Apply Random Forest Classifier and Gradient Boosted Decision Trees

In [1]:

```
%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

from chart_studio.plotly import plotly
import plotly.offline as offline
import plotly.graph_objs as go
offline.init_notebook_mode()
from collections import Counter
```

1) Splitting data into Train and cross validation(or test): Stratified Sampling

In [2]:

```
project_data = pd.read_csv("train_data.csv", nrows = 30000)
resource_data = pd.read_csv("resources.csv", nrows = 30000)
```

In [3]:

```
print("Number of data points in train data", project_data.shape)
print('-'*50)
print("The attributes of data :", project_data.columns.values)
```

```
Number of data points in train data (30000, 17)
--------------------------------------------------
The attributes of data : ['Unnamed: 0' 'id' 'teacher_id' 'teacher_prefix' 'school_state'
 'project_submitted_datetime' 'project_grade_category'
 'project_subject_categories' 'project_subject_subcategories'
 'project_title' 'project_essay_1' 'project_essay_2' 'project_essay_3'
 'project_essay_4' 'project_resource_summary'
```

```
 'teacher_number_of_previously_posted_projects' 'project_is_approved']
```

In [4]:

```
# Let's check for any "null" or "missing" values
project_data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 30000 entries, 0 to 29999
Data columns (total 17 columns):
Unnamed: 0                                      30000 non-null int64
id                                              30000 non-null object
teacher_id                                      30000 non-null object
teacher_prefix                                  29999 non-null object
school_state                                    30000 non-null object
project_submitted_datetime                      30000 non-null object
project_grade_category                          30000 non-null object
project_subject_categories                      30000 non-null object
project_subject_subcategories                   30000 non-null object
project_title                                   30000 non-null object
project_essay_1                                 30000 non-null object
project_essay_2                                 30000 non-null object
project_essay_3                                 1013 non-null object
project_essay_4                                 1013 non-null object
project_resource_summary                        30000 non-null object
teacher_number_of_previously_posted_projects    30000 non-null int64
project_is_approved                             30000 non-null int64
dtypes: int64(3), object(14)
memory usage: 3.9+ MB
```

In [5]:

```
project_data['teacher_prefix'].isna().sum()
```

Out[5]:

```
1
```

In [6]:

```
# "teacher_prefix" seems to contain 2 "missing" values, let't use mode replacement strategy to fil
l those missing values
project_data['teacher_prefix'].mode()
```

Out[6]:

```
0    Mrs.
dtype: object
```

In [7]:

```
# Let's replace the missing values with "Mrs." , as it is the mode of the "teacher_prefix"
project_data['teacher_prefix'] = project_data['teacher_prefix'].fillna('Mrs.')
```

In [8]:

```
price_data = resource_data.groupby('id').agg({'price':'sum', 'quantity':'sum'}).reset_index()
project_data = pd.merge(project_data, price_data, on='id', how='left')
```

In [9]:

```
# Let's select only the selected features or columns, dropping "project_resource_summary" as it is
optional
#
project_data.drop(['id','teacher_id','project_submitted_datetime','project_resource_summary'],axis
=1, inplace=True)
project_data.columns
```

Out[9]:

```
Index(['Unnamed: 0', 'teacher_prefix', 'school_state',
       'project_grade_category', 'project_subject_categories',
       'project_subject_subcategories', 'project_title', 'project_essay_1',
       'project_essay_2', 'project_essay_3', 'project_essay_4',
       'teacher_number_of_previously_posted_projects', 'project_is_approved',
       'price', 'quantity'],
      dtype='object')
```

In [10]:

```
# Data seems to be highly imbalanced since the ratio of "class 1" to "class 0" is nearly 5.5
project_data['project_is_approved'].value_counts()
```

Out[10]:

```
1    25380
0     4620
Name: project_is_approved, dtype: int64
```

In [11]:

```
number_of_approved = project_data['project_is_approved'][project_data['project_is_approved'] == 1].
count()
number_of_not_approved = project_data['project_is_approved'][project_data['project_is_approved'] =
= 0].count()

print("Ratio of Project approved to Not approved is:", number_of_approved/number_of_not_approved)
```

```
Ratio of Project approved to Not approved is: 5.4935064935064934
```

In [12]:

```
# merge two column text dataframe:
project_data["essay"] = project_data["project_essay_1"].map(str) +\
                        project_data["project_essay_2"].map(str) + \
                        project_data["project_essay_3"].map(str) + \
                        project_data["project_essay_4"].map(str)
```

In [13]:

```
project_data.head(2)
```

Out[13]:

	Unnamed: 0	teacher_prefix	school_state	project_grade_category	project_subject_categories	project_subject_subcatego
0	160221	Mrs.	IN	Grades PreK-2	Literacy & Language	ESL, Literacy
1	140945	Mr.	FL	Grades 6-8	History & Civics, Health & Sports	Civics & Government, Team Sports

In [14]:

```
# Let's drop the project essay columns from the dadaset now, as we have captured the essay text da
ta into single "essay" column
project_data.drop(['project_essay_1','project_essay_2','project_essay_3','project_essay_4'],axis=1
```

```
, inplace=True)
```

In [15]:

```
y = project_data['project_is_approved'].values
X = project_data.drop(['project_is_approved'], axis=1)
X.head(1)
```

Out[15]:

	Unnamed: 0	teacher_prefix	school_state	project_grade_category	project_subject_categories	project_subject_subcatego
0	160221	Mrs.	IN	Grades PreK-2	Literacy & Language	ESL, Literacy

In [16]:

```
# 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)
```

2) Make Data Model Ready: encoding numerical, categorical features

In [17]:

```
def cleaning_text_data(list_text_feature,df,old_col_name,new_col_name):

    # remove special characters from list of strings python: 
https://stackoverflow.com/a/47301924/4084039
    # https://www.geeksforgeeks.org/removing-stop-words-nltk-python/
    # https://stackoverflow.com/questions/23669024/how-to-strip-a-specific-word-from-a-string
    # https://stackoverflow.com/questions/8270092/remove-all-whitespace-in-a-string-in-python
    feature_list = []
    for i in list_text_feature:
        temp = ""
        # consider we have text like this "Math & Science, Warmth, Care & Hunger"
        for j in i.split(','): # it will split it in three parts ["Math & Science", "Warmth", "Care 
& Hunger"]
            if 'The' in j.split(): # this will split each of the catogory based on space "Math & Sc
ience"=> "Math","&", "Science"
                j=j.replace('The','') # if we have the words "The" we are going to replace it with 
''(i.e removing 'The')
            j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty) ex:"Math & Sc
ience"=>"Math&Science"
            temp+=j.strip()+" " #" abc ".strip() will return "abc", remove the trailing spaces
            temp = temp.replace('&','_') # we are replacing the & value into
        feature_list.append(temp.strip())

    df[new_col_name] = feature_list
    df.drop([old_col_name], axis=1, inplace=True)

    from collections import Counter
    my_counter = Counter()
    for word in df[new_col_name].values:
        my_counter.update(word.split())

    feature_dict = dict(my_counter)
    sorted_feature_dict = dict(sorted(feature_dict.items(), key=lambda kv: kv[1]))
    return sorted_feature_dict
```

In [18]:

```
def clean_project_grade(list_text_feature,df,old_col_name,new_col_name):

    # remove special characters from list of strings python:
https://stackoverflow.com/a/47301924/4084039
    # https://www.geeksforgeeks.org/removing-stop-words-nltk-python/
    # https://stackoverflow.com/questions/23669024/how-to-strip-a-specific-word-from-a-string
    # https://stackoverflow.com/questions/8270092/remove-all-whitespace-in-a-string-in-python
    feature_list = []
    for i in list_text_feature:
        temp = i.split(' ')
        last_dig = temp[-1].split('-')
        fin = [temp[0]]
        fin.extend(last_dig)
        feature = '_'.join(fin)
        feature_list.append(feature.strip())

    df[new_col_name] = feature_list
    df.drop([old_col_name], axis=1, inplace=True)

    from collections import Counter
    my_counter = Counter()
    for word in df[new_col_name].values:
        my_counter.update(word.split())

    feature_dict = dict(my_counter)
    sorted_feature_dict = dict(sorted(feature_dict.items(), key=lambda kv: kv[1]))
    return sorted_feature_dict
```

2.1) Text Preprocessing: project_subject_categories

In [19]:

```
x_train_sorted_category_dict = cleaning_text_data(X_train['project_subject_categories'],X_train,'project_subject_categories','clean_categories')
x_test_sorted_category_dict =
cleaning_text_data(X_test['project_subject_categories'],X_test,'project_subject_categories','clean_categories')
```

2.2) Text Preprocessing : project_subject_subcategories

In [20]:

```
x_train_sorted_subcategories = cleaning_text_data(X_train['project_subject_subcategories'],X_train,'project_subject_subcategories','clean_subcategories')
x_test_sorted_subcategories = cleaning_text_data(X_test['project_subject_subcategories'],X_test,'project_subject_subcategories','clean_subcategories')
```

2.3) Text Preprocessing: project_grade_category

In [21]:

```
x_train_sorted_grade =
clean_project_grade(X_train['project_grade_category'],X_train,'project_grade_category','clean_grade')
x_test_sorted_grade =
clean_project_grade(X_test['project_grade_category'],X_test,'project_grade_category','clean_grade')
```

2.4) Text Preprocessing (stowords): project_essay, project_title

In [22]:

```
# 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 [23]:

```
# https://gist.github.com/sebleier/554280
# we are removing the words from the stop words list: 'no', 'nor', 'not'
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',
'their',\
            'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'that', "that'll",
'these', 'those', \
            'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'has', 'had', 'having',
'do', 'does', \
            'did', 'doing', 'a', 'an', 'the', 'and', 'but', 'if', 'or', 'because', 'as', 'until', '
while', 'of', \
            'at', 'by', 'for', 'with', 'about', 'against', 'between', 'into', 'through', 'during',
'before', 'after',\
            'above', 'below', 'to', 'from', 'up', 'down', 'in', 'out', 'on', 'off', 'over', 'under'
, 'again', 'further',\
            'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'all', 'any', 'both', 'e
ach', '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', "do
esn'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 [24]:

```
# Combining all the above stundents
from tqdm import tqdm
def process_text(df,col_name):
    preprocessed_feature = []
    # tqdm is for printing the status bar
    for sentance in tqdm(df[col_name].values):
        sent = decontracted(sentance)
        sent = sent.replace('\\r', ' ')
        sent = sent.replace('\\"', ' ')
        sent = sent.replace('\\n', ' ')
        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_feature.append(sent.lower().strip())
    return preprocessed_feature
```

In [25]:

```
x_train_essay_preprocessed = process_text(X_train,'essay')
x_test_essay_preprocessed = process_text(X_test,'essay')
```

```
100%|██████████████████████████████████████████████████████████████████████| 20100/20100
[00:14<00:00, 1413.65it/s]
```

```
100%|██████████████████████████████████████████████████████████████████████████| 9900/9900
[00:06<00:00, 1435.06it/s]
```

In [26]:

```python
x_train_title_preprocessed = process_text(X_train,'project_title')
x_test_title_preprocessed = process_text(X_test,'project_title')
```

```
100%|███████████████████████████████████████████████████████████████████████| 20100/20100
[00:00<00:00, 27107.65it/s]
100%|█████████████████████████████████████████████████████████████████████████| 9900/9900
[00:00<00:00, 27890.32it/s]
```

2.5) Response Coding for Categorical Data

In [27]:

```python
# We have following categorical features
# 1) school_state, 2) project_categories(clean_categories), 3)
project_subcategories(clean_subcategories),
# 4) project_grade_categories(clean_grade), 5) teacher_prefix
```

In [28]:

```python
def response_coded(x_train,y_train,x_test,y_test,col_name):

    train_list = []
    test_list = []

    if (len(x_train[col_name]) != len(y_train)) or (len(x_test[col_name]) != len(y_test)):
        return "rows mismatch"

    train_set = list(set(x_train[col_name]))
    test_set = list(set(x_test[col_name]))

    # Let's process train data
    for index in range(len(train_set)):
        label_1 = 0
        label_0 = 0
        temp = {}
        for attr,label in zip(x_train[col_name],y_train):
            if train_set[index] == attr:
                if label == 0:
                    label_0 += 1
                else:
                    label_1 += 1
        temp['attribute'] = train_set[index].lower()
        temp['prob_label_1'] = label_1 / (label_1 + label_0)
        temp['prob_label_0'] = label_0 / (label_1 + label_0)
        train_list.append(temp)
    # Let's process test data
    for index in range(len(test_set)):
        label_1 = 0
        label_0 = 0
        temp = {}
        for attr,label in zip(x_test[col_name],y_test):
            if test_set[index] == attr:
                if label == 0:
                    label_0 += 1
                else:
                    label_1 += 1
        temp['attribute'] = test_set[index].lower()
        temp['prob_label_1'] = label_1 / (label_1 + label_0)
        temp['prob_label_0'] = label_0 / (label_1 + label_0)
        test_list.append(temp)

    # let's check for elements in test data that is not there in train data
    in_test = list(set(x_test[col_name]) - set(x_train[col_name]))

    if len(in_test) != 0:
        for attr in in_test:
            train_list.append({'attribute':attr.lower(),'prob_label_1':0.5,'prob_label_0':0.5})
```

```
            test_list.append({'attribute':attr.lower(),'prob_label_1':0.5,'prob_label_0':0.5})

    train_list_1 = [0] * len(x_train[col_name])
    train_list_0 = [0] * len(x_train[col_name])
    train_attr = ["-"] * len(x_train[col_name])
    for index,value in enumerate(x_train[col_name]):
        for tr in train_list:
            if tr['attribute'] == value.lower():
                train_list_1[index] = tr['prob_label_1']
                train_list_0[index] = tr['prob_label_0']
                train_attr[index] = tr['attribute']


    test_list_1 = [0] * len(x_test[col_name])
    test_list_0 = [0] * len(x_test[col_name])
    test_attr = ["-"] * len(x_test[col_name])

    for index, value in enumerate(x_test[col_name]):
        for te in test_list:
            if te['attribute'] == value.lower():
                test_list_1[index] = te['prob_label_1']
                test_list_0[index] = te['prob_label_0']
                test_attr[index] = te['attribute']

    return train_list_1, train_list_0, test_list_1, test_list_0
```

school_state

In [29]:

```
x_train_school_state_1,x_train_school_state_0, x_test_school_state_1,x_test_school_state_0 =
response_coded(X_train,y_train,X_test,y_test,'school_state')
```

In [30]:

```
X_train['train_school_state_1'] = x_train_school_state_1
X_train['train_school_state_0'] = x_train_school_state_0
X_test['test_school_state_1'] = x_test_school_state_1
X_test['test_school_state_0'] = x_test_school_state_0
```

In [31]:

```
X_train['train_school_state_1'][:10]
```

Out[31]:

```
10010    0.857675
868      0.847015
26899    0.835214
6909     0.848485
7151     0.847015
12755    0.861533
15456    0.886878
25829    0.813688
22949    0.879828
2244     0.850099
Name: train_school_state_1, dtype: float64
```

In [32]:

```
X_train['train_school_state_0'][:10]
```

Out[32]:

```
10010    0.142325
868      0.152985
26899    0.164786
```

```
6909     0.151515
7151     0.152985
12755    0.138467
15456    0.113122
25829    0.186312
22949    0.120172
2244     0.149901
Name: train_school_state_0, dtype: float64
```

