DonorsChoose

DonorsChoose.org receives hundreds of thousands of project proposals each year for classroom projects in need of funding. Right now, a large number of volunteers is needed to manually screen each submission before it's approved to be posted on the DonorsChoose.org website.

Next year, DonorsChoose.org expects to receive close to 500,000 project proposals. As a result, there are three main problems they need to solve:

- How to scale current manual processes and resources to screen 500,000 projects so that they can be posted as quickly and as efficiently as possible
- How to increase the consistency of project vetting across different volunteers to improve the experience for teachers
- How to focus volunteer time on the applications that need the most assistance

The goal of the competition is to predict whether or not a DonorsChoose.org project proposal submitted by a teacher will be approved, using the text of project descriptions as well as additional metadata about the project, teacher, and school. DonorsChoose.org can then use this information to identify projects most likely to need further review before approval.

About the DonorsChoose Data Set

The `train.csv` data set provided by DonorsChoose contains the following features:

Feature	
`project_id`	A unique identifier for the proposed project.
`project_title`	Title of th • `Art Will` •
`project_grade_category`	Grade level of students for which the project is targeted. • • • •

Feature	
`project_subject_categories`	One or more (comma-separated) subject categories fo following enum • • • • • `Lit` • • • • • • `Literacy & Language`
`school_state`	State where school is located ([Two-le (https://en.wikipedia.org/wiki/List_of_U.S._state_abbreviati](https://en.wikipedia.org/wiki/List_of_U.S._state_abbreviati)
`project_subject_subcategories`	One or more (comma-separated) subject subcateg • • `Literature & Writing,`
`project_resource_summary`	An explanation of the resources needed for th • `My students need hands on literacy mat sens`
`project_essay_1`	Fi
`project_essay_2`	Seco
`project_essay_3`	Thi
`project_essay_4`	Four
`project_submitted_datetime`	Datetime when project application was submitted. **Exa**
`teacher_id`	A unique identifier for the teacher of the propos `bdf8baa8fedef6bf`
`teacher_prefix`	Teacher's title. One of the following • • • • • •
`teacher_number_of_previously_posted_projects`	Number of project applications previously submitted

[*] See the section **Notes on the Essay Data** for more details about these features.

Additionally, the `resources.csv` data set provides more data about the resources required for each project. Each line in this file represents a resource required by a project:

Feature	Description
id	A `project_id` value from the `train.csv` file. **Example:** `p036502`
description	Desciption of the resource. **Example:** `Tenor Saxophone Reeds, Box of 25`
quantity	Quantity of the resource required. **Example:** `3`
price	Price of the resource required. **Example:** `9.95`

Note: Many projects require multiple resources. The `id` value corresponds to a `project_id` in train.csv, so you use it as a key to retrieve all resources needed for a project:

The data set contains the following label (the value you will attempt to predict):

Label	Description
`project_is_approved`	A binary flag indicating whether DonorsChoose approved the project. A value of `0` indicates the project was not approved, and a value of `1` indicates the project was approved.

Notes on the Essay Data

Prior to May 17, 2016, the prompts for the essays were as follows:

- **project_essay_1:** "Introduce us to your classroom"
- **project_essay_2:** "Tell us more about your students"
- **project_essay_3:** "Describe how your students will use the materials you're requesting"
- **project_essay_3:** "Close by sharing why your project will make a difference"

Starting on May 17, 2016, the number of essays was reduced from 4 to 2, and the prompts for the first 2 essays were changed to the following:

- **project_essay_1:** "Describe your students: What makes your students special? Specific details about their background, your neighborhood, and your school are all helpful."
- **project_essay_2:** "About your project: How will these materials make a difference in your students' learning and improve their school lives?"

For all projects with project_submitted_datetime of 2016-05-17 and later, the values of project_essay_3 and project_essay_4 will be NaN.

In [196]:

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

1.1 Reading Data

In [197]:

```
project_data = pd.read_csv('train_data.csv')
resource_data = pd.read_csv('resources.csv')
```

In [198]:

```
project_data.shape
```

Out[198]:

```
(109248, 17)
```

In [199]:

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

```
Number of data points in train data (109248, 17)
--------------------------------------------------
The attributes of data : ['Unnamed: 0' 'id' 'teacher_id' 'teacher_prefix' 'scho
ol_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']
```

Out[199]:

```
1    92706
0    16542
Name: project_is_approved, dtype: int64
```

In [200]:

```
print("Number of data points in train data", resource_data.shape)
print(resource_data.columns.values)
resource_data.head(2)
```

```
Number of data points in train data (1541272, 4)
['id' 'description' 'quantity' 'price']
```

Out[200]:

	id	description	quantity	price
0	p233245	LC652 - Lakeshore Double-Space Mobile Drying Rack	1	149.00
1	p069063	Bouncy Bands for Desks (Blue support pipes)	3	14.95

1.2 preprocessing of `project_subject_categories`

In [201]:

```
catogories = list(project_data['project_subject_categories'].values)
# remove special characters from list of strings python: https://stackoverflow.com

# https://www.geeksforgeeks.org/removing-stop-words-nltk-python/
# https://stackoverflow.com/questions/23669024/how-to-strip-a-specific-word-from-
# https://stackoverflow.com/questions/8270092/remove-all-whitespace-in-a-string-i
cat_list = []
for i in catogories:
    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", "
        if 'The' in j.split(): # this will split each of the catogory based on sp
            j=j.replace('The','') # if we have the words "The" we are going to re
        j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty)
        temp+=j.strip()+" " #" abc ".strip() will return "abc", remove the traili
        temp = temp.replace('&','_') # we are replacing the & value into
    cat_list.append(temp.strip())

project_data['clean_categories'] = cat_list
project_data.drop(['project_subject_categories'], axis=1, inplace=True)

from collections import Counter
my_counter = Counter()
for word in project_data['clean_categories'].values:
    my_counter.update(word.split())

cat_dict = dict(my_counter)
sorted_cat_dict = dict(sorted(cat_dict.items(), key=lambda kv: kv[1]))
```

1.3 preprocessing of `project_subject_subcategories`

In [202]:

```
sub_catogories = list(project_data['project_subject_subcategories'].values)
# remove special characters from list of strings python: https://stackoverflow.co

# https://www.geeksforgeeks.org/removing-stop-words-nltk-python/
# https://stackoverflow.com/questions/23669024/how-to-strip-a-specific-word-from-
# https://stackoverflow.com/questions/8270092/remove-all-whitespace-in-a-string-i

sub_cat_list = []
for i in sub_catogories:
    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", "
        if 'The' in j.split(): # this will split each of the catogory based on sp
            j=j.replace('The','') # if we have the words "The" we are going to re
        j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty)
        temp +=j.strip()+" "#" abc ".strip() will return "abc", remove the traili
        temp = temp.replace('&','_')
    sub_cat_list.append(temp.strip())

project_data['clean_subcategories'] = sub_cat_list
project_data.drop(['project_subject_subcategories'], axis=1, inplace=True)

# count of all the words in corpus python: https://stackoverflow.com/a/22898595/4
my_counter = Counter()
for word in project_data['clean_subcategories'].values:
    my_counter.update(word.split())

sub_cat_dict = dict(my_counter)
sorted_sub_cat_dict = dict(sorted(sub_cat_dict.items(), key=lambda kv: kv[1]))
```

In [203]:
```
sorted_sub_cat_dict
```

Out[203]:
```
{'Economics': 269,
 'CommunityService': 441,
 'FinancialLiteracy': 568,
 'ParentInvolvement': 677,
 'Extracurricular': 810,
 'Civics_Government': 815,
 'ForeignLanguages': 890,
 'NutritionEducation': 1355,
 'Warmth': 1388,
 'Care_Hunger': 1388,
 'SocialSciences': 1920,
 'PerformingArts': 1961,
 'CharacterEducation': 2065,
 'TeamSports': 2192,
 'Other': 2372,
 'College_CareerPrep': 2568,
 'Music': 3145,
 'History_Geography': 3171,
 'Health_LifeScience': 4235,
 'EarlyDevelopment': 4254,
 'ESL': 4367,
 'Gym_Fitness': 4509,
 'EnvironmentalScience': 5591,
 'VisualArts': 6278,
 'Health_Wellness': 10234,
 'AppliedSciences': 10816,
 'SpecialNeeds': 13642,
 'Literature_Writing': 22179,
 'Mathematics': 28074,
 'Literacy': 33700}
```

1.4 preprocessing of project grade categories

In [204]:
```
project_data['project_grade_category'].value_counts()
```

Out[204]:
```
Grades PreK-2    44225
Grades 3-5       37137
Grades 6-8       16923
Grades 9-12      10963
Name: project_grade_category, dtype: int64
```

In [205]:
```
preprocessed_project_grade_categories= []
for grade_cat in tqdm(project_data["project_grade_category"]):
    grade_cat = grade_cat.replace('-', '_')  #Replacing(-) with(_)
    grade_cat = grade_cat.replace('Grades', '') #Removing grades as it is redunda
    grad_cat = ' '.join(f for f in grade_cat.split())
    preprocessed_project_grade_categories.append(grad_cat.strip())
```

```
100%|██████████████████████████████████████████████████████████████████████| 10
9248/109248 [00:00<00:00, 702043.11it/s]
```

In [206]:
```
print(preprocessed_project_grade_categories[12])
print("="*50)
print(preprocessed_project_grade_categories[502])
print("="*50)
print(preprocessed_project_grade_categories[5002])
print("="*50)
print(preprocessed_project_grade_categories[50002])
print("="*50)
print(preprocessed_project_grade_categories[100013])
print("="*50)
```

```
6_8
==================================================
6_8
==================================================
6_8
==================================================
3_5
==================================================
PreK_2
==================================================
```

1.5 preprocessing of teacher prefix

In [207]:
```
project_data['teacher_prefix'].value_counts()
```

Out[207]:
```
Mrs.       57269
Ms.        38955
Mr.        10648
Teacher     2360
Dr.           13
Name: teacher_prefix, dtype: int64
```

Replacing Nan Values with maximum frequencies values i.e Mrs.

In [208]:
```
project_data['teacher_prefix'] = project_data['teacher_prefix'].fillna('Mrs.')
```

In [209]:
```
def replace_cate(lst):          # Removing (.) in Mrs.
    return lst.replace('.','')
project_data['teacher_prefix']= project_data['teacher_prefix'].astype(str).apply(
```

In [210]:
```
preprocessed_teacher_prefix = []
for teach_prefix in tqdm(project_data["teacher_prefix"]):
    preprocessed_teacher_prefix.append(teach_prefix.strip())
```

```
100%|█████████████████████████████████████████████████████| 109
248/109248 [00:00<00:00, 2235597.90it/s]
```

In [211]:

```
print(preprocessed_teacher_prefix[1])
print("="*50)
print(preprocessed_teacher_prefix[50])
print("="*50)
project_data.teacher_prefix.value_counts()
```

```
Mr
==================================================
Mrs
==================================================
```

Out[211]:

```
Mrs        57272
Ms         38955
Mr         10648
Teacher     2360
Dr            13
Name: teacher_prefix, dtype: int64
```

1.6 Adding a new feature Number of words in title(optional)

In [212]:

```
title_word_count = []
```

In [213]:

```
for a in project_data["project_title"] :
    b = len(a.split())
    title_word_count.append(b)
```

In [214]:

```
project_data["title_word_count"] = title_word_count
```

In [215]:
```
project_data.head(5)
```

Out[215]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_sul
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs	IN	20
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr	FL	20
2	21895	p182444	3465aaf82da834c0582ebd0ef8040ca0	Ms	AZ	20
3	45	p246581	f3cb9bffbba169bef1a77b243e620b60	Mrs	KY	20
4	172407	p104768	be1f7507a41f8479dc06f047086a39ec	Mrs	TX	20

combining 4 essays into 1 essay

In [216]:
```
# 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)
```

Adding a new feature Number of words in essay

In [217]:
```
essay_word_count=[]
```

In [218]:

```
for ess in project_data["essay"] :
    c = len(ess.split())
    essay_word_count.append(c)
```

