_tfidf.shape, y_train.shape)
print(x_cv_project_title_tfidf.shape, y_cv.shape)
print(x_test_project_title_tfidf.shape, y_test.shape)
```

```
(49041, 9) (49041,)
(24155, 9) (24155,)
(36052, 9) (36052,)
====================================================================================================
After vectorizations
(49041, 3447) (49041,)
(24155, 3447) (24155,)
(36052, 3447) (36052,)
```

Final data matrix

In [36]:

In [36]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039
from scipy.sparse import hstack
x_tr = hstack((x_train_essay_tfidf,x_train_project_title_tfidf, x_train_state_ohe, x_train_teacher_ohe,
x_train_grade_ohe,x_train_clean_cat_ohe,x_train_subcat_ohe, x_train_price_norm,x_train_teacher_num_norm
)).tocsr()
x_cr = hstack((x_cv_essay_tfidf,x_cv_project_title_tfidf, x_cv_state_ohe, x_cv_teacher_ohe, x_cv_grade_
ohe,x_cv_clean_cat_ohe,x_cv_subcat_ohe, x_cv_price_norm,x_cv_teacher_num_norm)).tocsr()
x_te = hstack((x_test_essay_tfidf,x_test_project_title_tfidf, x_test_state_ohe, x_test_teacher_ohe, x_t
est_grade_ohe,x_test_clean_cat_ohe,x_test_subcat_ohe, x_test_price_norm,x_test_teacher_num_norm)).tocsr
()

print("Final Data matrix")
print(x_tr.shape, y_train.shape)
print(x_cr.shape, y_cv.shape)
print(x_te.shape, y_test.shape)
print("="*100)
```

```
Final Data matrix
(49041, 8548) (49041,)
(24155, 8548) (24155,)
(36052, 8548) (36052,)
====================================================================================================
```

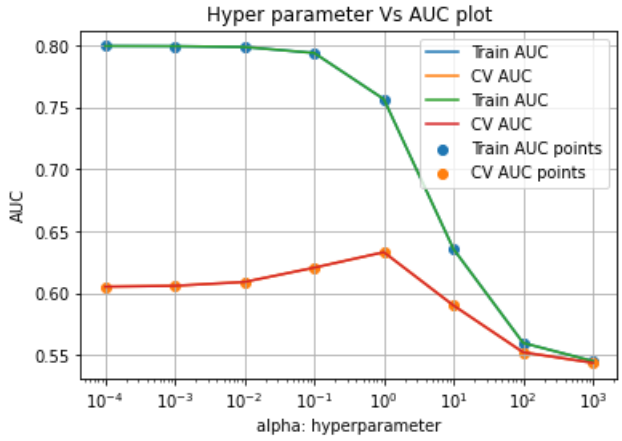
Hyper parameter tuning for tf-idf

In [37]:

```
from sklearn.naive_bayes import MultinomialNB
from scipy.stats import randint as sp_randint
from sklearn.model_selection import RandomizedSearchCV
import random
import matplotlib.pyplot as plt


nb = MultinomialNB()

parameters = {'alpha':[0.0001, 0.001, 0.01, 0.1, 1, 10, 100, 1000]}
classifier = RandomizedSearchCV(nb, parameters, cv=3, return_train_score=True,scoring='roc_auc',)

classifier.fit(x_tr,y_train)


results = pd.DataFrame.from_dict(classifier.cv_results_)
results = results.sort_values(['param_alpha'])

train_auc= results['mean_train_score']
train_auc_std= results['std_train_score']
cv_auc = results['mean_test_score']
cv_auc_std= results['std_test_score']
alpha =  results['param_alpha']


plt.plot(alpha, train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
# plt.gca().fill_between(K, train_auc - train_auc_std,train_auc + train_auc_std,alpha=0.2,color='darkbl
ue')

plt.plot(alpha, cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
# plt.gca().fill_between(K, cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.2,color='darkorange')

plt.semilogx(alpha, train_auc, label='Train AUC')
plt.semilogx(alpha, cv_auc, label='CV AUC')

plt.scatter(alpha, train_auc, label='Train AUC points')
plt.scatter(alpha, cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
```

```
plt.grid()
plt.show()

results.head()
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_search.py:281: UserWarning: The total space of parameters 8 is smaller than n_iter=10. Running 8 iterations. For exhaustive searches, use GridSearchCV.
  % (grid_size, self.n_iter, grid_size), UserWarning)
```



Out[37]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_alpha	params	split0_test_score	split1_test_score	split2_te
0	0.052759	0.001813	0.018010	0.000695	0.0001	{'alpha': 0.0001}	0.606335	0.598528	
1	0.053001	0.002547	0.018812	0.003193	0.001	{'alpha': 0.001}	0.607297	0.599323	
2	0.051813	0.001986	0.017911	0.001140	0.01	{'alpha': 0.01}	0.610717	0.602990	
3	0.049190	0.000324	0.017058	0.000475	0.1	{'alpha': 0.1}	0.621928	0.616011	
4	0.050385	0.000663	0.016512	0.000490	1	{'alpha': 1}	0.633112	0.628677	