In [33]:

```
X_test['test_school_state_1'][:10]
```

Out[33]:

```
3779     0.826783
22936    0.806985
10115    0.849029
29791    0.822674
11587    0.849029
7617     0.826783
27165    0.876761
24916    0.831169
24849    0.865385
21430    0.857143
Name: test_school_state_1, dtype: float64
```

In [34]:

```
X_test['test_school_state_0'][:10]
```

Out[34]:

```
3779     0.173217
22936    0.193015
10115    0.150971
29791    0.177326
11587    0.150971
7617     0.173217
27165    0.123239
24916    0.168831
24849    0.134615
21430    0.142857
Name: test_school_state_0, dtype: float64
```

project_categories (clean_categories)

In [35]:

```
x_train_pro_cat_1,x_train_pro_cat_0, x_test_pro_cat_1,x_test_pro_cat_0 =
response_coded(X_train,y_train,X_test,y_test,'clean_categories')
```

In [36]:

```
X_train['train_pro_cat_1'] = x_train_pro_cat_1
X_train['train_pro_cat_0'] = x_train_pro_cat_0
X_test['test_pro_cat_1'] = x_test_pro_cat_1
X_test['test_pro_cat_0'] = x_test_pro_cat_0
```

In [37]:

```
X_train['train_pro_cat_1'][:10]
```

Out[37]:

```
10010    0.930894
868      0.870438
26899    0.843127
6909     0.500000
7151     0.866491
12755    0.818931
```

```
12755    0.818951
15456    0.870438
25829    0.848326
22949    0.800000
2244     0.866491
Name: train_pro_cat_1, dtype: float64
```

In [38]:

```
X_train['train_pro_cat_0'][:10]
```

Out[38]:

```
10010    0.069106
868      0.129562
26899    0.156873
6909     0.500000
7151     0.133509
12755    0.181069
15456    0.129562
25829    0.151674
22949    0.200000
2244     0.133509
Name: train_pro_cat_0, dtype: float64
```

In [39]:

```
X_test['test_pro_cat_1'][:10]
```

Out[39]:

```
3779     0.861368
22936    0.862297
10115    0.861368
29791    0.915423
11587    0.791209
7617     0.862297
27165    0.827302
24916    0.848073
24849    0.827302
21430    0.862297
Name: test_pro_cat_1, dtype: float64
```

In [40]:

```
X_test['test_pro_cat_0'][:10]
```

Out[40]:

```
3779     0.138632
22936    0.137703
10115    0.138632
29791    0.084577
11587    0.208791
7617     0.137703
27165    0.172698
24916    0.151927
24849    0.172698
21430    0.137703
Name: test_pro_cat_0, dtype: float64
```

project_subcategories (clean_subcategories)

In [41]:

```
x_train_pro_subcat_1,x_train_pro_subcat_0, x_test_pro_subcat_1,x_test_pro_subcat_0 =
response_coded(X_train,y_train,X_test,y_test,'clean_subcategories')
```

In [42]:

```
X_train['train_pro_subcat_1'] = x_train_pro_subcat_1
```

```
X_train['train_pro_subcat_0'] = x_train_pro_subcat_0
X_test['test_pro_subcat_1'] = x_test_pro_subcat_1
X_test['test_pro_subcat_0'] = x_test_pro_subcat_0
```

In [43]:

```
X_train['train_pro_subcat_1'][:10]
```

Out[43]:

```
10010    0.930894
868      0.866536
26899    0.857741
6909     0.000000
7151     0.826087
12755    0.819376
15456    0.881449
25829    0.796163
22949    0.800000
2244     0.874675
Name: train_pro_subcat_1, dtype: float64
```

In [44]:

```
X_train['train_pro_subcat_0'][:10]
```

Out[44]:

```
10010    0.069106
868      0.133464
26899    0.142259
6909     1.000000
7151     0.173913
12755    0.180624
15456    0.118551
25829    0.203837
22949    0.200000
2244     0.125325
Name: train_pro_subcat_0, dtype: float64
```

In [45]:

```
X_test['test_pro_subcat_1'][:10]
```

Out[45]:

```
3779     0.873294
22936    0.863818
10115    0.873294
29791    0.914286
11587    0.875000
7617     0.865149
27165    0.858896
24916    0.771084
24849    0.815735
21430    0.863818
Name: test_pro_subcat_1, dtype: float64
```

In [46]:

```
X_test['test_pro_subcat_0'][:10]
```

Out[46]:

```
3779     0.126706
22936    0.136182
10115    0.126706
29791    0.085714
11587    0.125000
7617     0.134851
27165    0.141104
24916    0.228916
```

```
24849    0.184265
21430    0.136182
Name: test_pro_subcat_0, dtype: float64
```

project_grade_categories (clean_grade)

In [47]:

```
x_train_grade_1,x_train_grade_0, x_test_grade_1,x_test_grade_0 = response_coded(X_train,y_train,X_t
est,y_test,'clean_grade')
```

In [48]:

```
X_train['train_grade_1'] = x_train_grade_1
X_train['train_grade_0'] = x_train_grade_0
X_test['test_grade_1'] = x_test_grade_1
X_test['test_grade_0'] = x_test_grade_0
```

In [49]:

```
X_train['train_grade_1'][:10]
```

Out[49]:

```
10010    0.832957
868      0.832957
26899    0.846456
6909     0.846456
7151     0.837961
12755    0.846456
15456    0.846456
25829    0.853715
22949    0.846456
2244     0.846456
Name: train_grade_1, dtype: float64
```

In [50]:

```
X_train['train_grade_0'][:10]
```

Out[50]:

```
10010    0.167043
868      0.167043
26899    0.153544
6909     0.153544
7151     0.162039
12755    0.153544
15456    0.153544
25829    0.146285
22949    0.153544
2244     0.153544
Name: train_grade_0, dtype: float64
```

In [51]:

```
X_test['test_grade_1'][:10]
```

Out[51]:

```
3779     0.850442
22936    0.844942
10115    0.841229
29791    0.842742
11587    0.844942
7617     0.844942
27165    0.850442
24916    0.841229
24849    0.842742
21430    0.844942
Name: test_grade_1, dtype: float64
```

Name: test_grade_1, dtype: float64

In [52]:

```
X_test['test_grade_0'][:10]
```

Out[52]:

```
3779     0.149558
22936    0.155058
10115    0.158771
29791    0.157258
11587    0.155058
7617     0.155058
27165    0.149558
24916    0.158771
24849    0.157258
21430    0.155058
Name: test_grade_0, dtype: float64
```

teacher_prefix

In [53]:

```
x_train_prefix_1,x_train_prefix_0, x_test_prefix_1, x_test_prefix_0 = response_coded(X_train,y_trai
n,X_test,y_test,'teacher_prefix')
```

In [54]:

```
X_train['train_prefix_1'] = x_train_prefix_1
X_train['train_prefix_0'] = x_train_prefix_0
X_test['test_prefix_1'] = x_test_prefix_1
X_test['test_prefix_0'] = x_test_prefix_0
```

In [55]:

```
X_train['train_prefix_1'][:10]
```

Out[55]:

```
10010    0.846304
868      0.846304
26899    0.846586
6909     0.846586
7151     0.846586
12755    0.846586
15456    0.846304
25829    0.846586
22949    0.846586
2244     0.846586
Name: train_prefix_1, dtype: float64
```

In [56]:

```
X_train['train_prefix_0'][:10]
```

Out[56]:

```
10010    0.153696
868      0.153696
26899    0.153414
6909     0.153414
7151     0.153414
12755    0.153414
15456    0.153696
25829    0.153414
22949    0.153414
2244     0.153414
Name: train_prefix_0, dtype: float64
```

In [57]:

```
X_test['test_prefix_1'][:10]
```

Out[57]:

```
3779     0.839867
22936    0.853163
10115    0.853163
29791    0.840659
11587    0.853163
7617     0.839867
27165    0.853163
24916    0.853163
24849    0.853163
21430    0.853163
Name: test_prefix_1, dtype: float64
```

In [58]:

```
X_test['test_prefix_0'][:10]
```

Out[58]:

```
3779     0.160133
22936    0.146837
10115    0.146837
29791    0.159341
11587    0.146837
7617     0.160133
27165    0.146837
24916    0.146837
24849    0.146837
21430    0.146837
Name: test_prefix_0, dtype: float64
```

2.6) Vectorizing text Data

2.6.1) Bag of Words (essay)

In [59]:

```
def bow_vectorizer(X_train,col_name,df):
    vectorizer = CountVectorizer()
    vectorizer.fit(X_train[col_name].values)
    df_bow = vectorizer.transform(df[col_name].values)
    return df_bow, vectorizer.get_feature_names()
```

In [60]:

```
x_train_essay_bow, x_train_essay_feat = bow_vectorizer(X_train,'essay',X_train)
x_test_essay_bow,  x_test_essay_feat  = bow_vectorizer(X_train,'essay',X_test)
```

In [61]:

```
print(x_train_essay_bow.shape)
print(x_test_essay_bow.shape)
```

```
(20100, 31041)
(9900, 31041)
```

2.6.2) Bag of Words (title)

In [62]:

```
def bow_vectorizer_title(X_train,col_name,df):
```

```
def bow_vectorizer_title(X_train,col_name,df):
    vectorizer = CountVectorizer()
    vectorizer.fit(X_train[col_name].values)
    df_bow = vectorizer.transform(df[col_name].values)
    return df_bow, vectorizer.get_feature_names()
```

In [63]:

```
x_train_title_bow, x_train_title_feat = bow_vectorizer_title(X_train,'project_title',X_train)
x_test_title_bow,  x_test_title_feat  = bow_vectorizer_title(X_train,'project_title',X_test)
```

In [64]:

```
print(x_train_title_bow.shape)
print(x_test_title_bow.shape)
```

```
(20100, 7857)
(9900, 7857)
```

2.6.3) TFIDF (essay)

In [65]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
def tfidf_vectorizer(X_train,col_name,df):
    vectorizer = TfidfVectorizer()
    vectorizer.fit(X_train[col_name].values)
    df_tfidf = vectorizer.transform(df[col_name].values)
    return df_tfidf, vectorizer.get_feature_names()
```

In [66]:

```
# Lets vectorize essay
x_train_essay_tfidf, x_train_essay_tfidf_feat = tfidf_vectorizer(X_train,'essay',X_train)
x_test_essay_tfidf, x_test_essay_tfidf_feat = tfidf_vectorizer(X_train,'essay',X_test)
```

In [67]:

```
print(x_train_essay_tfidf.shape)
print(x_test_essay_tfidf.shape)
```

```
(20100, 31041)
(9900, 31041)
```

2.6.4) TFIDF (title)

In [68]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
def tfidf_vectorizer_title(X_train,col_name,df):
    vectorizer = TfidfVectorizer()
    vectorizer.fit(X_train[col_name].values)
    df_tfidf = vectorizer.transform(df[col_name].values)
    return df_tfidf, vectorizer.get_feature_names()
```

In [69]:

```
# Lets vectorize essay
x_train_title_tfidf, x_train_title_tfidf_feat =
tfidf_vectorizer_title(X_train,'project_title',X_train)
x_test_title_tfidf, x_test_title_tfidf_feat =
tfidf_vectorizer_title(X_train,'project_title',X_test)
```

In [70]:

```
print(x_train_title_tfidf.shape)
```

```
print(x_test_title_tfidf.shape)
```

```
(20100, 7857)
(9900, 7857)
```

2.6.5) Using Pretrained Models: Avg W2V

In [71]:

```
'''
# Reading glove vectors in python: https://stackoverflow.com/a/38230349/4084039
def loadGloveModel(gloveFile):
    print ("Loading Glove Model")
    f = open(gloveFile,'r', encoding="utf8")
    model = {}
    for line in tqdm(f):
        splitLine = line.split()
        word = splitLine[0]
        embedding = np.array([float(val) for val in splitLine[1:]])
        model[word] = embedding
    print ("Done.",len(model)," words loaded!")
    return model
model = loadGloveModel('glove.42B.300d.txt')

# ============================
Output:

Loading Glove Model
1917495it [06:32, 4879.69it/s]
Done. 1917495  words loaded!

# ============================

words = []
for i in preproced_texts:
    words.extend(i.split(' '))

for i in preproced_titles:
    words.extend(i.split(' '))
print("all the words in the coupus", len(words))
words = set(words)
print("the unique words in the coupus", len(words))

inter_words = set(model.keys()).intersection(words)
print("The number of words that are present in both glove vectors and our coupus", \
      len(inter_words),"(",np.round(len(inter_words)/len(words)*100,3),"%)")

words_courpus = {}
words_glove = set(model.keys())
for i in words:
    if i in words_glove:
        words_courpus[i] = model[i]
print("word 2 vec length", len(words_courpus))


# stronging variables into pickle files python: http://www.jessicayung.com/how-to-use-pickle-to-sa
ve-and-load-variables-in-python/

import pickle
with open('glove_vectors', 'wb') as f:
    pickle.dump(words_courpus, f)


'''
```

Out[71]:

```
'\n# Reading glove vectors in python: https://stackoverflow.com/a/38230349/4084039\ndef
loadGloveModel(gloveFile):\n    print ("Loading Glove Model")\n    f = open(gloveFile,\'r\',
encoding="utf8")\n    model = {}\n    for line in tqdm(f):\n        splitLine = line.split()\n
word = splitLine[0]\n        embedding = np.array([float(val) for val in splitLine[1:]])\n        m
odel[word] = embedding\n    print ("Done.",len(model)," words loaded!")\n    return model\nmodel =
loadGloveModel(\'glove.42B.300d.txt\')\n\n# ============================\nOutput:\n    \nLoading G
love Model\n1917495it [06:32, 4879.69it/s]\nDone. 1917495  words loaded!\n\n#
```

```
=============================\n\nwords = []\nfor i in preproced_texts:\n    words.extend(i.split(\'
\'))\n\nfor i in preproced_titles:\n    words.extend(i.split(\' \'))\nprint("all the words in the
coupus", len(words))\nwords = set(words)\nprint("the unique words in the coupus",
len(words))\n\ninter_words = set(model.keys()).intersection(words)\nprint("The number of words tha
t are present in both glove vectors and our coupus",      len(inter_words),"
(",np.round(len(inter_words)/len(words)*100,3),"%)")\n\nwords_courpus = {}\nwords_glove =
set(model.keys())\nfor i in words:\n    if i in words_glove:\n        words_courpus[i] = model[i]\r
print("word 2 vec length", len(words_courpus))\n\n\n# stronging variables into pickle files python
: http://www.jessicayung.com/how-to-use-pickle-to-save-and-load-variables-in-python/\n\nimport pic
kle\nwith open(\'glove_vectors\', \'wb\') as f:\n    pickle.dump(words_courpus, f)\n\n\n'
```

In [72]:

```python
# stronging variables into pickle files python: http://www.jessicayung.com/how-to-use-pickle-to-sa
ve-and-load-variables-in-python/
# make sure you have the glove_vectors file
with open('glove_vectors', 'rb') as f:
    model = pickle.load(f)
    glove_words =  set(model.keys())
```

In [73]:

```python
# Combining all the above stundents
from tqdm import tqdm
def preprocess_essay(df,col_name):
    preprocessed_essays = []
    # tqdm is for printing the status bar
    for sentance in tqdm(df[col_name].values):
        sent = decontracted(sentance)
        sent = sent.replace('\\r', ' ')
        sent = sent.replace('\\"', ' ')
        sent = sent.replace('\\n', ' ')
        sent = re.sub('[^A-Za-z0-9]+', ' ', sent)
        # https://gist.github.com/sebleier/554280
        sent = ' '.join(e for e in sent.split() if e not in stopwords)
        preprocessed_essays.append(sent.lower().strip())
    return preprocessed_essays
```