In [219]:

```
project_data["essay_word_count"] = essay_word_count
```

In [220]:

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

Out[220]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_sul
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs	IN	20
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr	FL	20

In [221]:

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

Out[221]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_sul
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs	IN	20
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr	FL	20

Train Test split

In [222]:
```
# train test split using sklearn.model_selection
from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(project_data, project_data['p
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train, test_size=0.33,
```

In [223]:
```
project_data.head()
```

Out[223]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_sul
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs	IN	20
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr	FL	20
2	21895	p182444	3465aaf82da834c0582ebd0ef8040ca0	Ms	AZ	20
3	45	p246581	f3cb9bffbba169bef1a77b243e620b60	Mrs	KY	20
4	172407	p104768	be1f7507a41f8479dc06f047086a39ec	Mrs	TX	20

In [224]:
```
X_train.drop(['project_is_approved'], axis=1, inplace=True)
X_test.drop(['project_is_approved'], axis=1, inplace=True)
X_cv.drop(['project_is_approved'], axis=1, inplace=True)
```

In [225]:

```
X_train.head(2)
```

Out[225]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	projec
21389	75072	p146651	c50bfe62d50fdb9dc30d5bfa107e4c5a	Ms	PA	
34546	74550	p090750	ae699781d1e0eb2fd89d02008ec23b05	Mrs	IA	

1.8 Text preprocessing

In [226]:

```
# printing some random reviews

print(X_train['essay'].values[0])
print("="*50)
print(X_train['essay'].values[500])
print("="*50)
```

```
As a teacher in a low-income/high poverty school, my students are faced with se
veral challenges both inside and outside the classroom. Despite the many challe
nges they face, I want to provide an environment that is safe, fun and engaging
so they can get the most out of their day in my room.\r\n\r\nMy students are cr
eative, clever, and very unique. They like to move, to help and love lots of po
sitive attention. Many of them are being raised in single-parent households and
receive a free lunch based on their socioeconomic status. These things may prev
ent them from getting ahead early in life and may not provide them with the lif
e experiences many of us see as \"typical\". From the minute they walk in the d
oor of my classroom, I focus on their potential and growth while they are with
me. I may not be able to control their home lives but I can certainly control t
heir experience during the school day. By doing this in a creative and positive
way, I am hopeful to inspire my students to continue on a path of academic exce
llence.\r\nBeing able to display their hard work gives my students a sense of p
ride and accomplishment. Their face shows it when their hard work is hung in th
e hallway and in the classroom. They have satisfaction when they can bring home
their work to their families.\r\n\r\nMy students work hard and love when they a
re able to share their work with others.  We are requesting some copy paper and
toner for our printer so that we can continue to share our work with others. Th
ese much needed supplies will allow our creativity and passion to continue thro
ughout the school year.nannan
==================================================
As a teacher in a low-income/high poverty school district, my students are face
d with several challenges both in and out of the classroom.  When the students
enter the class each morning they know they are safe. Our classroom is home and
we are family. The students know this is a place they can let their guards down
and be their unique selves. They know they are safe to take risks and engage in
challenges to grow in academics and social and emotional skills. My babies know
I am their \"Mama Bear\" for five days a week.This donation will be used daily
in small group math interactive activities. This donation will ale be used for
students to read comfortably books of their choice.  It will also create an are
a the students will feel comfortable to take risks and increase their daily edu
cation. This will improve their lives because they will increase education thro
ugh peer discussions and interactions more frequently. \r\n\r\nA new rug helps
to create a classroom where students feel free to learn in a setting of their c
hoice. Students can move away from the standard desks and into learning centers
where they have more opportunities to have academic discussions.nannan
==================================================
```

In [227]:

```
# 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 [228]:

```
sent = decontracted(X_train['essay'].values[20000])
print(sent)
print("="*50)
```

```
My students are fun, hard-working and excited about learning. It is not fun eve
ry minute of every day but we do a pretty good job of making learning fun. They
enter the room with the confidence and enthusiasm for learning. They travel the
world through books and make real world connections through talk and interactio
ns. We always talk about the importance of our education so they always strive
to do their very best. Their bright faces are my motivation to work harder.Befo
re the historic flooding in the city of Baton Rouge, I welcomed my students bac
k to school with a smiling face and warm hugs. Many came to school excited but
with minimal supplies. We were in school two days before the flood. Our school
is neighborhood, which many of our students live, took in water. A lot of stude
nts lost everything including school supplies they had not brought to school. T
he project will furnish my students with the supplies they need and take the ad
ded stress off of the parents who are already dealing with a lot of devastatio
n. Thanks a bunch!nannan
==================================================
```

In [229]:

```
# \r \n \t remove from string python: http://texthandler.com/info/remove-line-bre
sent = sent.replace('\\r', ' ')
sent = sent.replace('\\"', ' ')
sent = sent.replace('\\n', ' ')
print(sent)
```

```
My students are fun, hard-working and excited about learning. It is not fun eve
ry minute of every day but we do a pretty good job of making learning fun. They
enter the room with the confidence and enthusiasm for learning. They travel the
world through books and make real world connections through talk and interactio
ns. We always talk about the importance of our education so they always strive
to do their very best. Their bright faces are my motivation to work harder.Befo
re the historic flooding in the city of Baton Rouge, I welcomed my students bac
k to school with a smiling face and warm hugs. Many came to school excited but
with minimal supplies. We were in school two days before the flood. Our school
is neighborhood, which many of our students live, took in water. A lot of stude
nts lost everything including school supplies they had not brought to school. T
he project will furnish my students with the supplies they need and take the ad
ded stress off of the parents who are already dealing with a lot of devastatio
n. Thanks a bunch!nannan
```

In [230]:

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

```
My students are fun hard working and excited about learning It is not fun every
minute of every day but we do a pretty good job of making learning fun They ent
er the room with the confidence and enthusiasm for learning They travel the wor
ld through books and make real world connections through talk and interactions
We always talk about the importance of our education so they always strive to d
o their very best Their bright faces are my motivation to work harder Before th
e historic flooding in the city of Baton Rouge I welcomed my students back to s
chool with a smiling face and warm hugs Many came to school excited but with mi
nimal supplies We were in school two days before the flood Our school is neighb
orhood which many of our students live took in water A lot of students lost eve
rything including school supplies they had not brought to school The project wi
ll furnish my students with the supplies they need and take the added stress of
f of the parents who are already dealing with a lot of devastation Thanks a bun
ch nannan
```

In [231]:

```
# 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'll", "you'd", 'your', 'yours', 'yourself', 'yourselves', 'he', '
            'she', "she's", 'her', 'hers', 'herself', 'it', "it's", 'its', 'itsel
            'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'that
            'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'has
            'did', 'doing', 'a', 'an', 'the', 'and', 'but', 'if', 'or', 'because'
            'at', 'by', 'for', 'with', 'about', 'against', 'between', 'into', 'th
            'above', 'below', 'to', 'from', 'up', 'down', 'in', 'out', 'on', 'off
            'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'all'
            'most', 'other', 'some', 'such', 'only', 'own', 'same', 'so', 'than',
            's', 't', 'can', 'will', 'just', 'don', "don't", 'should', "should've
            've', 'y', 'ain', 'aren', "aren't", 'couldn', "couldn't", 'didn', "di
            "hadn't", 'hasn', "hasn't", 'haven', "haven't", 'isn', "isn't", 'ma',
            "mustn't", 'needn', "needn't", 'shan', "shan't", 'shouldn', "shouldn'
            'won', "won't", 'wouldn', "wouldn't"]
```

1.8.1 Preprocessesd training data - Text

In [232]:

```
from tqdm import tqdm
def preprocess_textual(row_value):
    preprocessed_train = []
    for sentences in tqdm(row_value):
        sent = decontracted(sentences)
        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_train.append(sent.lower().strip())
    return preprocessed_train
```

In [233]:

```
preprocessed_essays_train=preprocess_textual(X_train['essay'].values)
```

```
100%|██████████████████████████████████████████████████████████████████████████
| 49041/49041 [00:25<00:00, 1932.75it/s]
```

In [234]:

```
preprocessed_essays_test=preprocess_textual(X_test['essay'].values)
```

```
100%|██████████████████████████████████████████████████████████████████████████
| 36052/36052 [00:20<00:00, 1791.95it/s]
```

In [235]:

```
preprocessed_essays_test
```

```
oked would not know pride students show take immaculate care instruments equi
pment represent school pride everything funded materials requested placed ban
d hall new school year main component binders page protectors binder home bas
e beginner band help teach organizational skills not help band program studie
s show skills transfer areas education lives binder store notes practice logs
handouts importantly music dividers allow students insert music make marks th
roughout removed no longer need dividers assist moving quickly throughout bin
ders rehearsal starting beginning band sort organization recipe success penci
ls markers erasers paper help keep supplies students hands student purchase m
any supplies classrooms difficult every student bring supplies music classroo
m helpful materials specifically music create learn ease nannan',
 'title one school 70 students free reduced priced lunch number may people th
ink hear school not hear students working together everyday solve problems wi
thin classroom despite students adversities eager come school learn day stude
nts hardest working students able work happiest students despite everything g
o daily basis even make school students coming traumatic backgrounds school s
afe place students come educators students families want able give best mater
ials help foster learning goal give students materials need successful studen
ts love active learn always wanting move lessons want students understand imp
ortant fit healthy attentive learners asked students needed classroom next ye
```

1.8.3 Preprocessed cross validation data

In [236]:

```
preprocessed_essays_cv=preprocess_textual(X_cv['essay'].values)
```

```
100%|████████████████████████████████████████████████████████████████████████
| 24155/24155 [00:14<00:00, 1699.17it/s]
```

1.9 preprocessing of project title

In [237]:

```
# printing some randomproject titles.
print(project_data['project_title'].values[1])
print("="*50)
print(project_data['project_title'].values[1501])
print("="*50)
print(project_data['project_title'].values[10001])
print("="*50)
print(project_data['project_title'].values[20001])
print("="*50)
```

```
Wanted: Projector for Hungry Learners
==================================================
Making Every Day at School Count
==================================================
Becoming 'Readerly' Readers
==================================================
The Beautiful Life of a Butterfly
==================================================
```

In [238]:
```
title = decontracted(X_train['project_title'].values[2000])
```

1.9.1 Preprocessing of Project Title(Train)

In [239]:
```
preprocessed_titles_train=preprocess_textual(X_train["project_title"].values)
```

```
100%|██████████████████████████████████████████████████████████████|
49041/49041 [00:01<00:00, 44925.38it/s]
```

1.9.2 Preprocessing of Project Title(Test)

In [240]:
```
preprocessed_titles_test=preprocess_textual(X_test["project_title"])
```

```
100%|██████████████████████████████████████████████████████████████|
36052/36052 [00:00<00:00, 43200.58it/s]
```

In [241]:
```
preprocessed_titles_test[10]
```

Out[241]:
```
'chromebooks empower students 21st century learning'
```

1.9.2 Preprocessing of Project Title(CV)

In [242]:
```
preprocessed_titles_cv=preprocess_textual(X_cv["project_title"])
```

```
100%|██████████████████████████████████████████████████████████████|
24155/24155 [00:00<00:00, 46958.40it/s]
```

In [243]:
```
preprocessed_titles_cv[10]
```

Out[243]:
```
'newbery books 5th grade'
```

1.5 Preparing data for models

In [244]:
```
project_data.columns
```

Out[244]:
```
Index(['Unnamed: 0', 'id', 'teacher_id', 'teacher_prefix', 'school_state',
       'project_submitted_datetime', 'project_grade_category', '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',
       'clean_categories', 'clean_subcategories', 'title_word_count', 'essay',
       'essay_word_count'],
      dtype='object')
```

we are going to consider

```
- school_state : categorical data
- clean_categories : categorical data
- clean_subcategories : categorical data
- project_grade_category : categorical data
- teacher_prefix : categorical data

- project_title : text data
- text : text data
- project_resource_summary: text data (optinal)