In [0]:

```
#Best alpha
tfidf_alpha = 1
```

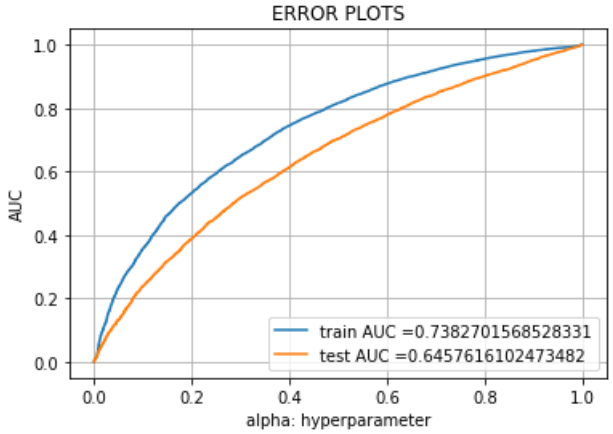
Traning model on best alpha

In [0]:

```
def batch_predict(clf, data):
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive class
    # not the predicted outputs

    y_data_pred = []
    tr_loop = data.shape[0] - data.shape[0]%1000
    # consider you X_tr shape is 49041, then your tr_loop will be 49041 - 49041%1000 = 49000
    # in this for loop we will iterate unti the last 1000 multiplier
    for i in range(0, tr_loop, 1000):
        y_data_pred.extend(clf.predict_proba(data[i:i+1000])[:,1])
    # we will be predicting for the last data points
    if data.shape[0]%1000 !=0:
        y_data_pred.extend(clf.predict_proba(data[tr_loop:])[:,1])

    return y_data_pred
```

In [40]:

```
# https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve
from sklearn.metrics import roc_curve, auc


nb = MultinomialNB(alpha=tfidf_alpha)
nb.fit(x_tr, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive class
# not the predicted outputs

y_train_pred = batch_predict(nb, x_tr)
y_test_pred = batch_predict(nb, x_te)

train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred)

train_auc_tfidf = round(auc(train_fpr, train_tpr),2)
test_auc_tfidf = round(auc(test_fpr, test_tpr),2)

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("alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.grid()
plt.show()
```



In [0]:

```
# we are writing our own function for predict, with defined thresould
# we will pick a threshold that will give the least fpr
def find_best_threshold(threshould, fpr, tpr):
    t = threshould[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for threshold", np.round(t,3))
    return t

def predict_with_best_t(proba, threshould):
    predictions = []
    for i in proba:
        if i>=threshould:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

Confusion Matrix

In [42]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
```

```
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
print(confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t)))
print("Test confusion matrix")
print(confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))
```

```
====================================================================================================
the maximum value of tpr*(1-fpr) 0.45501847553557306 for threshold 0.862
Train confusion matrix
[[ 5164  2262]
 [14385 27230]]
Test confusion matrix
[[ 3149  2310]
 [11066 19527]]
```

2. Top 20 features

In [45]:

```
#Reffered from
#https://datascience.stackexchange.com/questions/65219/find-the-top-n-features-from-feature-set-using-absolute-values-of-feature-log-p

# For positive class

sorted_prob_class_1_ind = nb_bow.feature_log_prob_[1, :].argsort()
# For negative class
sorted_prob_class_0_ind = nb_bow.feature_log_prob_[0, :].argsort()

Most_imp_words_1 = []
Most_imp_words_0 = []

for index in sorted_prob_class_1_ind[-20:-1]:
    Most_imp_words_1.append(final_feature_names[index])

for index in sorted_prob_class_0_ind[-20:-1]:
    Most_imp_words_0.append(final_feature_names[index])

print("20 most imp features for positive class:\n")
print(Most_imp_words_1)

print("\n" + "-"*100)

print("\n20 most imp features for negative class:\n")
print(Most_imp_words_0)
```

```
20 most imp features for positive class:

['mr', 'grades_9_12', 'appliedlearning', 'students', 'specialneeds', 'specialneeds', 'health_sports', '
ca', 'grades_6_8', 'literature_writing', 'mathematics', 'literacy', 'grades_3_5', 'ms', 'math_science',
'grades_prek_2', 'literacy_language', 'mrs', 'teacher_number_of_previously_posted_projects']

----------------------------------------------------------------------------------------------------

20 most imp features for negative class:

['grades_9_12', 'appliedsciences', 'students', 'appliedlearning', 'health_sports', 'ca', 'specialneeds'
, 'specialneeds', 'grades_6_8', 'literature_writing', 'literacy', 'mathematics', 'grades_3_5', 'ms', 'm
ath_science', 'grades_prek_2', 'literacy_language', 'mrs', 'teacher_number_of_previously_posted_project
s']
```

3. Summary

In [46]:

```
from prettytable import PrettyTable
t = PrettyTable(['Vectorizer', 'Model','Alpha(Hyper-parameter)','Train AUC','Test AUC'])
t.add_row(['BoW', 'Multinominal Naive Bayes',bow_alpha,train_auc_bow,test_auc_bow])
t.add_row(['Tf-idf', 'Multinominal Naive Bayes',tfidf_alpha,train_auc_tfidf,test_auc_tfidf])
print(t)
```

```
print(t)
```

```
+------------+--------------------------+-----------------------+-----------+----------+
| Vectorizer |          Model           | Alpha(Hyper-parameter) | Train AUC | Test AUC |
+------------+--------------------------+-----------------------+-----------+----------+
|    BoW     | Multinominal Naive Bayes |          10           |    0.72   |   0.69   |
|   Tf-idf   | Multinominal Naive Bayes |          1            |    0.74   |   0.65   |
+------------+--------------------------+-----------------------+-----------+----------+
```