In [74]:

```python
# average Word2Vec
# compute average word2vec for each review.
def compute_avg_W2V(preprocessed_feature):
    avg_w2v_vectors = []; # the avg-w2v for each sentence/review is stored in this list
    for sentence in tqdm(preprocessed_feature): # for each review/sentence
        vector = np.zeros(300) # as word vectors are of zero length
        cnt_words =0; # num of words with a valid vector in the sentence/review
        for word in sentence.split(): # for each word in a review/sentence
            if word in glove_words:
                vector += model[word]
                cnt_words += 1
        if cnt_words != 0:
            vector /= cnt_words
        avg_w2v_vectors.append(vector)
    return avg_w2v_vectors
```

In [75]:

```python
x_train_preprocessed_essay = preprocess_essay(X_train,'essay')
x_test_preprocessed_essay = preprocess_essay(X_test,'essay')
```

```
100%|██████████████████████████████████████████████████████████████████████████| 20100/20100
[00:13<00:00, 1441.69it/s]
100%|████████████████████████████████████████████████████████████████████████████| 9900/9900
[00:06<00:00, 1415.28it/s]
```

In [76]:

```python
x_train_preprocessed_title = preprocess_essay(X_train,'project_title')
x_test_preprocessed_title = preprocess_essay(X_test,'project_title')
```

```
100%|██████████████████████████████████████████████████| 20100/20100
[00:00<00:00, 26177.59it/s]
100%|████████████████████████████████████████████████████| 9900/9900
[00:00<00:00, 26318.96it/s]
```

In [77]:

```
x_train_avg_w2v_essay = compute_avg_W2V(x_train_preprocessed_essay)
x_test_avg_w2v_essay = compute_avg_W2V(x_test_preprocessed_essay)
```

```
100%|██████████████████████████████████████████████████| 20100/20100
[00:09<00:00, 2138.78it/s]
100%|████████████████████████████████████████████████████| 9900/9900
[00:04<00:00, 2188.44it/s]
```

In [78]:

```
x_train_avg_w2v_title = compute_avg_W2V(x_train_preprocessed_title)
x_test_avg_w2v_title = compute_avg_W2V(x_test_preprocessed_title)
```

```
100%|██████████████████████████████████████████████████| 20100/20100
[00:00<00:00, 38925.02it/s]
100%|████████████████████████████████████████████████████| 9900/9900
[00:00<00:00, 40226.97it/s]
```

2.6.6) Using Pretrained Models: TFIDF Weighted W2V

In [79]:

```
# S = ["abc def pqr", "def def def abc", "pqr pqr def"]
def get_tfidf_dict(preprocessed_feature):
    tfidf_model = TfidfVectorizer()
    tfidf_model.fit(preprocessed_feature)
    # we are converting a dictionary with word as a key, and the idf as a value
    dictionary = dict(zip(tfidf_model.get_feature_names(), list(tfidf_model.idf_)))
    tfidf_words = set(tfidf_model.get_feature_names())
    return dictionary, tfidf_words
```

In [80]:

```
# average Word2Vec
# compute average word2vec for each review.
def compute_tfidf_w2v_vectors(preprocessed_feature):
    tfidf_w2v_vectors = []; # the avg-w2v for each sentence/review is stored in this list
    dictionary, tfidf_words = get_tfidf_dict(preprocessed_feature)
    for sentence in tqdm(preprocessed_feature): # for each review/sentence
        vector = np.zeros(300) # as word vectors are of zero length
        tf_idf_weight =0; # num of words with a valid vector in the sentence/review
        for word in sentence.split(): # for each word in a review/sentence
            if (word in glove_words) and (word in tfidf_words):
                vec = model[word] # getting the vector for each word
                # here we are multiplying idf value(dictionary[word]) and the tf
value((sentence.count(word)/len(sentence.split())))
                tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split())) # getting
the tfidf value for each word
                vector += (vec * tf_idf) # calculating tfidf weighted w2v
                tf_idf_weight += tf_idf
        if tf_idf_weight != 0:
            vector /= tf_idf_weight
        tfidf_w2v_vectors.append(vector)
    return tfidf_w2v_vectors
```

In [81]:

```
x_train_weighted_w2v_essay = compute_tfidf_w2v_vectors(x_train_essay_preprocessed)
x_test_weighted_w2v_essay= compute_tfidf_w2v_vectors(x_test_essay_preprocessed)
```

```
100%|████████████████████████████████████████████████████| 20100/20100 [00:
56<00:00, 357.16it/s]
```

```
100%|██████████████████████████████████████████████████| 9900/9900
[00:28<00:00, 351.94it/s]
```

In [82]:

```
x_train_weighted_w2v_title = compute_tfidf_w2v_vectors(x_train_title_preprocessed)
x_test_weighted_w2v_title= compute_tfidf_w2v_vectors(x_test_title_preprocessed)
```

```
100%|██████████████████████████████████████████████| 20100/20100
[00:00<00:00, 22871.70it/s]
100%|███████████████████████████████████████████████| 9900/9900
[00:00<00:00, 23178.65it/s]
```

2.7) Vectorizing Numerical Features

We have 2 numerical features left, "price" and "teacher_number_of_previously_posted_projects". Let's check for the "missing" or "NaN" values present in those numerical features and use "Mean Replacement" for "price" and "Mode Replacement" for "teacher_number_of_previously_posted_projects".

In [83]:

```
print("Total number of \"Missing\" Values present in X_train price:",X_train['price'].isna().sum()
)
print("Total number of \"Missing\" Values present in X_test price:",X_test['price'].isna().sum())
```

```
Total number of "Missing" Values present in X_train price: 19718
Total number of "Missing" Values present in X_test price: 9715
```

In [84]:

```
print("Total number of \"Missing\" Values present in X_train previous teacher number:",X_train['te
acher_number_of_previously_posted_projects'].isna().sum())
print("Total number of \"Missing\" Values present in X_test previous teacher number:",X_test['teac
her_number_of_previously_posted_projects'].isna().sum())
```

```
Total number of "Missing" Values present in X_train previous teacher number: 0
Total number of "Missing" Values present in X_test previous teacher number: 0
```

In [85]:

```
print("Total number of \"Missing\" Values present in X_train quantity:",X_train['quantity'].isna()
.sum())
print("Total number of \"Missing\" Values present in X_test quantity:",X_test['quantity'].isna().s
um())
```

```
Total number of "Missing" Values present in X_train quantity: 19718
Total number of "Missing" Values present in X_test quantity: 9715
```

"teacher_number_of_previously_posted_projects" does not have any "missing" values.

In [86]:

```
X_train['price'].mean()
```

Out[86]:

```
274.02664921465987
```

In [87]:

```
X_train['price'] = X_train['price'].fillna(274.0266)
```

In [88]:

```
X_test['price'].mean()
```

Out[88]:

```
288.2436756756755
```

In [89]:

```
X_test['price'] = X_test['price'].fillna(288.2436)
```

In [90]:

```
print(X_train['quantity'].mean())
print(X_test['quantity'].mean())
```

```
18.020942408376964
19.967567567567567
```

In [91]:

```
X_train['quantity'] = X_train['quantity'].fillna(18.0209)
X_test['quantity'] = X_test['quantity'].fillna(19.9675)
```

In [92]:

```
# check this one: https://www.youtube.com/watch?v=0HOqOcln3Z4&t=530s
# https://scikit-learn.org/stable/modules/generated/sklearn.preprocessing.StandardScaler.html
from sklearn.preprocessing import StandardScaler
def scaler_function(df,col_name):

    scaler = StandardScaler()
    scaler.fit(df[col_name].values.reshape(-1,1)) # finding the mean and standard deviation of this
data

    # Now standardize the data with above maen and variance.
    print(f"Mean : {scaler.mean_[0]}, Standard deviation : {np.sqrt(scaler.var_[0])}")
    scaled = scaler.transform(df[col_name].values.reshape(-1, 1))
    return scaled
```

teacher_number_of_previously_posted_projects

In [93]:

```
x_train_teacher_number = scaler_function(X_train,'teacher_number_of_previously_posted_projects')
x_test_teacher_number = scaler_function(X_test,'teacher_number_of_previously_posted_projects')
```

```
Mean : 11.35726368159204, Standard deviation : 28.634018915945607
Mean : 10.915959595959595, Standard deviation : 26.43942586821415
```

price

In [94]:

```
x_train_price = scaler_function(X_train,'price')
x_test_price = scaler_function(X_test,'price')
```

```
Mean : 274.02660093532336, Standard deviation : 60.03146833870624
Mean : 288.2436014141413, Standard deviation : 41.114941277013656
```

quantity

In [95]:

```
x_train_quantity = scaler_function(X_train,'quantity')
x_test_quantity = scaler_function(X_test,'quantity')
```

```
Mean : 18.020900805970157, Standard deviation : 3.2232352374733524
Mean : 19.967501262626257, Standard deviation : 4.44596974919204
```

2.8) Merging all the features and building the sets

In [96]:

```
# train dataset
print("After Vectorization and One hot encoding train dataset shape becomes:")
print(np.asarray(X_train['train_pro_cat_1']).shape)
print(np.asarray(X_train['train_pro_cat_0']).shape)
print(np.asarray(X_train['train_pro_subcat_1']).shape)
print(np.asarray(X_train['train_pro_subcat_0']).shape)
print(np.asarray(X_train['train_school_state_1']).shape)
print(np.asarray(X_train['train_school_state_0']).shape)
print(np.asarray(X_train['train_prefix_1']).shape)
print(np.asarray(X_train['train_prefix_0']).shape)
print(np.asarray(X_train['train_grade_1']).shape)
print(np.asarray(X_train['train_grade_1']).shape)
print(x_train_essay_bow.shape)
print(x_train_title_bow.shape)
print(x_train_essay_tfidf.shape)
print(x_train_title_tfidf.shape)
print(np.asarray(x_train_avg_w2v_essay).shape)
print(np.asarray(x_train_avg_w2v_title).shape)
print(np.asarray(x_train_weighted_w2v_essay).shape)
print(np.asarray(x_train_weighted_w2v_title).shape)
print(x_train_teacher_number.shape)
print(x_train_price.shape)
print(x_train_quantity.shape)
print("="*50)

# test dataset
print("After Vectorization and One hot encoding test dataset shape becomes:")
print(np.asarray(X_test['test_pro_cat_1']).shape)
print(np.asarray(X_test['test_pro_cat_0']).shape)
print(np.asarray(X_test['test_pro_subcat_1']).shape)
print(np.asarray(X_test['test_pro_subcat_0']).shape)
print(np.asarray(X_test['test_school_state_1']).shape)
print(np.asarray(X_test['test_school_state_0']).shape)
print(np.asarray(X_test['test_prefix_1']).shape)
print(np.asarray(X_test['test_prefix_0']).shape)
print(np.asarray(X_test['test_grade_1']).shape)
print(np.asarray(X_test['test_grade_1']).shape)
print(x_test_essay_bow.shape)
print(x_test_title_bow.shape)
print(x_test_essay_tfidf.shape)
print(x_test_title_tfidf.shape)
print(np.asarray(x_test_avg_w2v_essay).shape)
print(np.asarray(x_test_avg_w2v_title).shape)
print(np.asarray(x_test_weighted_w2v_essay).shape)
print(np.asarray(x_test_weighted_w2v_title).shape)
print(x_test_teacher_number.shape)
print(x_test_price.shape)
print(x_test_quantity.shape)
print("="*50)
```

```
After Vectorization and One hot encoding train dataset shape becomes:
(20100,)
(20100,)
(20100,)
(20100,)
(20100,)
(20100,)
(20100,)
(20100,)
(20100,)
(20100,)
(20100, 31041)
(20100, 7857)
(20100, 31041)
(20100, 7857)
```

```
(20100, 300)
(20100, 300)
(20100, 300)
(20100, 300)
(20100, 1)
(20100, 1)
(20100, 1)
==================================================
After Vectorization and One hot encoding test dataset shape becomes:
(9900,)
(9900,)
(9900,)
(9900,)
(9900,)
(9900,)
(9900,)
(9900,)
(9900,)
(9900,)
(9900, 31041)
(9900, 7857)
(9900, 31041)
(9900, 7857)
(9900, 300)
(9900, 300)
(9900, 300)
(9900, 300)
(9900, 1)
(9900, 1)
(9900, 1)
==================================================
```

In [97]:

```
def enable_plotly_in_cell():
  import IPython
  from plotly.offline import init_notebook_mode
  display(IPython.core.display.HTML('''<script src="/static/components/requirejs/require.js"></scr
ipt>'''))
  init_notebook_mode(connected=False)
```

In [98]:

```
%matplotlib inline
import plotly.offline as offline
import plotly.graph_objs as go
offline.init_notebook_mode()

def plot_3d_plot(x_tr, y_tr, x_te, y_te, depth_list, split_list,algo):
    auc_tr = []
    auc_te = []
    y_train_pred_prob = []
    y_test_pred_prob = []

    for depth, split in zip(depth_list ,split_list):
        if algo == 'RF_':

            clf_ = RandomForestClassifier(max_depth = depth ,min_samples_split = split,
class_weight = "balanced")
            clf_.fit(x_tr,y_tr)

        elif algo == "GB_":

            clf_ = GradientBoostingClassifier(max_depth = depth ,min_samples_split = split)
            clf_.fit(x_tr,y_tr)

        y_train_pred = clf_.predict_proba(x_tr)
        y_test_pred = clf_.predict_proba(x_te)

        for index in range(len(y_train_pred)):
            y_train_pred_prob.append(y_train_pred[index][1])

        for index in range(len(y_test_pred)):
            y_test_pred_prob.append(y_test_pred[index][1])
```

```
        train_fpr, train_tpr, tr_thresholds = roc_curve(y_tr, y_train_pred_prob)
        test_fpr, test_tpr, tc_thresholds = roc_curve(y_te, y_test_pred_prob)

        y_train_pred_prob = []
        y_test_pred_prob = []


        auc_tr.append(auc(train_fpr,train_tpr))
        auc_te.append(auc(test_fpr,test_tpr))
    X = split_list
    Y = depth_list
    Z1 = auc_tr
    Z2 = auc_te
    # https://plot.ly/python/3d-axes/
    trace1 = go.Scatter3d(x=X,y=Y,z=Z1, name = 'train')
    trace2 = go.Scatter3d(x=X,y=Y,z=Z2, name = 'cv')
    data = [trace1,trace2]
    enable_plotly_in_cell()

    layout = go.Layout(scene = dict(
            xaxis = dict(title='min_samples_split'),
            yaxis = dict(title='max_depth'),
            zaxis = dict(title='AUC'),))

    fig = go.Figure(data=data, layout=layout)
    offline.iplot(fig, filename='3d-scatter-colorscale')
```

3.1) Random Forest Classifier

Set 1) categorical(response coding: use probability values), numerical features + project_title(BOW) + preprocessed_eassay (BOW)