- quantity : numerical (optinal)
- teacher_number_of_previously_posted_projects : numerical
- price : numerical
```

In [245]:
```
project_data.head(10)
```

Out[245]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_su
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs	IN	20
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr	FL	20
2	21895	p182444	3465aaf82da834c0582ebd0ef8040ca0	Ms	AZ	20
3	45	p246581	f3cb9bffbba169bef1a77b243e620b60	Mrs	KY	20
4	172407	p104768	be1f7507a41f8479dc06f047086a39ec	Mrs	TX	20
5	141660	p154343	a50a390e8327a95b77b9e495b58b9a6e	Mrs	FL	20
6	21147	p099819	9b40170bfa65e399981717ee8731efc3	Mrs	CT	20
7	94142	p092424	5bfd3d12fae3d2fe88684bbac570c9d2	Ms	GA	20
8	112489	p045029	487448f5226005d08d36bdd75f095b31	Mrs	SC	20

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	project_su
9	158561	p001713	140eeac1885c820ad5592a409a3a8994	Ms	NC	2(

1.5.1 Vectorizing Categorical data

In [246]:

```
print(project_data.shape)
```

```
(109248, 20)
```

one hot vector for clean categories of Projects (train,test,cv)

In [247]:

```
# we use count vectorizer to convert the values into one hot vectors

from sklearn.feature_extraction.text import CountVectorizer

vectorizer_proj = CountVectorizer(min_df=10,ngram_range=(1,1), max_features=5000)
vectorizer_proj.fit(X_train['clean_categories'].values)

categories_one_hot_train = vectorizer_proj.transform(X_train['clean_categories'].
categories_one_hot_test = vectorizer_proj.transform(X_test['clean_categories'].va
categories_one_hot_cv = vectorizer_proj.transform(X_cv['clean_categories'].values

print(vectorizer_proj.get_feature_names())

print("Shape of matrix of Train data after one hot encoding ",categories_one_hot_
print("Shape of matrix of Test data after one hot encoding ",categories_one_hot_t
print("Shape of matrix of CV data after one hot encoding ",categories_one_hot_cv.
```

```
['appliedlearning', 'care_hunger', 'health_sports', 'history_civics', 'literacy
_language', 'math_science', 'music_arts', 'specialneeds', 'warmth']
Shape of matrix of Train data after one hot encoding  (49041, 9)
Shape of matrix of Test data after one hot encoding  (36052, 9)
Shape of matrix of CV data after one hot encoding  (24155, 9)
```

one hot vector for clean subcategories (train ,test,cv)

In [248]:

```
# we use count vectorizer to convert the values into one

vectorizer_sub_proj = CountVectorizer(min_df=10,ngram_range=(1,1), max_features=5
vectorizer_sub_proj.fit(X_train['clean_subcategories'].values)

sub_categories_one_hot_train = vectorizer_sub_proj.transform(X_train['clean_subca
sub_categories_one_hot_test = vectorizer_sub_proj.transform(X_test['clean_subcate
sub_categories_one_hot_cv = vectorizer_sub_proj.transform(X_cv['clean_subcategori


print(vectorizer_sub_proj.get_feature_names())

print("Shape of matrix of Train data after one hot encoding ",sub_categories_one_
print("Shape of matrix of Test data after one hot encoding ",sub_categories_one_h
print("Shape of matrix of Cross Validation data after one hot encoding ",sub_cate
```

```
['appliedsciences', 'care_hunger', 'charactereducation', 'civics_government',
'college_careerprep', 'communityservice', 'earlydevelopment', 'economics', 'env
ironmentalscience', 'esl', 'extracurricular', 'financialliteracy', 'foreignlang
uages', 'gym_fitness', 'health_lifescience', 'health_wellness', 'history_geogra
phy', 'literacy', 'literature_writing', 'mathematics', 'music', 'nutritioneduca
tion', 'other', 'parentinvolvement', 'performingarts', 'socialsciences', 'speci
alneeds', 'teamsports', 'visualarts', 'warmth']
Shape of matrix of Train data after one hot encoding  (49041, 30)
Shape of matrix of Test data after one hot encoding  (36052, 30)
Shape of matrix of Cross Validation data after one hot encoding  (24155, 30)
```

In [249]:

```
sub_categories_one_hot_cv[0].toarray()
```

Out[249]:

```
array([[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0]], dtype=int64)
```

One hot vector for school states(train,test,cv)

In [250]:

```
my_counter = Counter()
for state in project_data['school_state'].values:
    my_counter.update(state.split())
```

In [251]:

```
school_state_cat_dict = dict(my_counter)
sorted_school_state_cat_dict = dict(sorted(school_state_cat_dict.items(), key=lam
```

In [252]:

```
## Using count vectorizer to convert the values into one hot encoded features

vectorizer_states = CountVectorizer(min_df=10,ngram_range=(1,1), max_features=500
vectorizer_states.fit(X_train['school_state'].values)

school_state_categories_one_hot_train = vectorizer_states.transform(X_train['scho
school_state_categories_one_hot_test = vectorizer_states.transform(X_test['school_
school_state_categories_one_hot_cv = vectorizer_states.transform(X_cv['school_sta

print(vectorizer_states.get_feature_names())

print("Shape of matrix of Train data after one hot encoding ",school_state_catego
print("Shape of matrix of Test data after one hot encoding ",school_state_categor
print("Shape of matrix of Cross Validation data after one hot encoding ",school_s
```

```
['ak', 'al', 'ar', 'az', 'ca', 'co', 'ct', 'dc', 'de', 'fl', 'ga', 'hi', 'ia',
'id', 'il', 'in', 'ks', 'ky', 'la', 'ma', 'md', 'me', 'mi', 'mn', 'mo', 'ms',
'mt', 'nc', 'nd', 'ne', 'nh', 'nj', 'nm', 'nv', 'ny', 'oh', 'ok', 'or', 'pa',
'ri', 'sc', 'sd', 'tn', 'tx', 'ut', 'va', 'vt', 'wa', 'wi', 'wv', 'wy']
Shape of matrix of Train data after one hot encoding  (49041, 51)
Shape of matrix of Test data after one hot encoding  (36052, 51)
Shape of matrix of Cross Validation data after one hot encoding  (24155, 51)
```

one hot vector for Project grade category (train,test,cv)

In [253]:

```
my_counter = Counter()
for project_grade in preprocessed_project_grade_categories:
    my_counter.update(project_grade.split())
```

In [254]:

```
project_grade_cat_dict = dict(my_counter)
sorted_project_grade_cat_dict = dict(sorted(project_grade_cat_dict.items(), key=l
```

In [255]:

```
## we use count vectorizer to convert the values into one hot encoded features
vectorizer_grade = CountVectorizer(min_df=10,ngram_range=(1,1), max_features=5000
vectorizer_grade.fit(X_train['project_grade_category'].values)

project_grade_categories_one_hot_train = vectorizer_grade.transform(X_train['proj
project_grade_categories_one_hot_test = vectorizer_grade.transform(X_test['projec
project_grade_categories_one_hot_cv = vectorizer_grade.transform(X_cv['project_gr

print(vectorizer_grade.get_feature_names())

print("Shape of matrix of Train data after one hot encoding ",project_grade_categ
print("Shape of matrix of Test data after one hot encoding ",project_grade_catego
print("Shape of matrix of Cross Validation data after one hot encoding ",project_
```

```
['12', 'grades', 'prek']
Shape of matrix of Train data after one hot encoding  (49041, 3)
Shape of matrix of Test data after one hot encoding  (36052, 3)
Shape of matrix of Cross Validation data after one hot encoding  (24155, 3)
```

One hot vector for teacher prefix(train,test,cv)

In [256]:

```
vectorizer_teacher = CountVectorizer()
vectorizer_teacher.fit(X_train['teacher_prefix'].values) # fit has to happen only

# we use the fitted CountVectorizer to convert the text to vector
teacher_prefix_categories_one_hot_train = vectorizer_teacher.transform(X_train['t
teacher_prefix_categories_one_hot_cv = vectorizer_teacher.transform(X_cv['teacher
teacher_prefix_categories_one_hot_test = vectorizer_teacher.transform(X_test['tea

print("After vectorizations")
print("Shape of matrix of Train data after one hot encoding",teacher_prefix_categ
print("Shape of matrix of cv data after one hot encoding",teacher_prefix_categori
print("Shape of matrix of Test data after one hot encoding",teacher_prefix_catego
print(vectorizer_teacher.get_feature_names())
print("="*100)
```

```
After vectorizations
Shape of matrix of Train data after one hot encoding (49041, 5) (49041,)
Shape of matrix of cv data after one hot encoding (24155, 5) (24155,)
Shape of matrix of Test data after one hot encoding (36052, 5) (36052,)
['dr', 'mr', 'mrs', 'ms', 'teacher']
===============================================================================
=====================
```

1.11 Vectorizing text data

A) Bag of words

BOW train data essays

In [257]:

```
# We are considering only the words which appeared in at least 10 documents(rows
vectorizer_bow_essay = CountVectorizer(min_df=10,max_features=5000)  #selecting t
vectorizer_bow_essay.fit(preprocessed_essays_train)

text_bow_train = vectorizer_bow_essay.transform(preprocessed_essays_train)

print("Shape of matrix after one hot encoding ",text_bow_train.shape)
```

```
Shape of matrix after one hot encoding  (49041, 5000)
```

BOW (test essays)

In [258]:

```
text_bow_test = vectorizer_bow_essay.transform(preprocessed_essays_test)
print("Shape of matrix after one hot encoding ",text_bow_test.shape)
```

```
Shape of matrix after one hot encoding  (36052, 5000)
```

Bow (cv essays)

In [259]:

```
text_bow_cv = vectorizer_bow_essay.transform(preprocessed_essays_cv)
print("Shape of matrix after one hot encoding ",text_bow_cv.shape)
```

```
Shape of matrix after one hot encoding  (24155, 5000)
```

Bow(train titles)

In [260]:

```
vectorizer_bow_title = CountVectorizer(min_df=10)
vectorizer_bow_title.fit(preprocessed_titles_train)
title_bow_train = vectorizer_bow_title.transform(preprocessed_titles_train)
print("Shape of matrix after one hot encoding ",title_bow_train.shape)
```

```
Shape of matrix after one hot encoding  (49041, 1990)
```

Bow(test titles)

In [261]:

```
title_bow_test = vectorizer_bow_title.transform(preprocessed_titles_test)
print("Shape of matrix after one hot encoding ",title_bow_test.shape)
```

```
Shape of matrix after one hot encoding  (36052, 1990)
```

Bow(cv titles)

In [262]:

```
title_bow_cv = vectorizer_bow_title.transform(preprocessed_titles_cv)
print("Shape of matrix after one hot encoding ",title_bow_cv.shape)
```

```
Shape of matrix after one hot encoding  (24155, 1990)
```

B) Tfidf

tfidf(train essays)

```
In [263]: from sklearn.feature_extraction.text import TfidfVectorizer

          vectorizer_tfidf_essay = TfidfVectorizer(min_df=10,max_features=5000) #Considerin
          vectorizer_tfidf_essay.fit(preprocessed_essays_train)

          text_tfidf_train = vectorizer_tfidf_essay.transform(preprocessed_essays_train)
          print("Shape of matrix after one hot encoding ",text_tfidf_train.shape)
```

```
Shape of matrix after one hot encoding  (49041, 5000)
```

tfidf(test essays)

```
In [264]: text_tfidf_test = vectorizer_tfidf_essay.transform(preprocessed_essays_test)
          print("Shape of matrix after one hot encoding ",text_tfidf_test.shape)
```

```
Shape of matrix after one hot encoding  (36052, 5000)
```

tfidf(cv essays)

```
In [265]: text_tfidf_cv = vectorizer_tfidf_essay.transform(preprocessed_essays_cv)
          print("Shape of matrix after one hot encoding ",text_tfidf_cv.shape)
```

```
Shape of matrix after one hot encoding  (24155, 5000)
```

tfidf(train titles)

```
In [266]: vectorizer_tfidf_titles = TfidfVectorizer(min_df=10)

          vectorizer_tfidf_titles.fit(preprocessed_titles_train)
          title_tfidf_train = vectorizer_tfidf_titles.transform(preprocessed_titles_train)
          print("Shape of matrix after one hot encoding ",title_tfidf_train.shape)
```