In [99]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039
from scipy.sparse import hstack
# with the same hstack function we are concatinating a sparse matrix and a dense matirx :)
X_train_set_1 = hstack((X_train['train_pro_cat_1'].values.reshape(-1,1), X_train['train_pro_cat_0']
.values.reshape(-1,1), X_train['train_pro_subcat_1'].values.reshape(-1,1),
X_train['train_pro_subcat_0'].values.reshape(-1,1), X_train['train_school_state_1'].values.reshape(
-1,1), X_train['train_school_state_0'].values.reshape(-1,1), X_train['train_grade_1'].values.reshap
e(-1,1),\
                        X_train['train_grade_0'].values.reshape(-1,1),X_train['train_prefix_1'].val
es.reshape(-1,1),X_train['train_prefix_0'].values.reshape(-1,1),x_train_teacher_number,x_train_pric
e,x_train_quantity,x_train_title_bow,x_train_essay_bow)).tocsr()
X_test_set_1 = hstack((X_test['test_pro_cat_1'].values.reshape(-1,1),X_test['test_pro_cat_0'].value
s.reshape(-1,1),X_test['test_pro_subcat_1'].values.reshape(-1,1),X_test['test_pro_subcat_0'].values
.reshape(-1,1),X_test['test_school_state_1'].values.reshape(-1,1),X_test['test_school_state_0'].val
ues.reshape(-1,1),X_test['test_grade_1'].values.reshape(-1,1),\
                    X_test['test_grade_0'].values.reshape(-1,1),X_test['test_prefix_1'].values.resh
pe(-1,1),X_test['test_prefix_0'].values.reshape(-1,1),x_test_teacher_number,x_test_price,x_test_qua
ntity,x_test_title_bow,x_test_essay_bow)).tocsr()
```

In [100]:

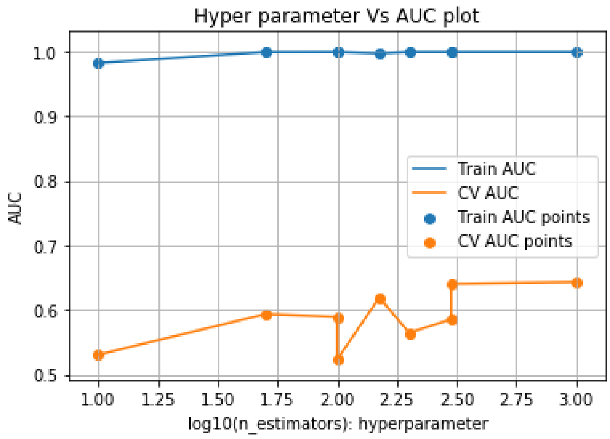
```
from sklearn.model_selection import GridSearchCV
from scipy.stats import randint as sp_randint
from sklearn.model_selection import RandomizedSearchCV
import matplotlib.pyplot as plt
from sklearn.metrics import roc_auc_score
from sklearn.ensemble import RandomForestClassifier
import math
```

Calculating Combine Hyper-Parameters

In [104]:

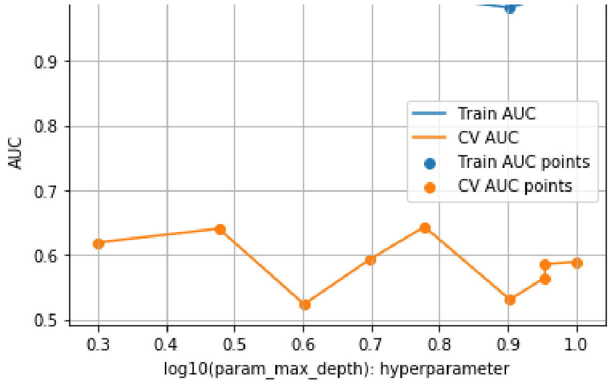
```
RF_ = RandomForestClassifier(class_weight = "balanced")
parameters = {'n_estimators':[10, 50, 100, 150, 200, 300, 500, 1000],'max_depth':[2,3,4,5,6,7,8,9,10
```

```
]}
clf = RandomizedSearchCV(RF_, parameters,n_iter = 9, scoring='roc_auc', return_train_score = True)
clf.fit(X_train_set_1, y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_n_estimators'])


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']
C_ =  results['param_n_estimators'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(n_estimators): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [105]:

```
results = results.sort_values(['param_max_depth'])


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']
C_ =  results['param_max_depth'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(param_max_depth): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [106]:

```
results
```

Out[106]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
3	0.247100	0.008275	0.020599	0.002960	150	2	{'n_estimators': 150, 'max_depth': 2}
4	0.548963	0.056624	0.036501	0.000896	300	3	{'n_estimators': 300, 'max_depth': 3}
7	0.214821	0.020349	0.013902	0.000196	100	4	{'n_estimators': 100, 'max_depth': 4}
8	0.094000	0.006139	0.007700	0.000402	50	5	{'n_estimators': 50, 'max_depth': 5}
5	2.074884	0.107347	0.122921	0.008777	1000	6	{'n_estimators': 1000, 'max_depth': 6}
6	0.022691	0.002152	0.002804	0.000236	10	8	{'n_estimators': 10, 'max_depth': 8}
0	0.536196	0.059843	0.028605	0.005120	200	9	{'n_estimators': 200, 'max_depth': 9}
2	0.689265	0.051618	0.043516	0.012311	300	9	{'n_estimators': 300, 'max_depth': 9}
1	0.228352	0.006613	0.014297	0.001160	100	10	{'n_estimators': 100, 'max_depth': 10}

9 rows × 22 columns

In [107]:

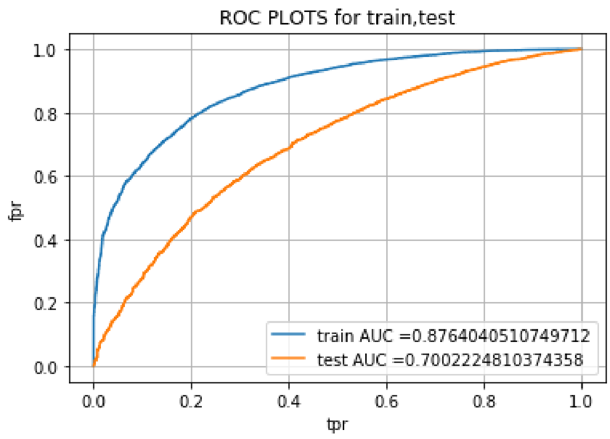
```
# the best value for n_estimators and max_depth from the above table
best_n_estimator = 200
best_max_depth = 9
```

In [108]:

```
from sklearn.metrics import roc_curve, auc
```

In [109]:

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


RF_ = RandomForestClassifier(n_estimators = best_n_estimator, max_depth = best_max_depth, class_wei
ght = "balanced")
RF_.fit(X_train_set_1, 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 = RF_.predict_proba(X_train_set_1)
y_test_pred =  RF_.predict_proba(X_test_set_1)

y_train_pred_prob = []
y_test_pred_prob = []

for index in range(len(y_train_pred)):
    y_train_pred_prob.append(y_train_pred[index][1])

for index in range(len(y_test_pred)):
    y_test_pred_prob.append(y_test_pred[index][1])


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred_prob)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred_prob)



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("tpr")
plt.ylabel("fpr")
plt.title("ROC PLOTS for train,test")
plt.grid()
plt.show()
```

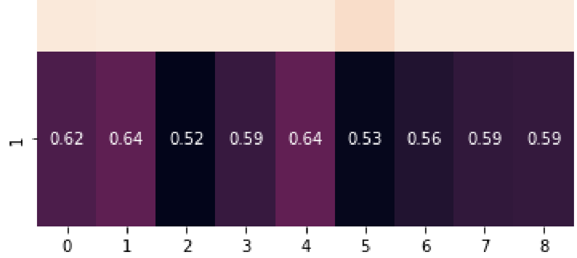


In [110]:

```
scores = [results['mean_train_score'].values,results['mean_test_score'].values]
sns.heatmap(np.asarray(scores),annot = True, cbar=False)
```

Out[110]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x25c85f3f588>
```



In [111]:

```
# 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
```

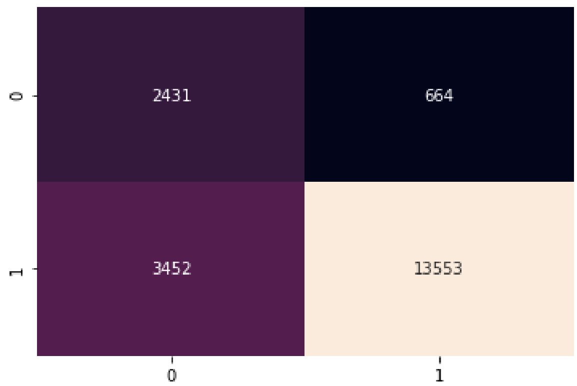
In [112]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
sns.heatmap(confusion_matrix(y_train, predict_with_best_t(y_train_pred_prob, best_t)),annot = True,
fmt = "d", cbar=False)
```

```
====================================================================================================

the maximum value of tpr*(1-fpr) 0.6260126476152837 for threshold 0.501
Train confusion matrix
```

Out[112]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x25c85e140b8>
```



In [113]:

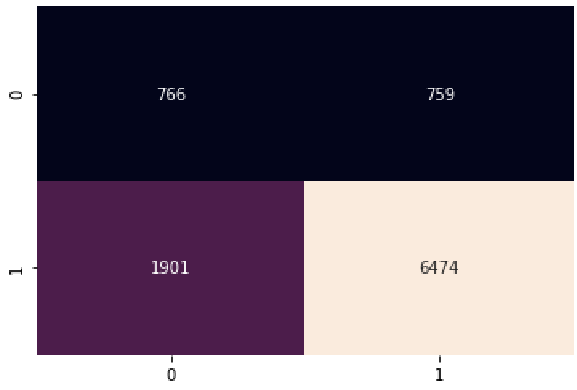
```
print("Test confusion matrix")
sns.heatmap(confusion_matrix(y_test, predict_with_best_t(y_test_pred_prob, best_t)), annot = True,
fmt = "d", cbar=False)
```

```
Test confusion matrix
```

Out[113]:

Out[113]:

<matplotlib.axes._subplots.AxesSubplot at 0x25c85d70978>



In [114]:

```
depth = [2,3,4,5,6,7,8,9,10]
estimators = [10,50,100,150,200,300,500]
plot_3d_plot(X_train_set_1, y_train, X_test_set_1, y_test, depth, estimators,"RF_")
```

Set 2) categorical(response coding: use probability values), numerical features + project_title(TFIDF)+ preprocessed_eassay (TFIDF)

In [115]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039
# with the same hstack function we are concatinating a sparse matrix and a dense matirx :)
from scipy.sparse import hstack
X_train_set_2 = hstack((X_train['train_pro_cat_1'].values.reshape(-1,1), X_train['train_pro_cat_0']
.values.reshape(-1,1), X_train['train_pro_subcat_1'].values.reshape(-1,1),
X_train['train_pro_subcat_0'].values.reshape(-1,1), X_train['train_school_state_1'].values.reshape(
-1,1), X_train['train_school_state_0'].values.reshape(-1,1), X_train['train_grade_1'].values.reshap
e(-1,1),\
                        X_train['train_grade_0'].values.reshape(-1,1),X_train['train_prefix_1'].val
es.reshape(-1,1),X_train['train_prefix_0'].values.reshape(-1,1),x_train_teacher_number,x_train_pric
e,x_train_quantity,x_train_title_tfidf,x_train_essay_tfidf)).tocsr()
```

```
X_test_set_2 = hstack((X_test['test_pro_cat_1'].values.reshape(-1,1),X_test['test_pro_cat_0'].value
s.reshape(-1,1),X_test['test_pro_subcat_1'].values.reshape(-1,1),X_test['test_pro_subcat_0'].values
.reshape(-1,1),X_test['test_school_state_1'].values.reshape(-1,1),X_test['test_school_state_0'].val
ues.reshape(-1,1),X_test['test_grade_1'].values.reshape(-1,1),\
                    X_test['test_grade_0'].values.reshape(-1,1),X_test['test_prefix_1'].values.resh
pe(-1,1),X_test['test_prefix_0'].values.reshape(-1,1),x_test_teacher_number,x_test_price,x_test_qua
ntity,x_test_title_tfidf,x_test_essay_tfidf)).tocsr()
```

Calculating Combine Hyper-Parameters

In [116]:

```
RF_ = RandomForestClassifier(class_weight = "balanced")
parameters = {'n_estimators':[10, 50, 100, 150, 200, 300, 500, 1000],'max_depth':[2,3,4,5,6,7,8,9,10
]}
clf = RandomizedSearchCV(RF_, parameters,n_iter = 9, scoring='roc_auc', return_train_score = True)
clf.fit(X_train_set_2, y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
```

In [117]:

```
results
```

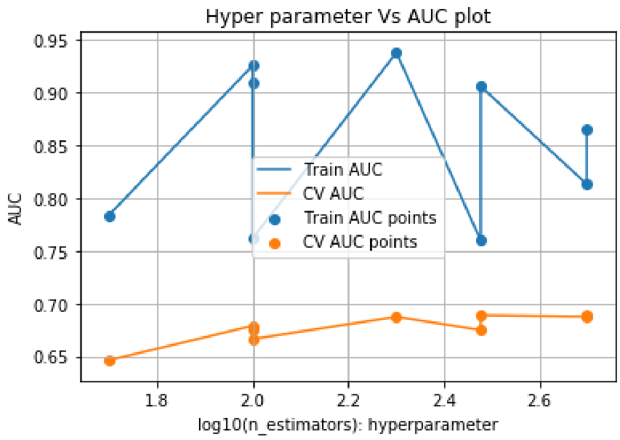
Out[117]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
0	7.640406	0.227881	1.144224	0.112074	500	4	{'n_estimators': 500, 'max_depth': 4}
1	1.137128	0.068535	0.136805	0.015658	50	5	{'n_estimators': 50, 'max_depth': 5}
2	4.007514	0.278102	0.270112	0.012062	100	10	{'n_estimators': 100, 'max_depth': 10}
3	2.704006	0.123833	0.683220	0.056569	300	2	{'n_estimators': 300, 'max_depth': 2}
4	3.466756	0.098852	0.241555	0.016177	100	9	{'n_estimators': 100, 'max_depth': 9}
5	1.271650	0.053347	0.224548	0.011704	100	3	{'n_estimators': 100, 'max_depth': 3}
6	7.544095	0.177640	0.540696	0.026809	200	10	{'n_estimators': 200, 'max_depth': 10}
7	10.873345	0.097874	1.123981	0.030397	500	6	{'n_estimators': 500, 'max_depth': 6}
8	8.924304	0.096602	0.671370	0.013667	300	8	{'n_estimators': 300, 'max_depth': 8}

9 rows × 22 columns

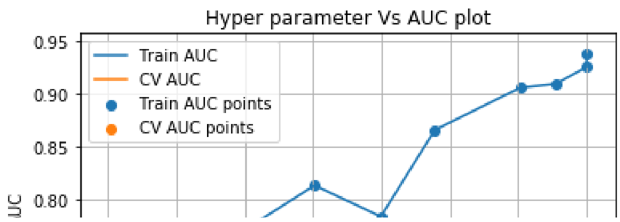
In [118]:

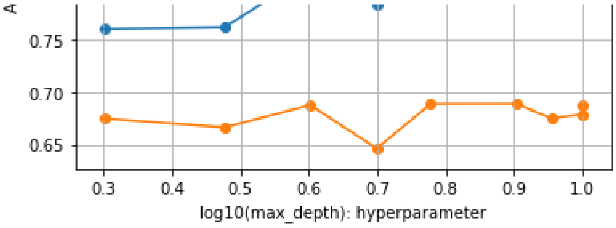
```
results = results.sort_values(['param_n_estimators'])


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']
C_ =  results['param_n_estimators'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(n_estimators): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [119]:

```
results = results.sort_values(['param_max_depth'])

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']
C_ =  results['param_max_depth'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(max_depth): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



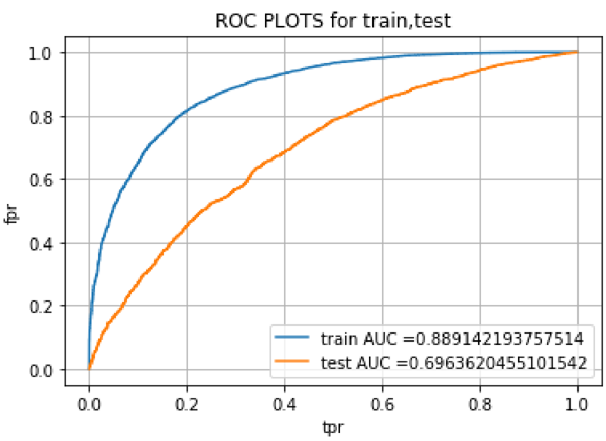


In [120]:

```
# the best value for n_estimators and max_depth from the above table are
best_n_estimator = 300
best_max_depth = 8
```

In [121]:

```
# https://scikit-
learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve
RF_ = RandomForestClassifier(n_estimators = best_n_estimator, max_depth = best_max_depth, class_wei
ght = "balanced")
RF_.fit(X_train_set_2, 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 = RF_.predict_proba(X_train_set_2)
y_test_pred =  RF_.predict_proba(X_test_set_2)

y_train_pred_prob = []
y_test_pred_prob = []

for index in range(len(y_train_pred)):
    y_train_pred_prob.append(y_train_pred[index][1])

for index in range(len(y_test_pred)):
    y_test_pred_prob.append(y_test_pred[index][1])


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred_prob)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred_prob)



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("tpr")
plt.ylabel("fpr")
plt.title("ROC PLOTS for train,test")
plt.grid()
plt.show()
```



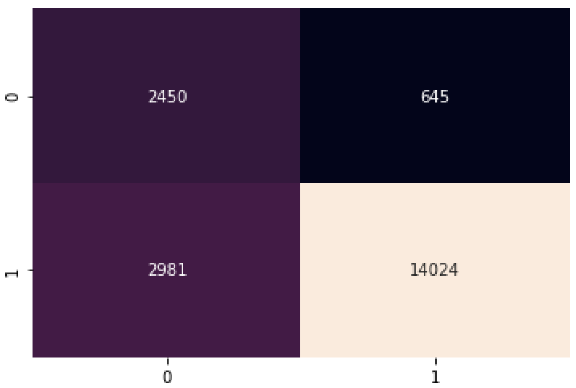
In [122]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
sns.heatmap(confusion_matrix(y_train, predict_with_best_t(y_train_pred_prob, best_t)),annot = True, fmt = "d", cbar=False)
```

```
====================================================================================================

the maximum value of tpr*(1-fpr) 0.6528308931279833 for threshold 0.506
Train confusion matrix
```

Out[122]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x25c85fb6a90>
```



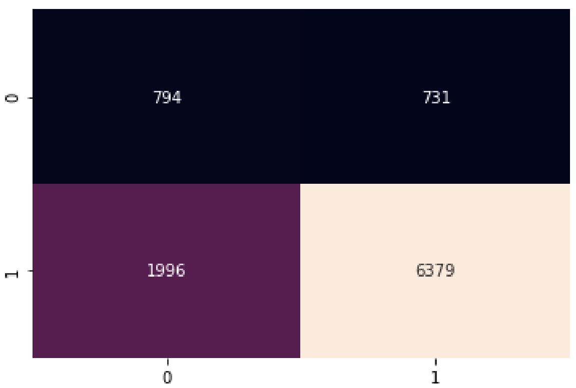
In [123]:

```
print("Test confusion matrix")
sns.heatmap(confusion_matrix(y_test, predict_with_best_t(y_test_pred_prob, best_t)), annot = True, fmt = "d", cbar=False)
```

```
Test confusion matrix
```

Out[123]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x25c9039e898>
```

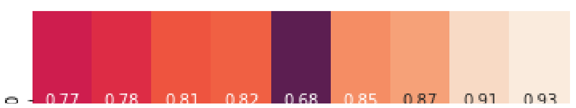


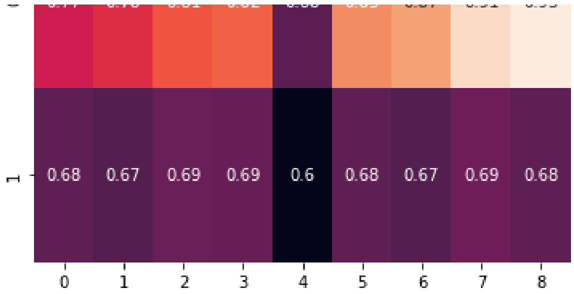
In [194]:

```
scores  = [results['mean_train_score'].values, results['mean_test_score'].values]
sns.heatmap(np.asarray(scores), annot=True, cbar= False)
```

Out[194]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208a5ea550>
```





In [98]:

```
depth = [2,3,4,5,6,7,8,9,10]
estimators = [10,50,100,150,200,300,500]
plot_3d_plot(X_train_set_2, y_train, X_test_set_2, y_test, depth, estimators,"RF_")
```

Set 3) categorical(response coding: use probability values), numerical features + project_title(AVG W2V)+ preprocessed_eassay (AVG W2V)

In [195]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039
# with the same hstack function we are concatinating a sparse matrix and a dense matirx :)
from scipy.sparse import csr_matrix
X_train_set_3 = hstack((csr_matrix(X_train['train_pro_cat_1'].values).reshape(-1,1), csr_matrix(X_t
rain['train_pro_cat_0'].values).reshape(-1,1),csr_matrix(X_train['train_pro_subcat_1'].values).resh
ape(-1,1), csr_matrix(X_train['train_pro_subcat_0'].values).reshape(-1,1),csr_matrix(X_train['train
_school_state_1'].values).reshape(-1,1),csr_matrix(X_train['train_school_state_0'].values).reshape(
-1,1),\
                        csr_matrix( X_train['train_grade_1'].values).reshape(-1,1),csr_matrix( X_tr
in['train_grade_0'].values).reshape(-1,1),csr_matrix(X_train['train_prefix_1'].values).reshape(-1,1
),csr_matrix(X_train['train_prefix_0'].values).reshape(-1,1),x_train_teacher_number,x_train_price,x
_train_quantity,x_train_avg_w2v_title, x_train_avg_w2v_essay)).tocsr()
X_test_set_3 = hstack((csr_matrix(X_test['test_pro_cat_1'].values).reshape(-1,1),csr_matrix(X_test[
'test_pro_cat_0'].values).reshape(-1,1),csr_matrix(X_test['test_pro_subcat_1'].values).reshape(-1,1
),csr_matrix(X_test['test_pro_subcat_0'].values).reshape(-1,1),csr_matrix(X_test['test_school_state_
1'].values).reshape(-1,1),csr_matrix(X_test['test_school_state_0'].values).reshape(-1,1),csr_matrix
(X_test['test_grade_1'].values).reshape(-1,1),\
                    csr_matrix(X_test['test_grade_0'].values).reshape(-1,1),csr_matrix(X_test['test_
```

```
prefix_1'].values).reshape(-1,1),csr_matrix(X_test['test_prefix_0'].values).reshape(-1,1),x_test_te
acher_number,x_test_price,x_test_quantity, x_test_avg_w2v_title,x_test_avg_w2v_essay)).tocsr()
```

Calculating Combine Hyper-Parameters

In [197]:

```
RF_ = RandomForestClassifier(class_weight = "balanced")
parameters = {'n_estimators':[10, 50, 100, 150, 200, 300, 500, 1000],'max_depth':[2,3,4,5,6,7,8,9,10
]}
clf = RandomizedSearchCV(RF_, parameters,n_iter = 9, scoring='roc_auc', return_train_score = True)
clf.fit(X_train_set_3, y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_n_estimators'])
```

In [198]:

```
results
```

Out[198]:

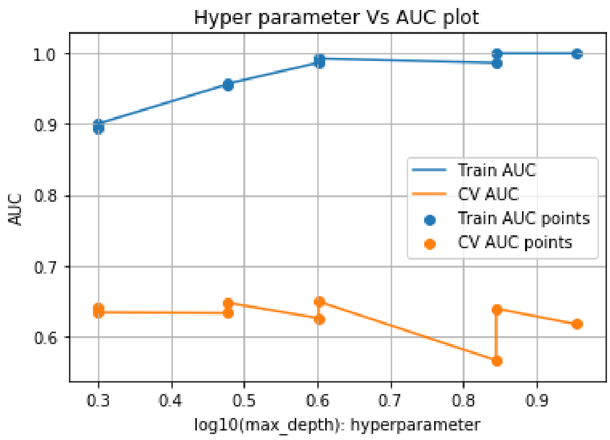
	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
3	0.396966	0.005997	0.021812	0.013566	10	7	{'n_estimators': 10, 'max_depth': 7}
8	2.017022	0.041508	0.056501	0.009760	50	9	{'n_estimators': 50, 'max_depth': 9}
4	2.239859	0.178913	0.117862	0.013082	100	4	{'n_estimators': 100, 'max_depth': 4}
1	5.408265	0.405228	0.170044	0.049033	150	7	{'n_estimators': 150, 'max_depth': 7}
7	3.004580	0.010015	0.176151	0.022817	200	3	{'n_estimators': 200, 'max_depth': 3}
2	4.847715	0.271939	0.313647	0.042912	300	3	{'n_estimators': 300, 'max_depth': 3}
5	3.368393	0.124852	0.313928	0.053726	300	2	{'n_estimators': 300, 'max_depth': 2}
0	10.127935	0.536526	0.522066	0.086801	500	4	{'n_estimators': 500, 'max_depth': 4}
6	10.946567	0.305066	0.809621	0.036345	1000	2	{'n_estimators': 1000, 'max_depth': 2}

9 rows × 22 columns

In [199]:

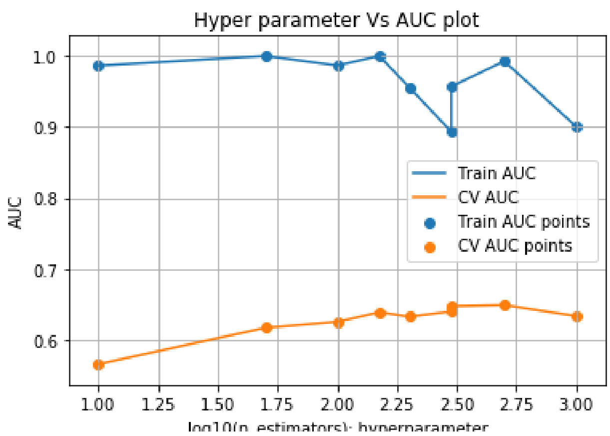
```
results = results.sort_values(['param_max_depth'])

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']
```

```
C_ =  results['param_max_depth'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(max_depth): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [200]:

```
results = results.sort_values(['param_n_estimators'])

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']
C_ =  results['param_n_estimators'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(n_estimators): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



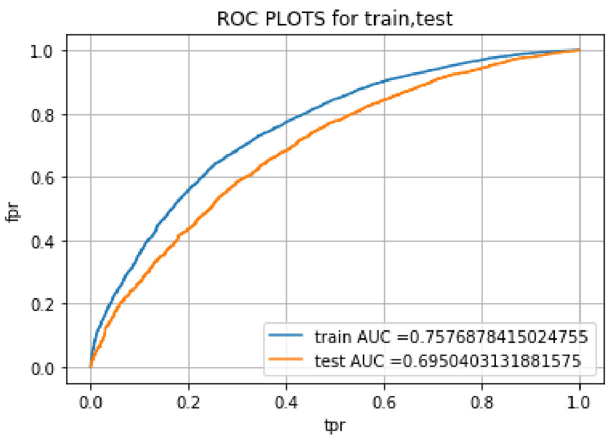
log10(n_estimators): hyperparameter

In [201]:

```
# the best value for n_estimators and max_depth from the above graphs are
best_n_estimator = 500
best_max_depth = 4
```

In [202]:

```
# https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve
RF_ = RandomForestClassifier(n_estimators = best_n_estimator, max_depth = best_max_depth, class_weight = "balanced")
RF_.fit(X_train_set_3, 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 = RF_.predict_proba(X_train_set_3)
y_test_pred =  RF_.predict_proba(X_test_set_3)

y_train_pred_prob = []
y_test_pred_prob = []

for index in range(len(y_train_pred)):
    y_train_pred_prob.append(y_train_pred[index][1])

for index in range(len(y_test_pred)):
    y_test_pred_prob.append(y_test_pred[index][1])


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred_prob)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred_prob)



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("tpr")
plt.ylabel("fpr")
plt.title("ROC PLOTS for train,test")
plt.grid()
plt.show()
```



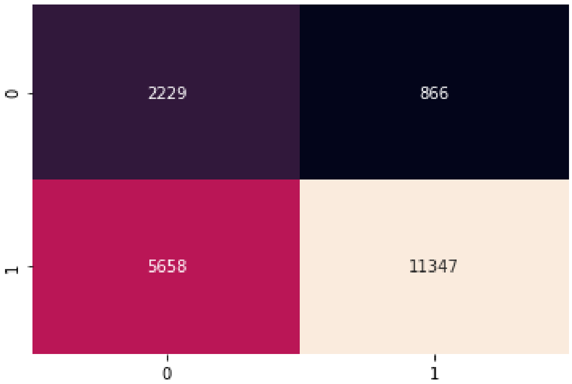
In [203]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
sns.heatmap(confusion_matrix(y_train, predict_with_best_t(y_train_pred_prob, best_t)),annot = True, fmt = "d", cbar=False)
```

```
==========================================================================================

the maximum value of tpr*(1-fpr) 0.48056687689024274 for threshold 0.508
Train confusion matrix
```

Out[203]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208a3a66a0>
```



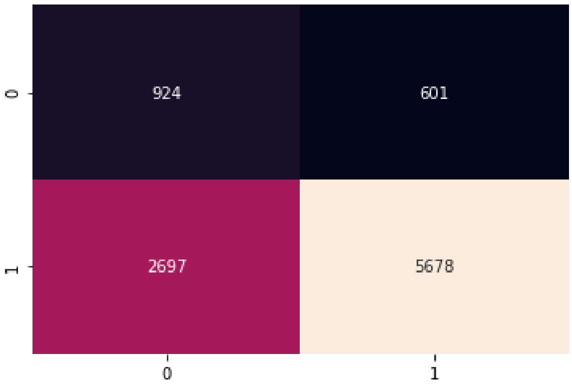
In [204]:

```python
print("Test confusion matrix")
sns.heatmap(confusion_matrix(y_test, predict_with_best_t(y_test_pred_prob, best_t)), annot = True,
fmt = "d", cbar=False)
```

```
Test confusion matrix
```

Out[204]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208a5df5c0>
```

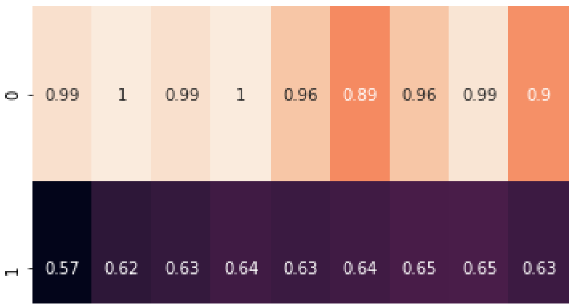


In [205]:

```python
scores = [results['mean_train_score'].values, results['mean_test_score'].values]
sns.heatmap(np.asarray(scores), annot = True, cbar=False)
```