```
Shape of matrix after one hot encoding  (49041, 1990)
```

tfidf(test titles)

```
In [267]: title_tfidf_test = vectorizer_tfidf_titles.transform(preprocessed_titles_test)
          print("Shape of matrix after one hot encoding ",title_tfidf_test.shape)
```

```
Shape of matrix after one hot encoding  (36052, 1990)
```

tfidf(cv titles)

```
In [268]: title_tfidf_cv = vectorizer_tfidf_titles.transform(preprocessed_titles_cv)
          print("Shape of matrix after one hot encoding ",title_tfidf_cv.shape)
```

```
Shape of matrix after one hot encoding  (24155, 1990)
```

1.5.2.3 Using Pretrained Models: Avg W2V

```
In [269]: 
          # stronging variables into pickle files python: http://www.jessicayung.com/how-to
          # make sure you have the glove_vectors file
          with open('glove_vectors', 'rb') as f:
              model = pickle.load(f)
              glove_words =  set(model.keys())
```

train essays

```
In [270]: def avg_word_vec(preprocessed_data):
              avg_w2v_vectors = [];
              for sentence in tqdm(preprocessed_data): # 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 [271]: avg_w2v_vectors_train =avg_word_vec(preprocessed_essays_train)
          print(len(avg_w2v_vectors_train))
          print(len(avg_w2v_vectors_train[0]))
```

```
100%|█████████████████████████████████████████████████████████████████████████
| 49041/49041 [00:11<00:00, 4251.97it/s]

49041
300
```

test essays

In [272]:
```
avg_w2v_vectors_test =avg_word_vec(preprocessed_essays_test)
print(len(avg_w2v_vectors_test))
print(len(avg_w2v_vectors_test[0]))
```

```
100%|████████████████████████████████████████████████████████████████████
| 36052/36052 [00:08<00:00, 4220.36it/s]

36052
300
```

cv essays

In [273]:
```
avg_w2v_vectors_cv =avg_word_vec(preprocessed_essays_cv)
print(len(avg_w2v_vectors_cv))
print(len(avg_w2v_vectors_cv[0]))
```

```
100%|████████████████████████████████████████████████████████████████████
| 24155/24155 [00:06<00:00, 3758.37it/s]

24155
300
```

train titles

In [274]:
```
avg_w2v_vectors_titles_train =avg_word_vec(preprocessed_titles_train)
print(len(avg_w2v_vectors_titles_train))
print(len(avg_w2v_vectors_titles_train[0]))
```

```
100%|███████████████████████████████████████████████████████████████████|
49041/49041 [00:00<00:00, 79370.90it/s]

49041
300
```

test titles

In [275]:
```
avg_w2v_vectors_titles_test =avg_word_vec(preprocessed_titles_test)
print(len(avg_w2v_vectors_titles_test))
print(len(avg_w2v_vectors_titles_test[0]))
```

```
100%|██████████████████████████████████████████████████|
36052/36052 [00:00<00:00, 46763.63it/s]

36052
300
```

Cv titles

In [276]:
```
avg_w2v_vectors_titles_cv =avg_word_vec(preprocessed_titles_cv)
print(len(avg_w2v_vectors_titles_cv))
print(len(avg_w2v_vectors_titles_cv[0]))
```

```
100%|██████████████████████████████████████████████████|
24155/24155 [00:00<00:00, 98446.65it/s]

24155
300
```

using pretrained models : Tfidf weighted W2V

train essays

In [277]:
```
# S = ["abc def pqr", "def def def abc", "pqr pqr def"]
tfidf_model = TfidfVectorizer()
tfidf_model.fit(preprocessed_essays_train)
# 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())
```

In [278]:
```
def tfidfWV(preprocessed_data):
    # average Word2Vec
    # compute average word2vec for each review.
    tfidf_w2v_vectors = []; # the avg-w2v for each sentence/review is stored in t
    for sentence in tqdm(preprocessed_data): # 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/revi
        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
                tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.spli
                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)
    print("The length of TFIDF word to vec is ", len(tfidf_w2v_vectors))
    print("The length of TFIDF word to vec of index 0 is ",len(tfidf_w2v_vectors[
    return tfidf_w2v_vectors
```

In [279]:
```
tfidf_w2v_vectors_train=tfidfWV(preprocessed_essays_train)
```

```
100%|██████████████████████████████████████████████████
█| 49041/49041 [01:24<00:00, 577.39it/s]

The length of TFIDF word to vec is  49041
The length of TFIDF word to vec of index 0 is  300
```

Test essays

In [280]:
```
tfidf_w2v_vectors_test=tfidfWV(preprocessed_essays_test)
```

```
100%|██████████████████████████████████████████████████
█| 36052/36052 [01:00<00:00, 599.19it/s]

The length of TFIDF word to vec is  36052
The length of TFIDF word to vec of index 0 is  300
```

cv essays

In [281]:
```
tfidf_w2v_vectors_cv = tfidfWV(preprocessed_essays_cv)
```

```
100%|██████████████████████████████████████████████████
█| 24155/24155 [00:40<00:00, 600.07it/s]

The length of TFIDF word to vec is  24155
The length of TFIDF word to vec of index 0 is  300
```

train titles

In [282]:

```

tfidf_model = TfidfVectorizer()
tfidf_model.fit(preprocessed_titles_train)
# 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())
```

In [283]:

```
tfidf_w2v_vectors_titles_train = tfidfWV(preprocessed_titles_train)
```

```
100%|████████████████████████████████████████████████████|
49041/49041 [00:01<00:00, 41268.04it/s]

The length of TFIDF word to vec is  49041
The length of TFIDF word to vec of index 0 is  300
```

test titles

In [284]:

```
tfidf_w2v_vectors_titles_test = tfidfWV(preprocessed_titles_test)
```

```
100%|████████████████████████████████████████████████████|
36052/36052 [00:01<00:00, 30763.99it/s]

The length of TFIDF word to vec is  36052
The length of TFIDF word to vec of index 0 is  300
```

cv titles

In [285]:

```
tfidf_w2v_vectors_titles_cv = tfidfWV(preprocessed_titles_cv)
```

```
100%|████████████████████████████████████████████████████|
24155/24155 [00:00<00:00, 41902.45it/s]

The length of TFIDF word to vec is  24155
The length of TFIDF word to vec of index 0 is  300
```

1.12 Vectorizing Numerical features

Various numerical feautures are :

1.Price

2.Quantity

3.Number of Projects previously proposed by Teacher

4.Title word Count (introduced by us)

5.Essay word Count (introduced by us)

1) Price

In [286]:

```
# https://stackoverflow.com/questions/22407798/how-to-reset-a-dataframes-indexes-
price_data = resource_data.groupby('id').agg({'price':'sum', 'quantity':'sum'}).r
price_data.head(4)
```

Out[286]:

	id	price	quantity
0	p000001	459.56	7
1	p000002	515.89	21
2	p000003	298.97	4
3	p000004	1113.69	98

In [287]:

```
# join two dataframes in python:
X_train = pd.merge(X_train, price_data, on='id', how='left')
X_test = pd.merge(X_test, price_data, on='id', how='left')
X_cv = pd.merge(X_cv, price_data, on='id', how='left')
```

In [288]:

```
X_train
```

49037	103804	p217443	a4adec7a1d197fcb38cd8d04c55736a9	Mrs	CA
49038	83859	p233438	cb0ff2b4f2830f05248d423aad50ffe3	Ms	ID
49039	8111	p202273	7ac85d702a9582190b2c068c33f5a65f	Ms	MI
49040	32480	p258261	95892c1b13f2aafce2643caf0d1f5f77	Ms	GA

49041 rows × 21 columns

In [289]:

```
from sklearn.preprocessing import Normalizer

normalizer = Normalizer()

# normalizer.fit(X_train['price'].values)
# this will rise an error Expected 2D array, got 1D array instead:
# array=[105.22 215.96  96.01 ... 368.98  80.53 709.67].
# Reshape your data either using
# array.reshape(-1, 1) if your data has a single feature
# array.reshape(1, -1)  if it contains a single sample.

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

price_train = normalizer.transform(X_train['price'].values.reshape(1,-1))
price_cv = normalizer.transform(X_cv['price'].values.reshape(1,-1))
price_test = normalizer.transform(X_test['price'].values.reshape(1,-1))

print("After vectorizations")
print(price_train.shape, y_train.shape)
print(price_cv.shape, y_cv.shape)
print(price_test.shape, y_test.shape)
print("="*100)
```

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

2) Quantity

In [290]:

```
normalizer = Normalizer()

# normalizer.fit(X_train['price'].values)
# this will rise an error Expected 2D array, got 1D array instead:
# array=[105.22 215.96  96.01 ... 368.98  80.53 709.67].
# Reshape your data either using
# array.reshape(-1, 1) if your data has a single feature
# array.reshape(1, -1)  if it contains a single sample.

normalizer.fit(X_train['quantity'].values.reshape(1,-1))

quantity_train = normalizer.transform(X_train['quantity'].values.reshape(1,-1))
quantity_cv = normalizer.transform(X_cv['quantity'].values.reshape(1,-1))
quantity_test = normalizer.transform(X_test['quantity'].values.reshape(1,-1))

print("After vectorizations")
print(quantity_train.shape, y_train.shape)
print(quantity_cv.shape, y_cv.shape)
print(quantity_test.shape, y_test.shape)
print("="*100)
```

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

3) Number of Projects previously proposed by Teacher

In [291]:

```
normalizer = Normalizer()

# normalizer.fit(X_train['price'].values)
# this will rise an error Expected 2D array, got 1D array instead:
# array=[105.22 215.96  96.01 ... 368.98  80.53 709.67].
# Reshape your data either using
# array.reshape(-1, 1) if your data has a single feature
# array.reshape(1, -1)  if it contains a single sample.

normalizer.fit(X_train['teacher_number_of_previously_posted_projects'].values.res

prev_projects_train = normalizer.transform(X_train['teacher_number_of_previously_
prev_projects_cv = normalizer.transform(X_cv['teacher_number_of_previously_posted_
prev_projects_test = normalizer.transform(X_test['teacher_number_of_previously_po

print("After vectorizations")
print(prev_projects_train.shape, y_train.shape)
print(prev_projects_cv.shape, y_cv.shape)
print(prev_projects_test.shape, y_test.shape)
print("="*100)
```

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

4) title word count

In [292]:

```
normalizer = Normalizer()

normalizer.fit(X_train['title_word_count'].values.reshape(1,-1))

title_word_count_train = normalizer.transform(X_train['title_word_count'].values.
title_word_count_cv = normalizer.transform(X_cv['title_word_count'].values.reshap
title_word_count_test = normalizer.transform(X_test['title_word_count'].values.re

print("After vectorizations")
print(title_word_count_train.shape, y_train.shape)
print(title_word_count_cv.shape, y_cv.shape)
print(title_word_count_test.shape, y_test.shape)
print("="*100)
```

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

5) essay word count

In [293]:
```
normalizer = Normalizer()

normalizer.fit(X_train['essay_word_count'].values.reshape(1,-1))

essay_word_count_train = normalizer.transform(X_train['essay_word_count'].values.
essay_word_count_cv = normalizer.transform(X_cv['essay_word_count'].values.reshap
essay_word_count_test = normalizer.transform(X_test['essay_word_count'].values.re

print("After vectorizations")
print(essay_word_count_train.shape, y_train.shape)
print(essay_word_count_cv.shape, y_cv.shape)
print(essay_word_count_test.shape, y_test.shape)
```

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

Assignment 4

1. Apply Multinomial NaiveBayes on these feature sets
    - : categorical, numerical features + project_title(BOW) + preprocessed_eassay (BOW)
    - : categorical, numerical features + project_title(TFIDF)+ preprocessed_eassay (TFIDF)
2. The hyper paramter tuning(find best Alpha)
    - : Find the best hyper parameter which will give the maximum AUC value
    - : Consider a wide range of alpha values for hyperparameter tuning, start as low as 0.00001
    - : Find the best hyper paramter using k-fold cross validation or simple cross validation data
    - : Use gridsearch cv or randomsearch cv or you can also write your own for loops to do this task of hyperparameter tuning
3. Feature importance
    - : Find the top 10 features of positive class and top 10 features of negative class for both feature sets and using values of `feature_log_prob_` parameter of MultinomialNB and print their corresponding feature names
4. Representation of results
    - : You need to plot the performance of model both on train data and cross validation data for each hyper parameter, like shown in the figure. Here on X-axis you will have alpha values, since they have a wide range, just to represent those alpha values on the graph, apply log function on those alpha values.
    - : Once after you found the best hyper parameter, you need to train your model with it, and find the AUC on test data and plot the ROC curve on both train and test.
    - : Along with plotting ROC curve, you need to print the confusion matrix with predicted and original labels of test data points. Please visualize your confusion matrices using seaborn heatmaps.
5. Conclusion
    - : You need to summarize the results at the end of the notebook, summarize it in the table format. To print out a table please refer to this prettytable library link

2. Naive Bayes

Set 1: categorical, numerical features + project_title(BOW) + preprocessed_essay (BOW

In [294]:

```
# reshaping to appt shape so that it can be used with hstack
```

In [295]:

```
price_train = (X_train['price'].values.reshape(-1,1))
price_cv = (X_cv['price'].values.reshape(-1,1))
price_test = (X_test['price'].values.reshape(-1,1))

quantity_train =(X_train['quantity'].values.reshape(-1,1))
quantity_cv = (X_cv['quantity'].values.reshape(-1,1))
quantity_test = (X_test['quantity'].values.reshape(-1,1))

prev_projects_train = (X_train['teacher_number_of_previously_posted_projects'].va
prev_projects_cv = (X_cv['teacher_number_of_previously_posted_projects'].values.r
prev_projects_test = (X_test['teacher_number_of_previously_posted_projects'].valu

title_word_count_train = (X_train['title_word_count'].values.reshape(-1,1))
title_word_count_cv = (X_cv['title_word_count'].values.reshape(-1,1))
title_word_count_test = (X_test['title_word_count'].values.reshape(-1,1))


essay_word_count_train = (X_train['essay_word_count'].values.reshape(-1,1))
essay_word_count_cv = (X_cv['essay_word_count'].values.reshape(-1,1))
essay_word_count_test = (X_test['essay_word_count'].values.reshape(-1,1))
```

In [296]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039
from scipy.sparse import hstack

X_tr = hstack((categories_one_hot_train, sub_categories_one_hot_train, school_sta
X_te = hstack((categories_one_hot_test, sub_categories_one_hot_test, school_state
X_cr = hstack((categories_one_hot_cv, sub_categories_one_hot_cv, school_state_cat
```

In [297]:

```
print("Final Data matrix")
print(X_tr.shape, y_train.shape)
print(X_cr.shape, y_cv.shape)
print(X_te.shape, y_test.shape)
print("="*100)
```

```
Final Data matrix
(49041, 7093) (49041,)
(24155, 7093) (24155,)
(36052, 7093) (36052,)
===============================================================================
=====================
```

In [298]:
```
def batch_predict(clf, data):
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability esti
    # not the predicted outputs
    y_data_pred = []
    tr_loop = data.shape[0] - data.shape[0]%1000
    # consider you X_tr shape is 49041, then your cr_loop will be 49041 - 49041%1
    # in this for loop we will iterate unti the last 1000 multiplier
    for i in range(0, tr_loop, 1000):
        y_data_pred.extend(clf.predict_proba(data[i:i+1000])[:,1])
    # we will be predicting for the last data points
    y_data_pred.extend(clf.predict_proba(data[tr_loop:])[:,1])
    return y_data_pred
```

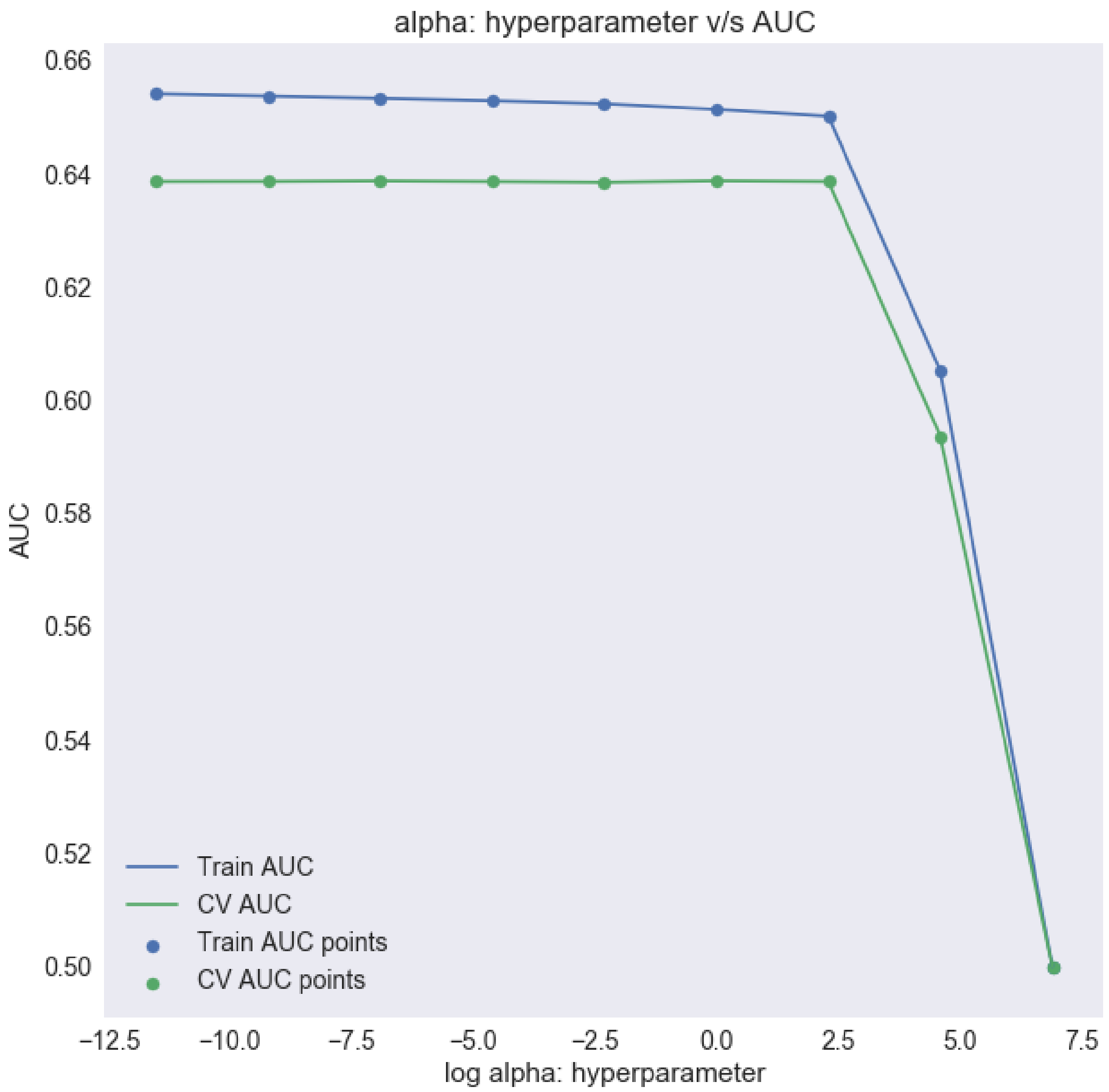
A) Random alpha values (hyperparameter)

In [299]:
```
import matplotlib.pyplot as plt
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import roc_auc_score
import math

train_auc = []
cv_auc = []
log_alphas = []

alphas = [0.00001, 0.0001, 0.001, 0.01, 0.1, 1, 10,  100,  1000]

for i in tqdm(alphas):
    nb = MultinomialNB(alpha = i,class_prior=[0.5,0.5])
    nb.fit(X_tr, y_train)
    y_train_pred = batch_predict(nb, X_tr)
    y_cv_pred = batch_predict(nb, X_cr)
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability esti
    # not the predicted outputs
    train_auc.append(roc_auc_score(y_train,y_train_pred))
    cv_auc.append(roc_auc_score(y_cv, y_cv_pred))

for a in tqdm(alphas):
    b = math.log(a)
    log_alphas.append(b)
```

```
100%|███████████████████████████████████████████████████████████████████████████
██████████| 9/9 [00:01<00:00,  5.68it/s]
100%|███████████████████████████████████████████████████████████████████████████
████████| 9/9 [00:00<00:00, 9022.16it/s]
```

In [300]:

```
plt.figure(figsize=(10,10))
plt.plot(log_alphas, train_auc, label='Train AUC')
plt.plot(log_alphas, cv_auc, label='CV AUC')

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

plt.legend()
plt.xlabel("log alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("alpha: hyperparameter v/s AUC")
plt.grid()
plt.show()
```



Summary

- As you can see in the plot, we've chosen hyperparameter alpha values as low as 0.0001 and as high as 1000. Since it's hard to plot the range provided, we've used log alphas on the x-axis and AUc on the y-axis.
- In addition to being able to display large ranges of values using log scales, log scales also prevent small values from being compressed into the graph's bottom.
- In both train and CV AUC lines, convergence can be observed at log alpha values closer to 7.
- We can see how both lines converge much more rapidly after alpha=10.

B) Gridsearch-cv using cv = 10 (K fold cross validation)

- return_train_score=True needs to be explicitly set for GridSearchCV function to return train scores
- Also verbose is set to 2 to display progress messages

In [301]:

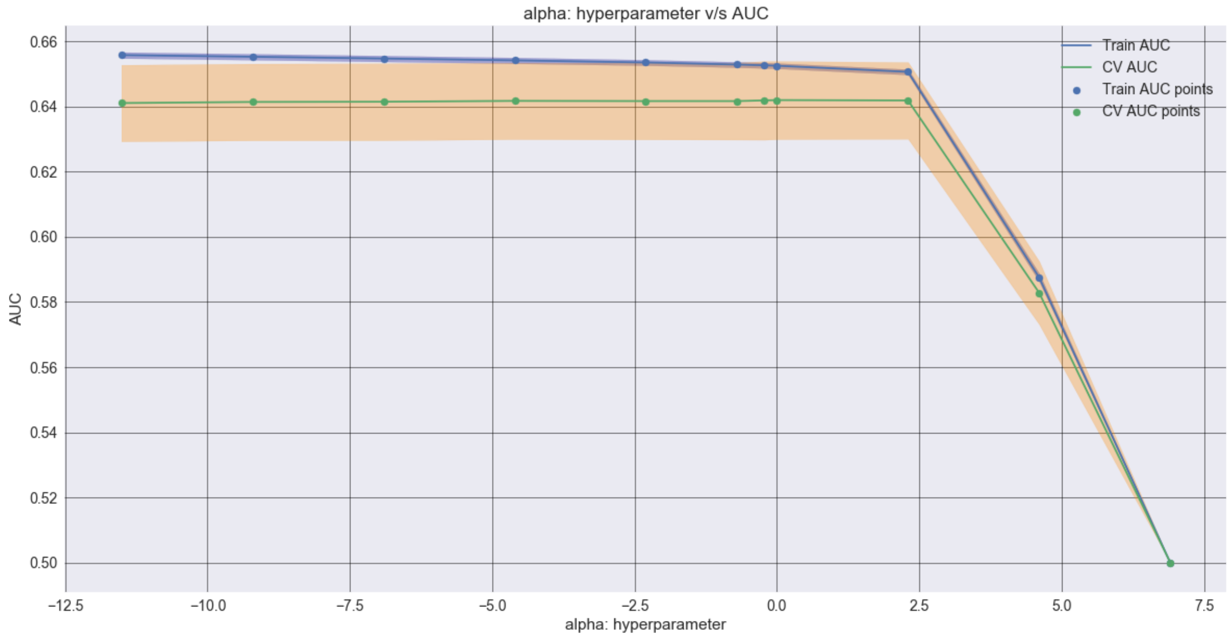
```
from sklearn.model_selection import GridSearchCV

nb = MultinomialNB(class_prior=[0.5,0.5])

parameters = {'alpha':[0.00001, 0.0001,0.001, 0.01, 0.1,0.5,0.8, 1, 10,  100,  10

clf = GridSearchCV(nb, parameters, cv= 10, scoring='roc_auc',return_train_score=T

clf.fit(X_tr, y_train)

train_auc= clf.cv_results_['mean_train_score']
train_auc_std= clf.cv_results_['std_train_score']
cv_auc = clf.cv_results_['mean_test_score']
cv_auc_std= clf.cv_results_['std_test_score']
```

```
Fitting 10 folds for each of 11 candidates, totalling 110 fits

[Parallel(n_jobs=-1)]: Done  25 tasks      | elapsed:    6.8s
[Parallel(n_jobs=-1)]: Done 110 out of 110 | elapsed:   15.5s finished
```