Out[205]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208a77f208>
```



In [108]:

```
depth = [2,3,4,5,6,7,8,9,10]
estimators = [10,50,100,150,200,300,500]
plot_3d_plot(X_train_set_3, y_train, X_test_set_3, y_test, depth, estimators, "RF_")
```

Set 4) categorical(response coding: use probability values), numerical features + project_title(TFIDF W2V)+ preprocessed_eassay (TFIDF W2V)

In [206]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039
# with the same hstack function we are concatinating a sparse matrix and a dense matirx :)
X_train_set_4 = hstack((csr_matrix(X_train['train_pro_cat_1'].values).reshape(-1,1), csr_matrix(X_t
rain['train_pro_cat_0'].values).reshape(-1,1),csr_matrix(X_train['train_pro_subcat_1'].values).resh
ape(-1,1), csr_matrix(X_train['train_pro_subcat_0'].values).reshape(-1,1),csr_matrix(X_train['train
_school_state_1'].values).reshape(-1,1),csr_matrix(X_train['train_school_state_0'].values).reshape(
-1,1),\
                        csr_matrix( X_train['train_grade_1'].values).reshape(-1,1),csr_matrix( X_tr
in['train_grade_0'].values).reshape(-1,1),csr_matrix(X_train['train_prefix_1'].values).reshape(-1,1
),csr_matrix(X_train['train_prefix_0'].values).reshape(-1,1),x_train_teacher_number,x_train_price,x
_train_quantity,x_train_weighted_w2v_title, x_train_weighted_w2v_essay)).tocsr()
X_test_set_4 = hstack((csr_matrix(X_test['test_pro_cat_1'].values).reshape(-1,1),csr_matrix(X_test[
'test_pro_cat_0'].values).reshape(-1,1),csr_matrix(X_test['test_pro_subcat_1'].values).reshape(-1,1
),csr_matrix(X_test['test_pro_subcat_0'].values).reshape(-1,1),csr_matrix(X_test['test_school_state_
1'].values).reshape(-1,1),csr_matrix(X_test['test_school_state_0'].values).reshape(-1,1),csr_matrix
(X_test['test_grade_1'].values).reshape(-1,1),\
                    csr_matrix(X_test['test_grade_0'].values).reshape(-1,1),csr_matrix(X_test['test_
prefix_1'].values).reshape(-1,1),csr_matrix(X_test['test_prefix_0'].values).reshape(-1,1),x_test_te
acher_number,x_test_price,x_test_quantity, x_test_weighted_w2v_title,x_test_weighted_w2v_essay)).t
ocsr()
```

Calculating Combine Hyper-Parameters

In [211]:

```
RF_ = RandomForestClassifier(class_weight = "balanced")
parameters = {'n_estimators':[10, 50, 100, 150, 200, 300, 500, 1000],'max_depth':[2,3,4,5,6,7,8,9,10
]}
clf = RandomizedSearchCV(RF_, parameters,n_iter = 9, scoring='roc_auc', return_train_score = True)
clf.fit(X_train_set_4, y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_n_estimators'])
```

In [212]:

```
results
```

Out[212]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
3	0.371997	0.008068	0.011294	0.000687	10	8	{'n_estimators': 10, 'max_depth': 8}
1	1.079607	0.037545	0.031998	0.002531	50	5	{'n_estimators': 50, 'max_depth': 5}
6	0.470455	0.007614	0.034295	0.000977	50	2	{'n_estimators': 50, 'max_depth': 2}
8	1.278673	0.067645	0.037629	0.003479	50	6	{'n_estimators': 50, 'max_depth': 6}
7	3.509688	0.026575	0.064440	0.001643	100	9	{'n_estimators': 100, 'max_depth': 9}
0	5.057817	0.343219	0.106022	0.018510	150	8	{'n_estimators': 150, 'max_depth': 8}
5	4.367771	0.087024	0.107195	0.021847	150	7	{'n_estimators': 150, 'max_depth': 7}
2	2.898401	0.142856	0.177992	0.017325	300	2	{'n_estimators': 300, 'max_depth': 2}
4	5.676710	0.443878	0.230635	0.034477	300	4	{'n_estimators': 300, 'max_depth': 4}

9 rows × 22 columns

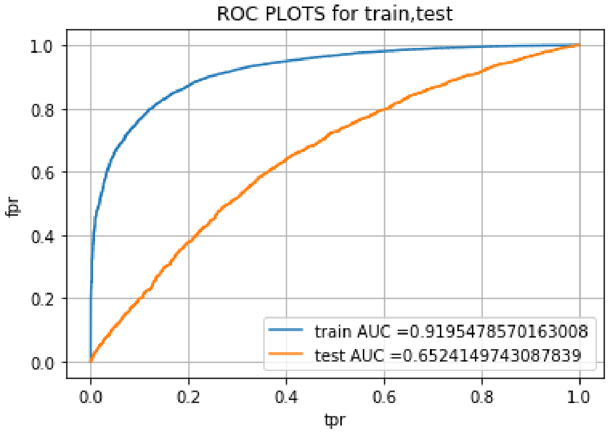
In [213]:

```
# the best value for n_estimators and max_depth from the above table are
best_n_estimator = 10
best_max_depth = 9
```

In [214]:

```
# https://scikit-
learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve
RF_ = RandomForestClassifier(n_estimators = best_n_estimator, max_depth = best_max_depth, class_wei
ght = "balanced")
RF_.fit(X_train_set_4, 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 = RF_.predict_proba(X_train_set_4)
y_test_pred =  RF_.predict_proba(X_test_set_4)

y_train_pred_prob = []
y_test_pred_prob = []

for index in range(len(y_train_pred)):
    y_train_pred_prob.append(y_train_pred[index][1])

for index in range(len(y_test_pred)):
    y_test_pred_prob.append(y_test_pred[index][1])


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred_prob)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred_prob)



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("tpr")
plt.ylabel("fpr")
plt.title("ROC PLOTS for train,test")
plt.grid()
plt.show()
```



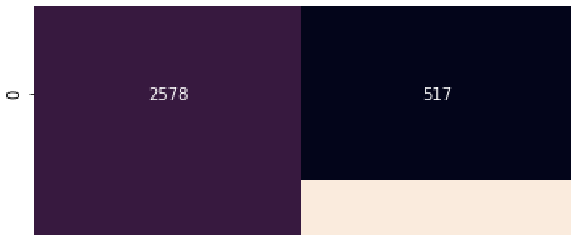
In [215]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
sns.heatmap(confusion_matrix(y_train, predict_with_best_t(y_train_pred_prob, best_t)),annot = True,
fmt = "d", cbar=False)
```

```
====================================================================================================

the maximum value of tpr*(1-fpr) 0.7069230517110097 for threshold 0.521
Train confusion matrix
```

Out[215]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208a61dba8>
```



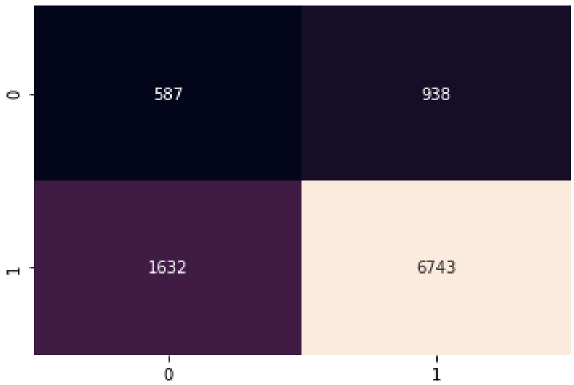
In [216]:

```
print("Test confusion matrix")
sns.heatmap(confusion_matrix(y_test, predict_with_best_t(y_test_pred_prob, best_t)), annot = True,
fmt = "d", cbar=False)
```

```
Test confusion matrix
```

Out[216]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208a5eac18>
```

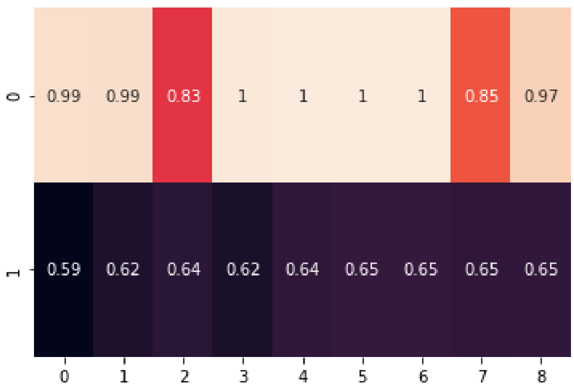


In [218]:

```
scores = [results['mean_train_score'].values, results['mean_test_score'].values]
sns.heatmap(np.asarray(scores),annot = True,cbar=False)
```

Out[218]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208a639978>
```



In [117]:

```
depth = [2,3,4,5,6,7,8,9,10]
estimators = [10,50,100,150,200,300,500]
plot_3d_plot(X_train_set_4, y_train, X_test_set_4, y_test, depth, estimators, "RF_")
```

3.2) Gradient Boosted Decision Trees

Set 1) categorical(response coding: use probability values), numerical features + project_title(BOW) + preprocessed_eassay (BOW)

In [219]:

```
from sklearn.ensemble import GradientBoostingClassifier
```

Calculating Combine Hyper-Parameters

In [232]:

```
GB_ = GradientBoostingClassifier()
parameters = {'n_estimators':[10, 50, 100, 150, 200, 300, 500, 1000], 'max_depth':[2,3,4,5,6,7,8,9,1
0]}
clf = RandomizedSearchCV(GB_, parameters,n_iter = 8, scoring='roc_auc', return_train_score=True)
clf.fit(X_train_set_1, y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_n_estimators'])
```

In [233]:

```
results
```

Out[233]:

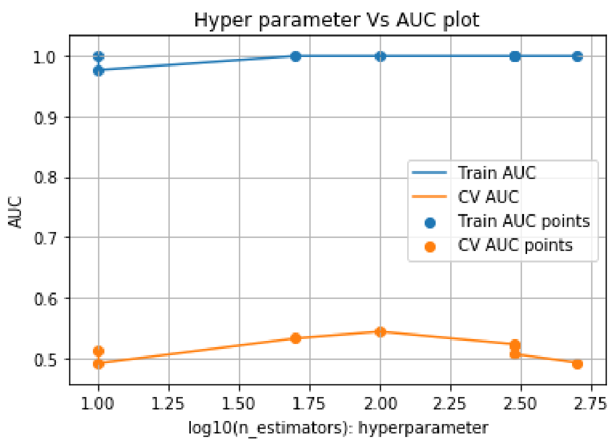
	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
3	0.803711	0.079007	0.003598	0.000373	10	9	{'n_estimators': 10, 'max_depth': 9}
5	0.528480	0.048005	0.004008	0.000318	10	5	{'n_estimators': 10, 'max_depth': 5}
6	2.080649	0.133949	0.004305	0.000808	50	4	{'n_estimators': 50, 'max_depth': 4}
							{'n_estimators':

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
0	6.533692	0.391517	0.004007	0.000450	100	7	{'n_estimators': 100, 'max_depth': 7}
1	7.742294	0.273951	0.004285	0.000583	300	2	{'n_estimators': 300, 'max_depth': 2}
4	17.355465	0.679673	0.007097	0.002400	300	7	{'n_estimators': 300, 'max_depth': 7}
7	22.236497	0.838947	0.006911	0.001243	300	9	{'n_estimators': 300, 'max_depth': 9}
2	26.305203	1.319721	0.008696	0.002461	500	7	{'n_estimators': 500, 'max_depth': 7}

8 rows × 22 columns

In [236]:

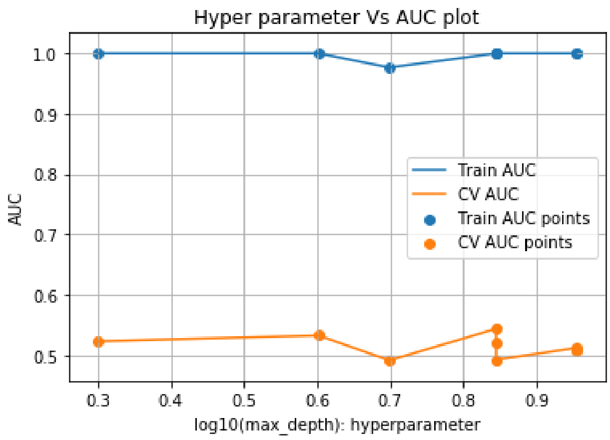
```
train_auc= results['mean_train_score']
train_auc_std= results['std_train_score']
cv_auc = results['mean_test_score']
cv_auc_std= results['std_test_score']
C_ =  results['param_n_estimators'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(n_estimators): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [237]:

```
results = results.sort_values(['param_max_depth'])

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']
C_ =  results['param_max_depth'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')
```

```
plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(max_depth): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```

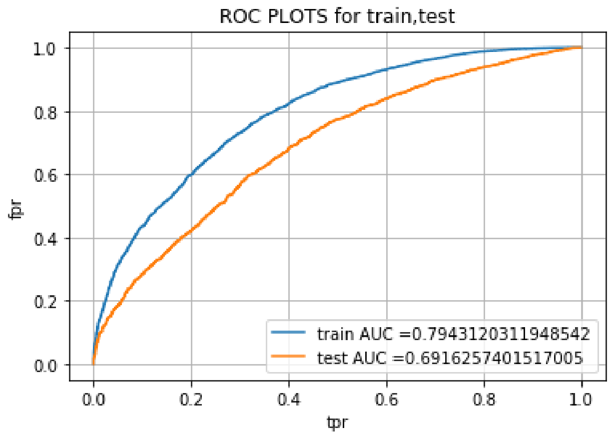


In [234]:

```
# the best value for n_estimators and max_depth from the above graphs are
best_n_estimator = 50
best_max_depth = 4
```

In [235]:

```
# https://scikit-
learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve
GB_ = GradientBoostingClassifier(n_estimators = best_n_estimator, max_depth = best_max_depth)
GB_.fit(X_train_set_1, 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 = GB_.predict_proba(X_train_set_1)
y_test_pred =  GB_.predict_proba(X_test_set_1)

y_train_pred_prob = []
y_test_pred_prob = []

for index in range(len(y_train_pred)):
    y_train_pred_prob.append(y_train_pred[index][1])

for index in range(len(y_test_pred)):
    y_test_pred_prob.append(y_test_pred[index][1])


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred_prob)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred_prob)



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("tpr")
plt.ylabel("fpr")
plt.title("ROC PLOTS for train,test")
plt.grid()
plt.show()
```



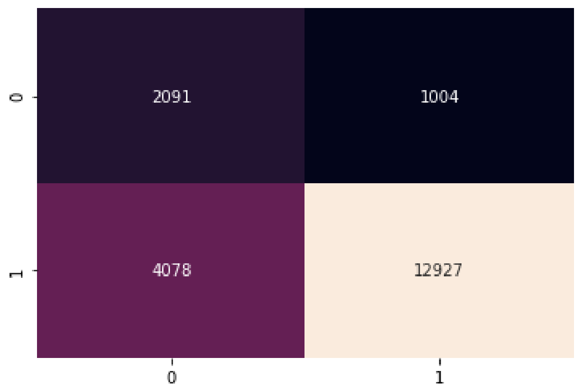
In [238]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
sns.heatmap(confusion_matrix(y_train, predict_with_best_t(y_train_pred_prob, best_t)),annot = True,
fmt = "d", cbar=False)
```