In [302]:

```
alphas = [0.00001, 0.0001, 0.001, 0.01, 0.1,0.5,0.8, 1, 10,  100,  1000]
log_alphas =[]

for a in tqdm(alphas):
    b = math.log(a)
    log_alphas.append(b)

plt.figure(figsize=(20,10))

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

plt.plot(log_alphas, cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(log_alphas,cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0

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


plt.legend()
plt.xlabel("alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("alpha: hyperparameter v/s AUC")
plt.grid(color='black', linestyle='-', linewidth=0.5)
plt.show()
```

```
100%|████████████████████████████████████████
████████| 11/11 [00:00<?, ?it/s]
```



Summary

- We have started with hyperparameter alpha with as low as 0.0001 to 1000.Since it is difficult to plot the given range we have used log alphas on x-axis and Auc on y axis as shown in the plot.
- One of the main reason for using log scale is log scales allow a large range to be displayed without small values being compressed down into bottom of the graph.
- we observe that as log alpha approaches close to 7 ,both train AUc and cv AUC lines converge
- Using this plot we see after alpha=100 both lines converge at amuch higher rate

Train model using the best hyper-parameter value

- Using best_params_ attribute of gridsearch cv we can obtain the optimal value of alpha among the values we have selected
- It simplifes our task and we can be rest assured that selected hyperparameter is most optimal one

In [303]:

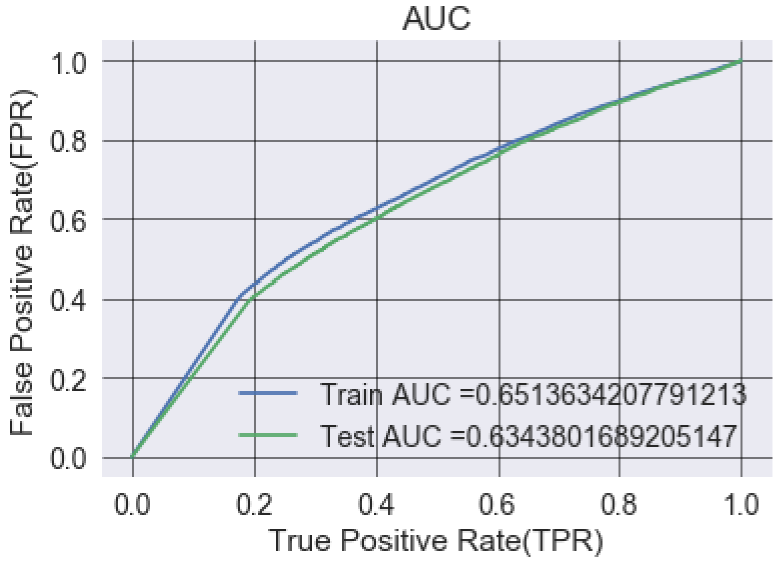
```
print(clf.best_params_)
```

```
{'alpha': 1}
```

In [304]:

```
best_alpha1=clf.best_params_
```

In [305]:
```
# https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.htm
from sklearn.metrics import roc_curve, auc

nb_bow = MultinomialNB(alpha = 1,class_prior=[0.5,0.5])

nb_bow.fit(X_tr, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimate.
# not the predicted outputs

y_train_pred = batch_predict(nb_bow, X_tr)
y_test_pred = batch_predict(nb_bow, X_te)

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

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("True Positive Rate(TPR)")
plt.ylabel("False Positive Rate(FPR)")
plt.title("AUC")
plt.grid(color='black', linestyle='-', linewidth=0.5)
plt.show()
```



summary

- For Bow model for alpha= 1 ,we get train AUC of 0.65 and Test AUC of 0.63

D) confusion matrix

In [306]:

```
def predict(proba, threshould, fpr, tpr):
    t = threshould[np.argmax(fpr*(1-tpr))]

    # (tpr*(1-fpr)) will be maximum if your fpr is ver+.+y low and tpr is very hi

    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for threshold",
    predictions = []
    for i in proba:
        if i>=t:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

train data

In [307]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
print("Train confusion matrix")
print(confusion_matrix(y_train, predict(y_train_pred, tr_thresholds, train_fpr, t
```

```
================================================================================
====================
Train confusion matrix
the maximum value of tpr*(1-fpr) 0.38243606289412657 for threshold 0.999
[[ 4137  3289]
 [14316 27299]]
```

In [308]:

```
conf_matr_df_train_1 = pd.DataFrame(data=confusion_matrix(y_train, predict(y_trai
```

```
the maximum value of tpr*(1-fpr) 0.38243606289412657 for threshold 0.999
```

In [309]:

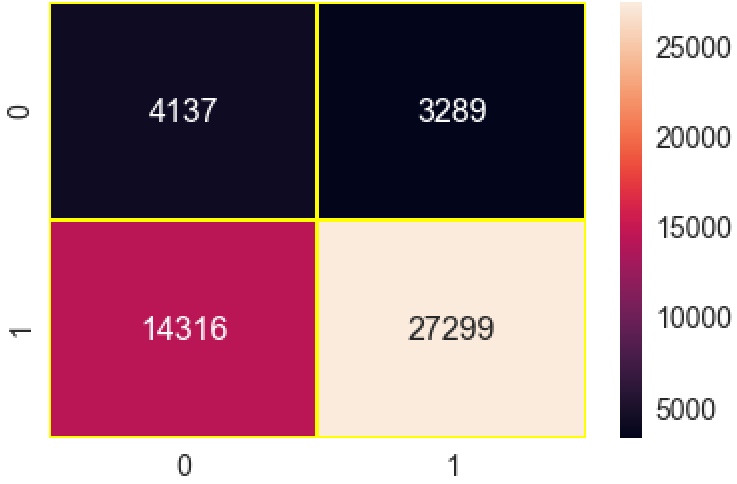
```
conf_matr_df_train_1
```

Out[309]:

	0	1
0	4137	3289
1	14316	27299

In [310]:
```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_train_1, annot=True,annot_kws={"size": 16}, fmt='.0f',li
#mention prediction and actual
```

Out[310]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1ba0e577f98>
```



Summary on train data

- In the following confusion matrix we observe that the model has 27268 true positives while true negatives are only 4174
- It has large number of false negatives which is 14347

test data

In [311]:
```
print("="*100)
print("Test confusion matrix")
print(confusion_matrix(y_test, predict(y_test_pred, tr_thresholds, test_fpr, test_
```

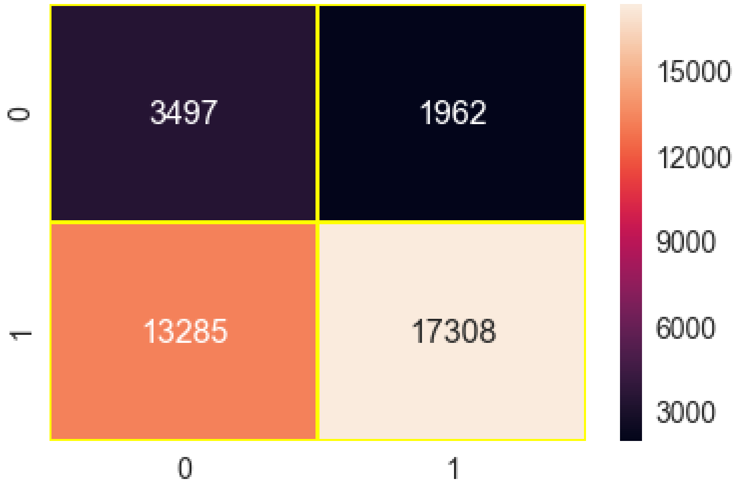
```
================================================================================
=====================
Test confusion matrix
the maximum value of tpr*(1-fpr) 0.3629947374659989 for threshold 1.0
[[ 3497  1962]
 [13285 17308]]
```

In [312]:
```
conf_matr_df_test_1 = pd.DataFrame(confusion_matrix(y_test, predict(y_test_pred, 
```

```
the maximum value of tpr*(1-fpr) 0.3629947374659989 for threshold 1.0
```

In [313]:
```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_test_1, annot=True,annot_kws={"size": 16}, fmt='g',linew
```

Out[313]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1b99495fd68>
```



Summary on test data

- The number of true positives dominate ,there are 19080 in number,
- The least number among 4 quantites is false positives which are 2321 false positives
- similar trend is observed for false negatives which are roughly 11513

Set 2 : categorical, numerical features + project_title(TFIDF) + preprocessed_essay (TFIDF)

In [314]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039
from scipy.sparse import hstack
X_tr = hstack((categories_one_hot_train, sub_categories_one_hot_train, school_sta
X_te = hstack((categories_one_hot_test, sub_categories_one_hot_test, school_state_
X_cr = hstack((categories_one_hot_cv, sub_categories_one_hot_cv, school_state_cat
```

In [315]:

```
print("Final Data matrix")
print(X_tr.shape, y_train.shape)
print(X_cr.shape, y_cv.shape)
print(X_te.shape, y_test.shape)
print("="*100)
```

```
Final Data matrix
(49041, 7093) (49041,)
(24155, 7093) (24155,)
(36052, 7093) (36052,)
================================================================================
====================
```

A) random alpha values

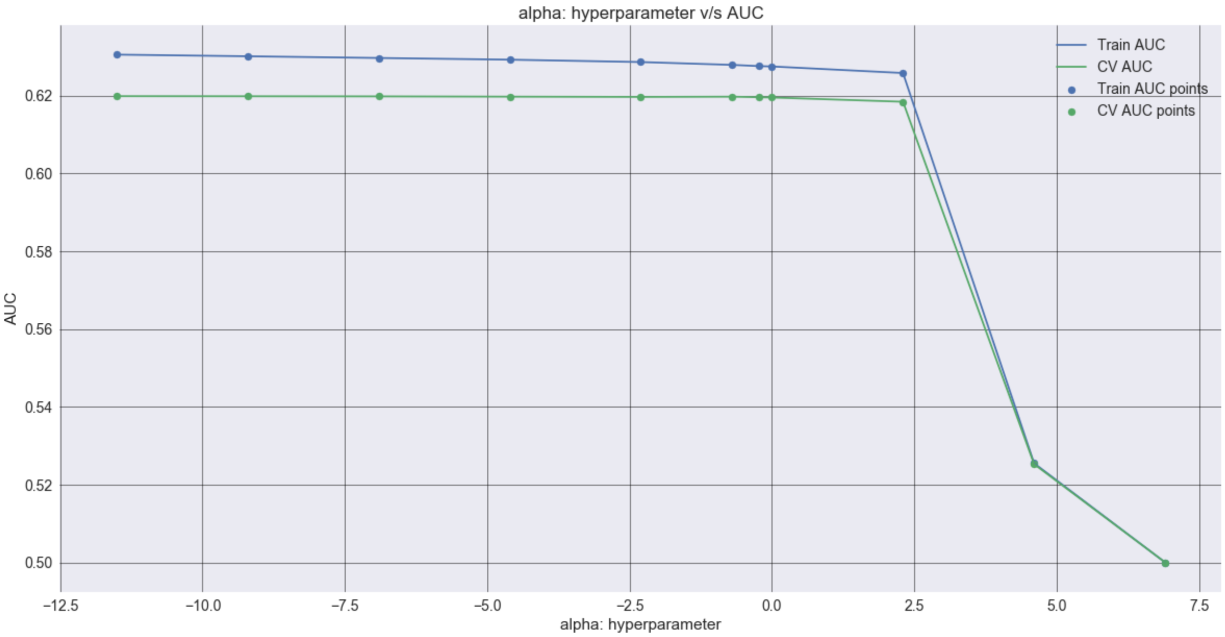
In [316]:

```
train_auc = []
cv_auc = []
log_alphas =[]

alphas = [0.00001, 0.0001, 0.001, 0.01, 0.1,0.5,0.8, 1, 10,  100,  1000]

for i in tqdm(alphas):
    nb = MultinomialNB(alpha = i,class_prior=[0.5,0.5])
    nb.fit(X_tr, y_train)
    y_train_pred = batch_predict(nb, X_tr)
    y_cv_pred = batch_predict(nb, X_cr)
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability esti
    # not the predicted outputs
    train_auc.append(roc_auc_score(y_train,y_train_pred))
    cv_auc.append(roc_auc_score(y_cv, y_cv_pred))
for a in tqdm(alphas):
    b = math.log(a)
    log_alphas.append(b)
```

```
100%|█████████████████████████████████████████████████████████████████████████
████████| 11/11 [00:01<00:00,  5.60it/s]
100%|█████████████████████████████████████████████████████████████████████████
█████| 11/11 [00:00<00:00, 11019.19it/s]
```

In [317]:

```
plt.figure(figsize=(20,10))

plt.plot(log_alphas, train_auc, label='Train AUC')
plt.plot(log_alphas, cv_auc, label='CV AUC')

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

plt.legend()
plt.xlabel("alpha: hyperparameter")
plt.ylabel("AUC")
plt.title("alpha: hyperparameter v/s AUC")
plt.grid(color='black', linestyle='-', linewidth=0.5)
plt.show()
```



Summary

- Starting with an alpha between 0.0001 and 1000, it has been difficult to plot the given range on an x-axis. As depicted in the plot, log alphas are plotted on the x-axis and auc is plotted on the y-axis.
- In addition to allowing a large range of values to be displayed, log scales allow smaller values to be compressed into the bottom of the graph.
- The log alpha converges in both the train and cv AUC lines as log alpha approaches near 7.
- In this plot we can see that alpha=100 accelerates convergence of both lines at a much higher rate.

- The Cv Auc line remains constant for a long time in comparison to set1, only dropping after alpha=10.

In [318]:
```
for it1,it2,it3 in zip(log_alphas, train_auc,cv_auc):
    print(2.71828**it1,it1,it2,it3)
```

```
1.0000077442305922e-05 -11.512925464970229 0.6305130724069298 0.619840639927975
4
0.0001000006195379677 -9.210340371976182 0.6300889526390047 0.6198141462169502
0.001000004646531159 -6.907755278982137 0.6296496306106348 0.6197826432468665
0.010000030976850406 -4.605170185988091 0.6292142660885494 0.6197096788196494
0.10000015488413208 -2.3025850929940455 0.6286031679012652 0.619643251108647
0.5000002331237219 -0.6931471805599453 0.6278726115939919 0.6197033355368737
0.8000001200785021 -0.2231435513142097 0.6275584040396465 0.619564997277391
1.0 0.0 0.6274713939116985 0.6195010308401471
9.999984511610785 2.302585092994046 0.6257835563122243 0.6184050503149723
99.99969023245559 4.605170185988092 0.5254896880103319 0.5252581182480224
999.9953534904313 6.907755278982137 0.5 0.5
```

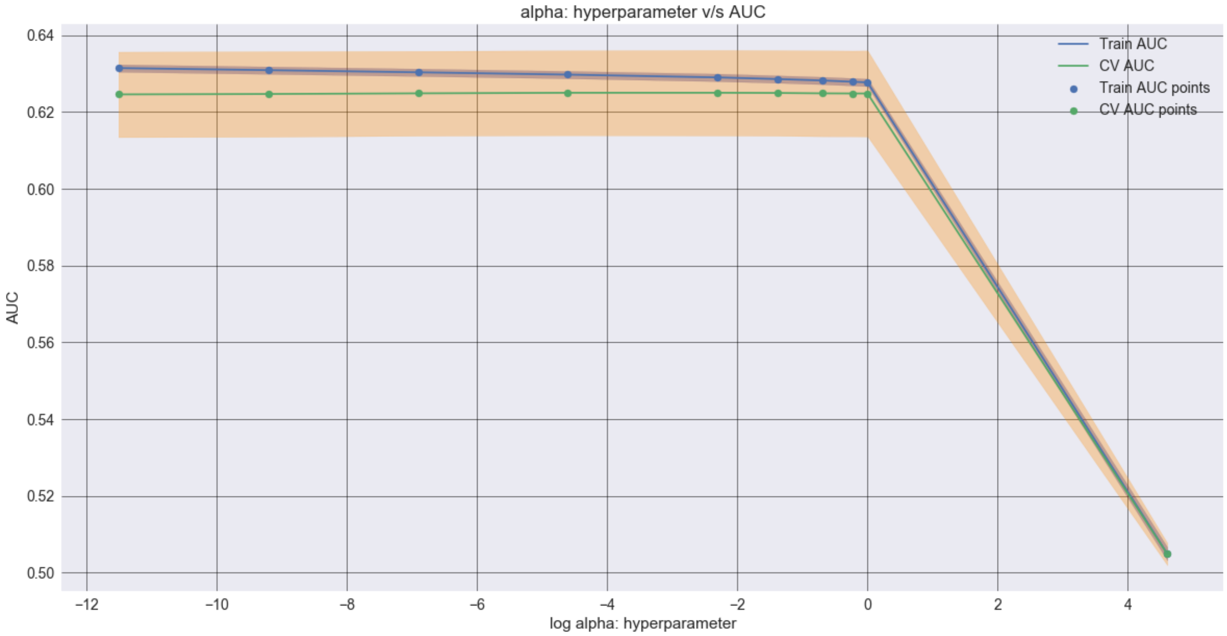
B) Gridsearch-cv using cv = 10 (K fold cross validation)

In [319]:
```
nb = MultinomialNB(class_prior=[0.5,0.5])

parameters = {'alpha':[0.00001, 0.0001, 0.001, 0.01, 0.1,0.25,0.5,0.8, 1,100]}

clf = GridSearchCV(nb, parameters, cv= 10, scoring='roc_auc',return_train_score=T

clf.fit(X_tr, y_train)

train_auc= clf.cv_results_['mean_train_score']
train_auc_std= clf.cv_results_['std_train_score']
cv_auc = clf.cv_results_['mean_test_score']
cv_auc_std= clf.cv_results_['std_test_score']
```

```
Fitting 10 folds for each of 10 candidates, totalling 100 fits

[Parallel(n_jobs=-1)]: Done  25 tasks      | elapsed:    6.3s
[Parallel(n_jobs=-1)]: Done 100 out of 100 | elapsed:   13.1s finished
```

```
In [320]: alphas = [0.00001, 0.0001, 0.001, 0.01, 0.1,0.25,0.5,0.8, 1,100]
          log_alphas =[]

          for a in tqdm(alphas):
              b = math.log(a)
              log_alphas.append(b)

          plt.figure(figsize=(20,10))

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

          plt.plot(log_alphas, cv_auc, label='CV AUC')
          # this code is copied from here: https://stackoverflow.com/a/48803361/4084039
          plt.gca().fill_between(log_alphas,cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0

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


          plt.legend()
          plt.xlabel("log alpha: hyperparameter")
          plt.ylabel("AUC")
          plt.title("alpha: hyperparameter v/s AUC")
          plt.grid(color='black', linestyle='-', linewidth=0.5)
          plt.show()
```

```
100%|████████████████████████████████████████████
███| 10/10 [00:00<00:00, 10022.23it/s]
```



In [321]:

```
print( 2.67**0.6282283144644325)
```

```
1.8533030942243873
```

Summary

In [322]:

```
for it1,it2,it3 in zip(log_alphas, train_auc,cv_auc):
    print(2.71828**it1,it1,it2)
```

```
1.0000077442305922e-05 -11.512925464970229 0.6314653388396043
0.0001000006195379677 -9.210340371976182 0.6309235800488118
0.001000004646531159 -6.907755278982137 0.6303640989349862
0.010000030976850406 -4.605170185988091 0.6297609865291701
0.10000015488413208 -2.3025850929940455 0.6290311619649992
0.25000023312377617 -1.3862943611198906 0.6286023244891439
0.5000002331237219 -0.6931471805599453 0.6282283144644325
0.8000001200785021 -0.2231435513142097 0.6278960124932909
1.0 0.0 0.6277296201884919
99.99969023245559 4.605170185988092 0.5049324818705895
```

- We have started with hyperparameter alpha with as low as 0.0001 to 1000.Since it is difficult to plot the given range we have used log alphas on x-axis and Auc on y axis as shown in the plot.
- One of the main reason for using log scale is log scales allow a large range to be displayed without small values being compressed down into bottom of the graph.
- we observe that as log alpha approaches close to 2 ,both train AUc and cv AUC lines converge
- Using this plot we see after alpha=100 both lines converge at a much higher rate
- One thing different from set1 plot is Cv Auc line remains constant for a long time ,only after log alpha=0.1 it starts dropping

C) Train model using the best hyper-parameter value of alpha

In [323]:

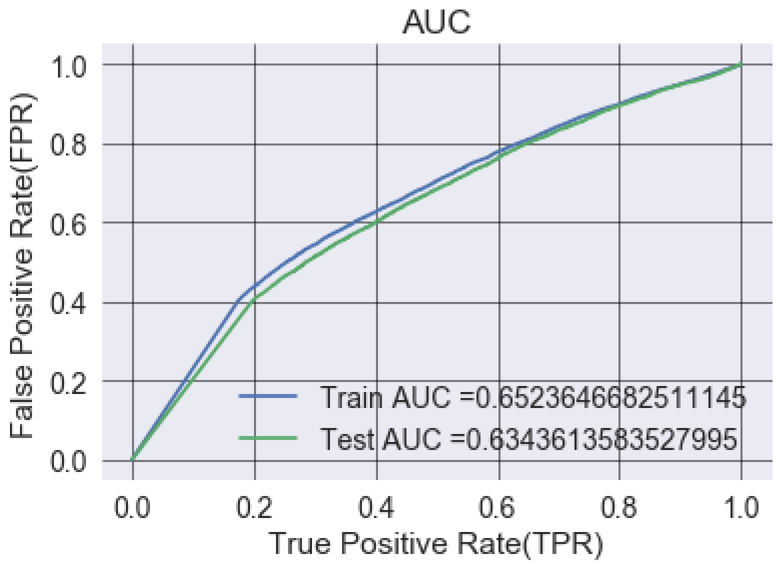
```
# Code idea for best_params_ taken from here https://datascience.stackexchange.co
```

In [324]:

```
best_alpha2=clf.best_params_
print(best_alpha2)
```

```
{'alpha': 0.1}
```

In [359]:
```
nb_tfidf = MultinomialNB(alpha = 0.1,class_prior=[0.5,0.5])

nb_tfidf.fit(X_tr, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimate
# not the predicted outputs

y_train_pred = batch_predict(nb_tfidf, X_tr)
y_test_pred = batch_predict(nb_tfidf, X_te)