```
====================================================================================================

the maximum value of tpr*(1-fpr) 0.5135875554989766 for threshold 0.829
Train confusion matrix
```

Out[238]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208d7bda90>
```



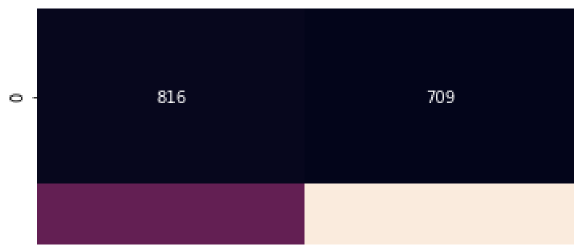
In [239]:

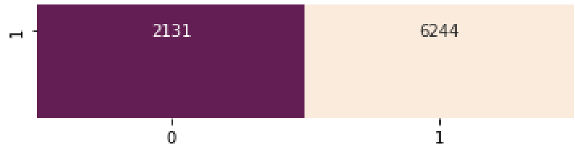
```
print("Test confusion matrix")
sns.heatmap(confusion_matrix(y_test, predict_with_best_t(y_test_pred_prob, best_t)), annot = True,
fmt = "d", cbar=False)
```

```
Test confusion matrix
```

Out[239]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208d87ed68>
```



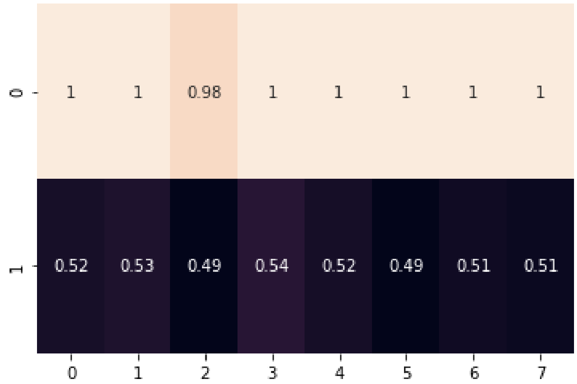


In [240]:

```
scores = [results['mean_train_score'].values, results['mean_test_score'].values]
sns.heatmap(np.asarray(scores),annot = True, cbar=False)
```

Out[240]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2208d8d7cc0>
```



In [241]:

```
depth = [2,3,4,5,6,7,8,9,10]
estimators = [10,50,100,150,200,300,500]
plot_3d_plot(X_train_set_1, y_train, X_test_set_1, y_test, depth, estimators, algo = "GB_")
```

Set 2) categorical(response coding: use probability values), numerical features + project_title(TFIDF)+ preprocessed_eassay (TFIDF)

In [242]:

```python
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.model_selection import GridSearchCV
from scipy.stats import randint as sp_randint
from sklearn.model_selection import RandomizedSearchCV
import matplotlib.pyplot as plt
from sklearn.metrics import roc_auc_score
from sklearn.ensemble import RandomForestClassifier
import math
```

Calculating Combine Hyper-Parameters

In [279]:

```python
GB_ = GradientBoostingClassifier()
parameters = {'n_estimators':[10, 50, 100, 150, 200, 300, 500, 1000],'max_depth':[2,3,4,5,6,7,8,9,10
]}
clf = RandomizedSearchCV(GB_, parameters,n_iter = 9, scoring='roc_auc', return_train_score = True)
clf.fit(X_train_set_2, y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_max_depth'])
results
```

Out[279]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
2	12.869973	0.069965	0.004296	0.000398	150	4	{'n_estimators': 150, 'max_depth': 4}
1	1.093199	0.053436	0.003795	0.001113	10	5	{'n_estimators': 10, 'max_depth': 5}
6	8.060015	0.314129	0.002496	0.000441	100	5	{'n_estimators': 100, 'max_depth': 5}
8	26.884331	1.973777	0.004499	0.000444	300	6	{'n_estimators': 300, 'max_depth': 6}
3	24.769889	0.596861	0.005410	0.000382	150	8	{'n_estimators': 150, 'max_depth': 8}
0	9.732167	0.502142	0.004898	0.001117	50	9	{'n_estimators': 50, 'max_depth': 9}
5	53.651707	5.584866	0.008706	0.001992	300	9	{'n_estimators': 300, 'max_depth': 9}
7	1.520379	0.065109	0.002502	0.000448	10	9	{'n_estimators': 10, 'max_depth': 9}
4	31.370350	0.579829	0.005707	0.000245	150	10	{'n_estimators': 150, 'max_depth': 10}

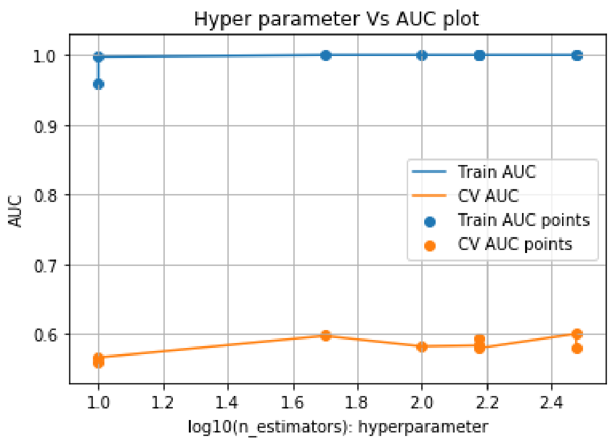
9 rows × 22 columns

In [280]:

```
# the best value for n_estimators and max_depth from the above graphs are
best_n_estimator = 50
best_max_depth = 9
```

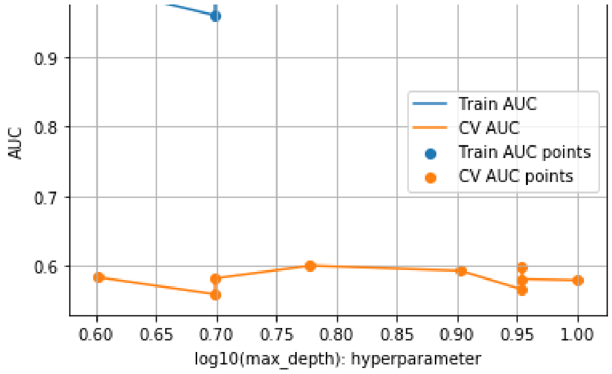
In [281]:

```
results = results.sort_values(['param_n_estimators'])

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']
C_ =  results['param_n_estimators'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(n_estimators): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



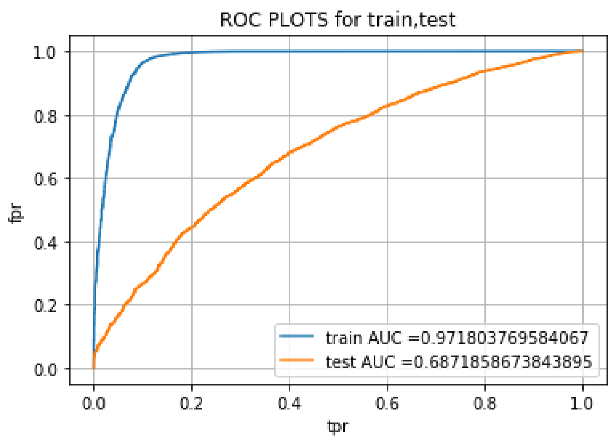
In [282]:

```
results = results.sort_values(['param_max_depth'])

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']
C_ =  results['param_max_depth'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(max_depth): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [283]:

```
# https://scikit-
learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve
GB_ = GradientBoostingClassifier(n_estimators = best_n_estimator, max_depth = best_max_depth)
GB_.fit(X_train_set_2, 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 = GB_.predict_proba(X_train_set_2)
y_test_pred =  GB_.predict_proba(X_test_set_2)

y_train_pred_prob = []
y_test_pred_prob = []

for index in range(len(y_train_pred)):
    y_train_pred_prob.append(y_train_pred[index][1])

for index in range(len(y_test_pred)):
    y_test_pred_prob.append(y_test_pred[index][1])


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred_prob)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred_prob)



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("tpr")
plt.ylabel("fpr")
plt.title("ROC PLOTS for train,test")
plt.grid()
plt.show()
```



In [284]:

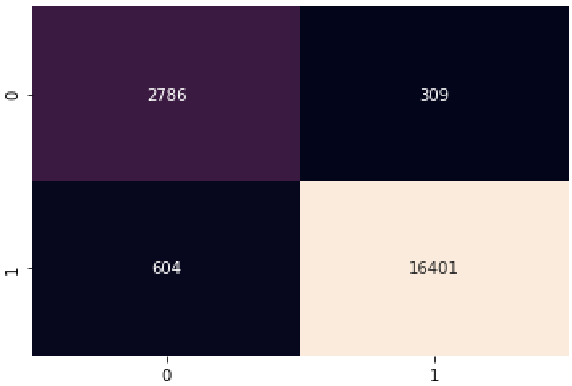
```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
```

```
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
sns.heatmap(confusion_matrix(y_train, predict_with_best_t(y_train_pred_prob, best_t)),annot = True, fmt = "d", cbar=False)
```

```
====================================================================================================

the maximum value of tpr*(1-fpr) 0.8681887442589109 for threshold 0.808
Train confusion matrix
```

Out[284]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x220984f0fd0>
```



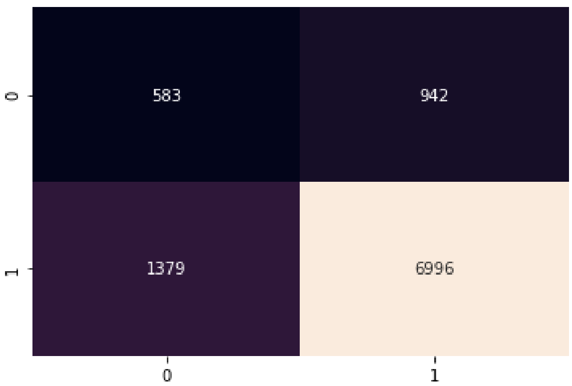
In [285]:

```
print("Test confusion matrix")
sns.heatmap(confusion_matrix(y_test, predict_with_best_t(y_test_pred_prob, best_t)), annot = True, fmt = "d", cbar=False)
```

```
Test confusion matrix
```

Out[285]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2209846e780>
```

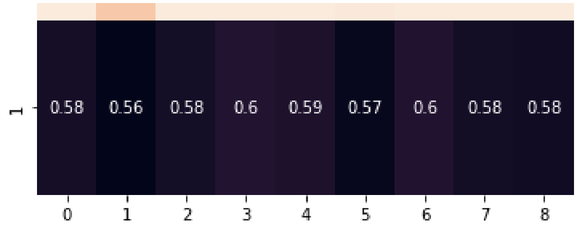


In [287]:

```
scores = [results['mean_train_score'].values, results['mean_test_score'].values]
sns.heatmap(np.asarray(scores),annot = True, cbar=False)
```

Out[287]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x220983e9438>
```



In [151]:

```
depth = [2,3,4,5,6,7,8,9,10]
estimators = [10,50,100,150,200,300,500]
plot_3d_plot(X_train_set_2, y_train, X_test_set_2, y_test, depth, estimators, algo = 'GB_')
```

Set 3) categorical(response coding: use probability values), numerical features + project_title(AVG W2V)+ preprocessed_eassay (AVG W2V)

Calculating Combine Hyper-Parameters

In [261]:

```
GB_ = GradientBoostingClassifier()
parameters = {'n_estimators':[10, 50, 100, 150, 200, 300, 500, 1000], 'max_depth':[2,3,4,5,6,7,8,9,1
0]}
clf = RandomizedSearchCV(GB_, parameters,n_iter = 8, scoring='roc_auc', return_train_score = True)
clf.fit(X_train_set_3, y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_n_estimators'])
results
```

Out[261]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
2	0.659660	0.024315	0.003902	0.001110	10	2	{'n_estimators': 10,

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
5	1.251189	0.021426	0.003403	0.000376	10	4	{'n_estimators': 10, 'max_depth': 4}
1	20.470414	0.633090	0.006907	0.002611	100	6	{'n_estimators': 100, 'max_depth': 6}
3	10.095314	0.721341	0.004967	0.001814	150	2	{'n_estimators': 150, 'max_depth': 2}
4	14.488546	0.815637	0.004400	0.000974	150	3	{'n_estimators': 150, 'max_depth': 3}
6	36.070863	5.697585	0.005698	0.001070	300	5	{'n_estimators': 300, 'max_depth': 5}
7	37.875498	0.954277	0.005904	0.000749	300	4	{'n_estimators': 300, 'max_depth': 4}
0	27.377544	3.319729	0.005572	0.000985	1000	7	{'n_estimators': 1000, 'max_depth': 7}

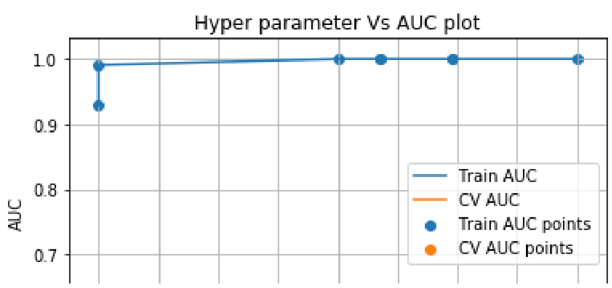
8 rows × 22 columns

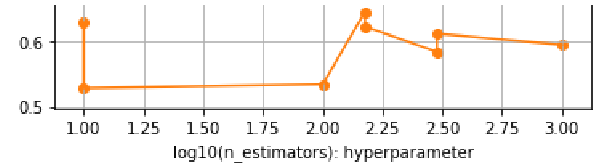
In [262]:

```
# the best value for n_estimators and max_depth from the above graphs are
best_n_estimator = 150
best_max_depth = 3
```

In [263]:

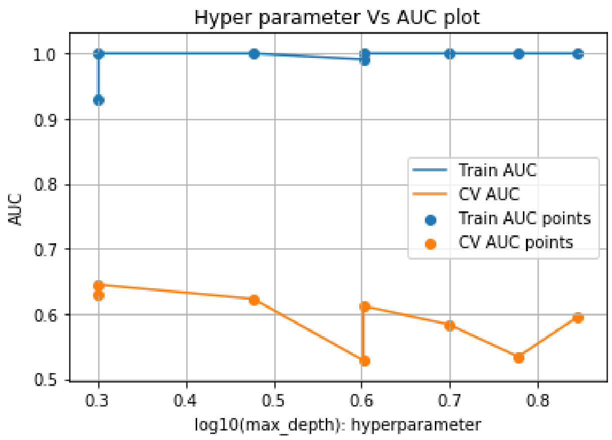
```
results = results.sort_values(['param_n_estimators'])

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']
C_ =  results['param_n_estimators'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(n_estimators): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```





In [264]:

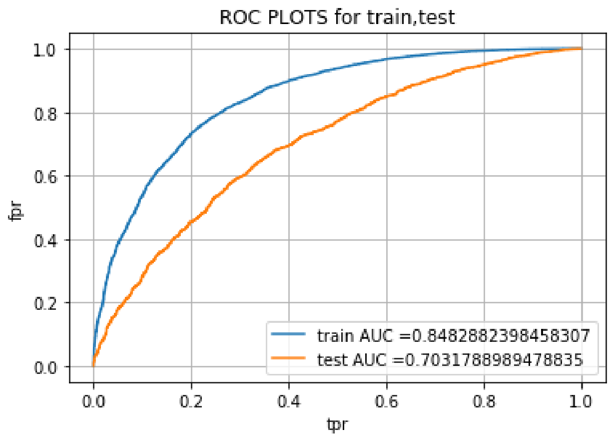
```
results = results.sort_values(['param_max_depth'])

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']
C_ =  results['param_max_depth'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(max_depth): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [265]:

```
# https://scikit-
learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve
GB_ = GradientBoostingClassifier(n_estimators = best_n_estimator, max_depth = best_max_depth)
GB_.fit(X_train_set_3, 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 = GB_.predict_proba(X_train_set_3)
y_test_pred =  GB_.predict_proba(X_test_set_3)

y_train_pred_prob = []
y_test_pred_prob = []

for index in range(len(y_train_pred)):
    y_train_pred_prob.append(y_train_pred[index][1])

for index in range(len(y_test_pred)):
    y_test_pred_prob.append(y_test_pred[index][1])


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred_prob)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred_prob)
```

```
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("tpr")
plt.ylabel("fpr")
plt.title("ROC PLOTS for train,test")
plt.grid()
plt.show()
```



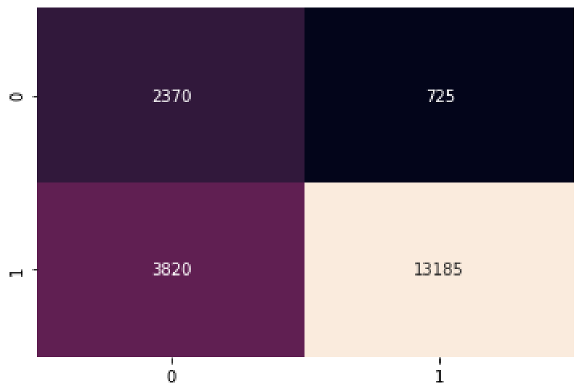
In [266]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
sns.heatmap(confusion_matrix(y_train, predict_with_best_t(y_train_pred_prob, best_t)),annot = True,
fmt = "d", cbar=False)
```

```
====================================================================================================

the maximum value of tpr*(1-fpr) 0.5937330035497496 for threshold 0.831
Train confusion matrix
```

Out[266]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x22098634f98>
```



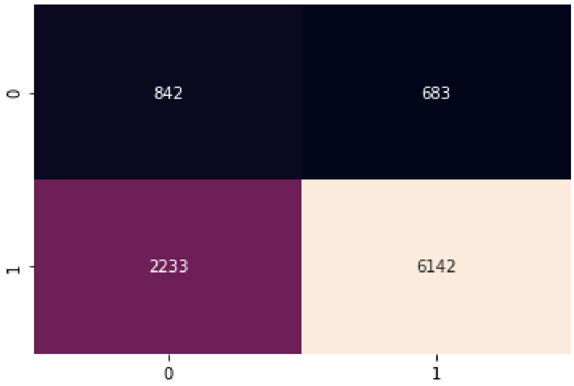
In [267]:

```
print("Test confusion matrix")
sns.heatmap(confusion_matrix(y_test, predict_with_best_t(y_test_pred_prob, best_t)), annot = True,
fmt = "d", cbar=False)
```

```
Test confusion matrix
```

Out[267]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x220986c7780>
```

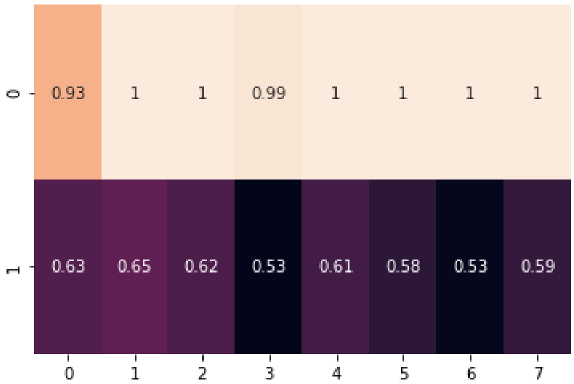


In [269]:

```
scores = [results['mean_train_score'].values, results['mean_test_score'].values]
sns.heatmap(np.asarray(scores), annot = True, cbar=False)
```

Out[269]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x220986e6588>
```



In [118]:

```
depth = [2,3,4,5,6,7,8,9,10]
estimators = [10,50,100,150,200,300,500]
plot_3d_plot(X_train_set_3, y_train, X_test_set_3, y_test, depth, estimators, algo = "GB_")
```

Set 4) categorical(response coding: use probability values), numerical features + project_title(TFIDF W2V)+ preprocessed_eassay (TFIDF W2V)

Calculating Combine Hyper-Parameters

In [278]:

```
GB_ = GradientBoostingClassifier()
parameters = {'n_estimators':[10, 50, 100, 150, 200, 300, 500, 1000], 'max_depth':[2,3,4,5,6,7,8,9,1
0]}
clf = RandomizedSearchCV(GB_, parameters,n_iter = 8, scoring='roc_auc', return_train_score = True)
clf.fit(X_train_set_4, y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_n_estimators'])
results
```

Out[278]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_n_estimators	param_max_depth	params
0	0.949910	0.016993	0.003100	0.000200	10	3	{'n_estimators': 10, 'max_depth': 3}
3	1.244781	0.026956	0.003100	0.000188	10	4	{'n_estimators': 10, 'max_depth': 4}
4	12.358133	0.226298	0.004489	0.000711	50	8	{'n_estimators': 50, 'max_depth': 8}
1	6.395110	0.078714	0.003395	0.000379	100	2	{'n_estimators': 100, 'max_depth': 2}
2	23.609481	0.533504	0.004304	0.000238	150	5	{'n_estimators': 150, 'max_depth': 5}
5	25.645134	1.874733	0.004691	0.000235	150	7	{'n_estimators': 150, 'max_depth': 7}
7	14.532658	0.386343	0.004300	0.000677	150	3	{'n_estimators': 150, 'max_depth': 3}
6	19.416899	0.542825	0.005507	0.000531	300	2	{'n_estimators': 300, 'max_depth': 2}

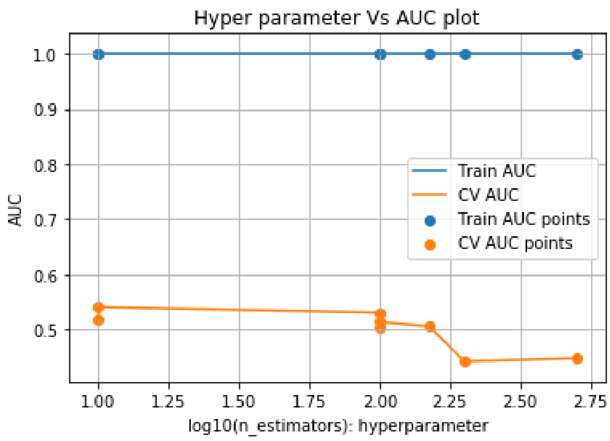
8 rows × 22 columns

In [271]:

```
# the best value for n_estimators and max_depth from the above graphs are
best_n_estimator = 10
best_max_depth = 10
```

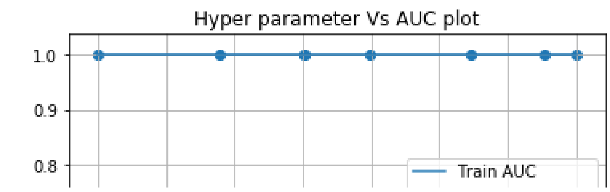
In [272]:

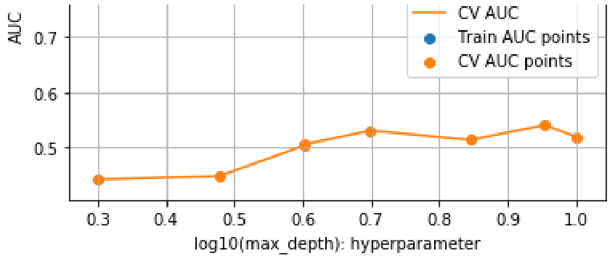
```
results = results.sort_values(['param_n_estimators'])

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']
C_ =  results['param_n_estimators'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(n_estimators): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```



In [273]:

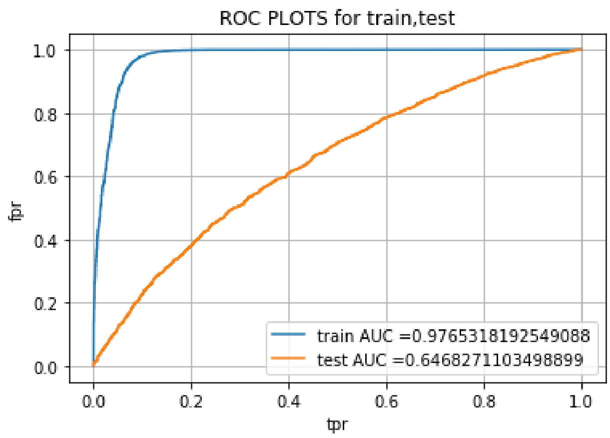
```
results = results.sort_values(['param_max_depth'])

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']
C_ =  results['param_max_depth'].apply(lambda x: math.log10(x))

plt.plot(C_, train_auc, label='Train AUC')

plt.plot(C_, cv_auc, label='CV AUC')

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


plt.legend()
plt.xlabel("log10(max_depth): hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()
```





In [274]:

```
# https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve
GB_ = GradientBoostingClassifier(n_estimators = best_n_estimator, max_depth = best_max_depth)
GB_.fit(X_train_set_4, 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 = GB_.predict_proba(X_train_set_4)
y_test_pred =  GB_.predict_proba(X_test_set_4)

y_train_pred_prob = []
y_test_pred_prob = []

for index in range(len(y_train_pred)):
    y_train_pred_prob.append(y_train_pred[index][1])

for index in range(len(y_test_pred)):
    y_test_pred_prob.append(y_test_pred[index][1])


train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred_prob)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred_prob)



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("tpr")
plt.ylabel("fpr")
plt.title("ROC PLOTS for train,test")
plt.grid()
plt.show()
```



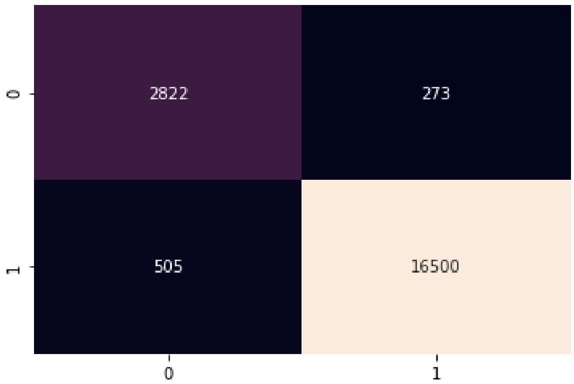
In [275]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
sns.heatmap(confusion_matrix(y_train, predict_with_best_t(y_train_pred_prob, best_t)),annot = True,
fmt = "d", cbar=False)
```

```
==========================================================================================

the maximum value of tpr*(1-fpr) 0.8847155569088061 for threshold 0.83
Train confusion matrix
```

Out[275]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x220986916a0>
```



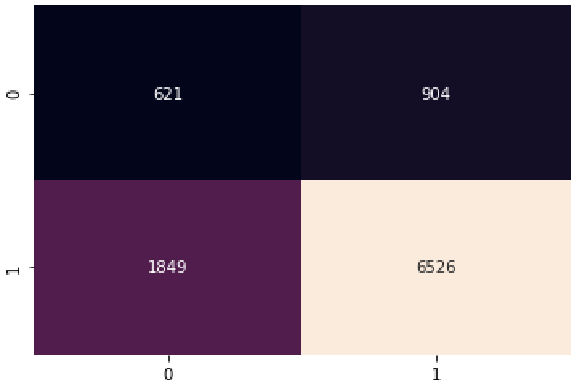
In [276]:

```python
print("Test confusion matrix")
sns.heatmap(confusion_matrix(y_test, predict_with_best_t(y_test_pred_prob, best_t)), annot = True,
fmt = "d", cbar=False)
```

```
Test confusion matrix
```

Out[276]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x22098596860>
```

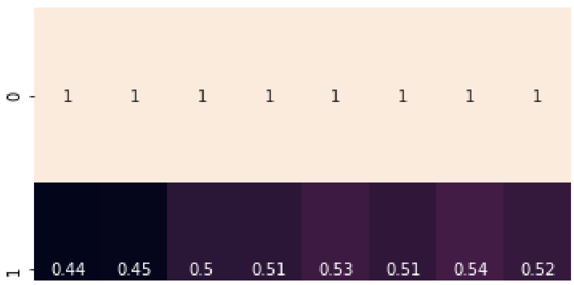


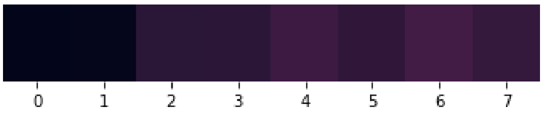
In [277]:

```python
scores = [results['mean_train_score'].values, results['mean_test_score'].values]
sns.heatmap(np.asarray(scores), annot = True, cbar=False)
```

Out[277]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x2209856ab70>
```





In [94]:

```
depth = [2,3,4,5,6,7,8,9,10]
estimators = [10,50,100,150,200,300,500]
plot_3d_plot(X_train_set_4, y_train, X_test_set_4, y_test, depth, estimators, algo = 'GB_')
```

In [124]:

```
from prettytable import PrettyTable

x = PrettyTable()

x.field_names = ["Model", "Dataset","best_n_estimator", "best_max_depth", "Train AUC", "Test AUC"]

x.add_row(["RandomForestClassfier", "BOW", 200, 9, 0.8760, 0.7002])
x.add_row(["RandomForestClassfier", "TFIDF", 300, 8, 0.8891, 0.6963])
x.add_row(["RandomForestClassfier", "AVG W2V", 500, 4, 0.7576, 0.6950])
x.add_row(["RandomForestClassfier", "TFIDF W2V", 10, 9, 0.9195, 0.6524])
x.add_row(["GradientBoostingClassifier", "BOW", 50, 4, 0.7943, 0.6916])
x.add_row(["GradientBoostingClassifier", "TFIDF", 50, 9, 0.9718, 0.6871])
x.add_row(["GradientBoostingClassifier", "AVG W2v", 150, 3, 0.8482, 0.7031])
x.add_row(["GradientBoostingClassifier", "TFIDF W2V", 10, 10, 0.9765, 0.6468])

print(x)
```

```
+----------------------------+-----------+------------------+----------------+-----------+---------
|           Model            |  Dataset  | best_n_estimator | best_max_depth | Train AUC | Test AUC
|
+----------------------------+-----------+------------------+----------------+-----------+---------
|   RandomForestClassfier    |    BOW    |       200        |       9        |   0.876   |  0.7002
|
|   RandomForestClassfier    |   TFIDF   |       300        |       8        |   0.8891  |  0.6963
|
|   RandomForestClassfier    |  AVG W2V  |       500        |       4        |   0.7576  |  0.695
|
|   RandomForestClassfier    | TFIDF W2V |        10        |       9        |   0.9195  |  0.6524
|
```

```
| GradientBoostingClassifier |    BOW    |        50        |        4        |   0.7943  |  0.6916
|
| GradientBoostingClassifier |   TFIDF   |        50        |        9        |   0.9718  |  0.6871
|
| GradientBoostingClassifier |  AVG W2v  |       150        |        3        |   0.8482  |  0.7031
|
| GradientBoostingClassifier | TFIDF W2V |        10        |        10       |   0.9765  |  0.6468
|
+----------------------------+-----------+------------------+-----------------+-----------+---------
```