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

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("True Positive Rate(TPR)")
plt.ylabel("False Positive Rate(FPR)")
plt.title("AUC")
plt.grid(color='black', linestyle='-', linewidth=0.5)
plt.show()
```



Summary

- From given plot we observe that we get train AUC of 0.652 and test AUC of 0.634

D) Confusion matrix

train data

In [360]:
```
print("="*100)
print("Train confusion matrix")
print(confusion_matrix(y_train, predict(y_train_pred, tr_thresholds, train_fpr, t
```

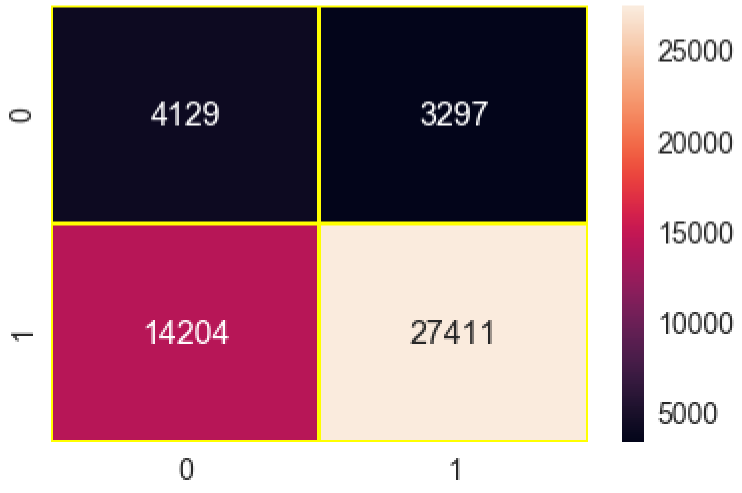
```
================================================================================
====================
Train confusion matrix
the maximum value of tpr*(1-fpr) 0.3830785282826924 for threshold 0.999
[[ 4129  3297]
 [14204 27411]]
```

In [361]:
```
conf_matr_df_train_2 = pd.DataFrame(confusion_matrix(y_train, predict(y_train_pre
```

```
the maximum value of tpr*(1-fpr) 0.3830785282826924 for threshold 0.999
```

In [362]:
```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_train_2, annot=True,annot_kws={"size": 16}, fmt='g',line
```

Out[362]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1b990ccbda0>
```



Summary

- For training data we get roughly 27411 true positives and 4129 true negatives and false positives each
- Again we have roughly 14204 false negatives which are alot in number

test data

In [363]:

```
print("="*100)
print("Test confusion matrix")
print(confusion_matrix(y_test, predict(y_test_pred, tr_thresholds, test_fpr, test_
```

```
===============================================================================
=====================
Test confusion matrix
the maximum value of tpr*(1-fpr) 0.363407001160974 for threshold 1.0
[[ 3480  1979]
 [13193 17400]]
```

In [364]:

```
conf_matr_df_test_2 = pd.DataFrame(confusion_matrix(y_test, predict(y_test_pred, 
```

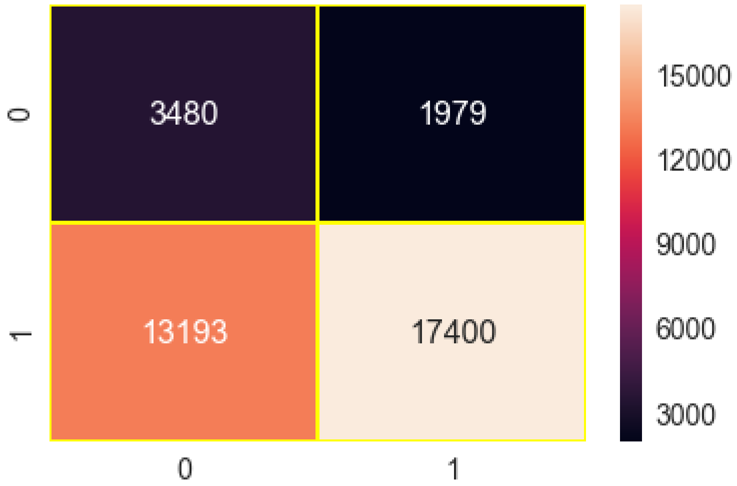
```
the maximum value of tpr*(1-fpr) 0.363407001160974 for threshold 1.0
```

In [365]:

```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_test_2, annot=True,annot_kws={"size": 16}, fmt='g',linew
```

Out[365]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1b990190780>
```



summary

- we have roughly 17400 true positives for test data and roughly 3480 true negatives
- Again false negatives are pretty high in number(13k)

Select best 30 features of both Positive and negative class for both the sets of data

set1 Bow

In [392]:

```
X_tr = hstack((categories_one_hot_train, sub_categories_one_hot_train, school_sta
X_te = hstack((categories_one_hot_test, sub_categories_one_hot_test, school_state_
X_cr = hstack((categories_one_hot_cv, sub_categories_one_hot_cv, school_state_cat
```

In [443]:

```
nb_bow = MultinomialNB(alpha = 1,class_prior=[0.5,0.5])

nb_bow.fit(X_tr, y_train)
```

Out[443]:

```
MultinomialNB(alpha=1, class_prior=[0.5, 0.5], fit_prior=True)
```

In [444]:

```
# Collecting feature names for BOW set1
# adding to end of list by concatening features
# Code snippet taken from here https://stackabuse.com/append-vs-extend-in-python-

bow_features_names1 = []
```

In [445]:

```
for cnt in vectorizer_proj.get_feature_names() :
    bow_features_names1.append(cnt)

for cnt1 in vectorizer_sub_proj.get_feature_names() :
    bow_features_names1.append(cnt1)

for cnt2 in vectorizer_states.get_feature_names() :
    bow_features_names1.append(cnt2)

for cnt3 in vectorizer_grade.get_feature_names() :
    bow_features_names1.append(cnt3)

for cnt4 in vectorizer_teacher.get_feature_names() :
    bow_features_names1.append(cnt4)
```

In [446]:

```
len(bow_features_names1)
```

Out[446]:

```
98
```

In [447]:

```

bow_features_names1.append("price")

bow_features_names1.append("quantity")


bow_features_names1.append("prev_proposed_projects")

bow_features_names1.append("title_word_count")

bow_features_names1.append("essay_word_count")

len(bow_features_names1)
```

Out[447]:

```
103
```

In [448]:

```
for cnt5 in vectorizer_bow_title.get_feature_names() :
    bow_features_names1.append(cnt5)
```

In [449]:

```
len(bow_features_names1)
```

Out[449]:

```
2093
```

In [450]:

```
for cnt6 in vectorizer_bow_essay.get_feature_names() :
    bow_features_names1.append(cnt6)
```

In [451]:

```
len(bow_features_names1)
```

Out[451]:

```
7093
```

Top 30 positive features BOW

NOTE

- Using argsort by default it sorts in ascending order,but we need sorted log probabilities in desc order.
- While sorting the log probabilities in ascending order we get least imp features because just for an example say f1 has prob -16 and f2 has prob -14 .The actual prob of f1 would be exp(-16) and actual prob of f2 would be exp(-14). Clearly f2 has higher prob so it is an imp feature

In [452]:

```
# To use argsort for descending order
# Code snippet taken from https://stackoverflow.com/questions/16486252/is-it-poss
```

In [453]:

```
pos_class_prob_sorted = nb_bow.feature_log_prob_[1, :].argsort()[::-1]
for i in pos_class_prob_sorted[:30]:
    print(bow_features_names1[i])
```

```
price
essay_word_count
quantity
prev_proposed_projects
students
title_word_count
school
learning
classroom
not
learn
help
grades
many
nannan
need
reading
work
use
love
able
day
come
class
would
technology
also
books
skills
year
```

30 negative features from BOW set1

In [454]:

```
# To use argsort for descending order
# Code snippet taken from https://stackoverflow.com/questions/16486252/is-it-poss
# using log_prob_ Code taken from https://scikit-learn.org/stable/modules/generat
```

In [455]:
```
neg_class_prob_sorted = nb_bow.feature_log_prob_[0,:].argsort()[::-1]
for i in neg_class_prob_sorted[0:30]:
    print(bow_features_names1[i])
```

```
price
essay_word_count
quantity
prev_proposed_projects
students
title_word_count
school
learning
classroom
not
learn
help
grades
nannan
many
need
work
come
love
reading
materials
able
skills
class
day
use
want
year
make
new
```

Summary

- Words like learn is present in negative class but not in positive class
- Few words are similar but their relative ordering is different between the two sets

tfidf top features

In [456]:
```
X_tr1 = hstack((categories_one_hot_train, sub_categories_one_hot_train, school_sta
X_te1 = hstack((categories_one_hot_test, sub_categories_one_hot_test, school_state
X_cr1 = hstack((categories_one_hot_cv, sub_categories_one_hot_cv, school_state_cat
```

In [432]:
```
X_tr1.shape
```

Out[432]:
```
(49041, 7093)
```

In [457]:
```
nb_tfidf = MultinomialNB(alpha = 0.1,class_prior=[0.5,0.5])

nb_tfidf.fit(X_tr, y_train)
```

Out[457]:
```
MultinomialNB(alpha=0.1, class_prior=[0.5, 0.5], fit_prior=True)
```

In [458]:
```
tfidf_features_names = []
```

In [459]:
```
for ct1 in vectorizer_proj.get_feature_names() :
    tfidf_features_names.append(ct1)

for ct2 in vectorizer_sub_proj.get_feature_names() :
    tfidf_features_names.append(ct2)

for ct3 in vectorizer_states.get_feature_names() :
    tfidf_features_names.append(ct3)


for ct4 in vectorizer_grade.get_feature_names() :
    tfidf_features_names.append(ct4)


for ct5 in vectorizer_teacher.get_feature_names() :
    tfidf_features_names.append(ct5)
```

In [460]:
```
len(tfidf_features_names)
```

Out[460]:
```
98
```

In [461]:
```
tfidf_features_names.append("price")

tfidf_features_names.append("quantity")

tfidf_features_names.append("prev_proposed_projects")

tfidf_features_names.append("title_word_count")

tfidf_features_names.append("essay_word_count")

for ct6 in vectorizer_tfidf_titles.get_feature_names() :
    tfidf_features_names.append(ct6)

for ct7 in vectorizer_tfidf_essay.get_feature_names() :
    tfidf_features_names.append(ct7)
```

In [462]:
```
len(tfidf_features_names)
```

Out[462]:
```
7093
```

positive features of tfidf

In [463]:

```
pos_class_prob_sorted_tfidf = nb_tfidf.feature_log_prob_[1, :].argsort()[::-1][:7
for i in pos_class_prob_sorted_tfidf[0:30]:
    print(tfidf_features_names[i])
```

```
price
essay_word_count
quantity
prev_proposed_projects
students
title_word_count
school
learning
classroom
not
learn
help
grades
many
nannan
need
reading
work
use
love
able
day
come
class
would
technology
also
books
skills
year
```

Negative features from Tfidf

In [464]:

```
neg_class_prob_sorted_tfidf = nb_tfidf.feature_log_prob_[0, :].argsort()[::-1][:7
for i in neg_class_prob_sorted_tfidf[0:30]:
    print(tfidf_features_names[i])
```

```
price
essay_word_count
quantity
prev_proposed_projects
students
title_word_count
school
learning
classroom
not
learn
help
grades
nannan
many
need
work
come
love
reading
materials
able
skills
class
day
use
want
year
make
new
```

summary

- Again important features appear similar at first glance but actually there are some differences compared to set1
- relative ordering is different between the two sets

conclusions

In [465]:

```
# Please compare all your models using Prettytable library
# http://zetcode.com/python/prettytable/

from prettytable import PrettyTable
x = PrettyTable()
x.field_names = ["Vectorizer", "Model", "Alpha:Hyper Parameter", " Test AUC"]

x.add_row(["BOW", "Naive Bayes", 1, 0.634380])
x.add_row(["TFIDF", "Naive Bayes", 0.1, 0.634361])

print(x)
```

```
+------------+-------------+-----------------------+-----------+
| Vectorizer |    Model    | Alpha:Hyper Parameter |  Test AUC |
+------------+-------------+-----------------------+-----------+
|    BOW     | Naive Bayes |           1           |  0.63438  |
|   TFIDF    | Naive Bayes |          0.1          |  0.634361 |
+------------+-------------+-----------------------+-----------+
```

- We conclude that Naive bayes gives better AUC than KNN
- also it is very fast as compared to KNN.
- naive Bayes is super interpretable because of probability values, we can get feature importance very easily as seen above
- There is strong possibility that Naive bayes can overfit if alpha has not been found properly