

# 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	Description
<code>project_id</code>	A unique identifier for the proposed project. <b>Example</b>
<code>project_title</code>	Title of the project. <b>Examples:</b> <ul style="list-style-type: none"> <li>• Art Will Make You Happy!</li> <li>• First Grade Fun</li> </ul>
<code>project_grade_category</code>	Grade level of students for which the project is targeted. Enumerated values: <ul style="list-style-type: none"> <li>• Grades PreK-2</li> <li>• Grades 3-5</li> <li>• Grades 6-8</li> <li>• Grades 9-12</li> </ul>
<code>project_subject_categories</code>	One or more (comma-separated) subject categories from the following enumerated list of values: <ul style="list-style-type: none"> <li>• Applied Learning</li> <li>• Care &amp; Hunger</li> <li>• Health &amp; Sports</li> <li>• History &amp; Civics</li> <li>• Literacy &amp; Language</li> <li>• Math &amp; Science</li> <li>• Music &amp; The Arts</li> <li>• Special Needs</li> <li>• Warmth</li> </ul> <b>Examples:</b> <ul style="list-style-type: none"> <li>• Music &amp; The Arts</li> <li>• Literacy &amp; Language, Math &amp; Science</li> </ul>
<code>school_state</code>	State where school is located ( <u>Two-letter U.S. postal code</u> ( <a href="https://en.wikipedia.org/wiki/List_of_U.S._state_abbreviations">https://en.wikipedia.org/wiki/List_of_U.S._state_abbreviations</a> )). <b>Example:</b> WY
<code>project_subject_subcategories</code>	One or more (comma-separated) subject subcategories. <b>Examples:</b> <ul style="list-style-type: none"> <li>• Literacy</li> <li>• Literature &amp; Writing, Social Sciences</li> </ul>
<code>project_resource_summary</code>	An explanation of the resources needed for the project. <ul style="list-style-type: none"> <li>• My students need hands on literacy materials to address sensory needs!</li> </ul>

Feature	Description
project_essay_1	First application essay*
project_essay_2	Second application essay*
project_essay_3	Third application essay*
project_essay_4	Fourth application essay*
project_submitted_datetime	Datetime when project application was submitted. <b>Example:</b> 12:43:56.245
teacher_id	A unique identifier for the teacher of the proposed project. <b>Example:</b> bdf8baa8fedef6bfeec7ae4ff1c15c56
teacher_prefix	Teacher's title. One of the following enumerated values: <ul style="list-style-type: none"> <li>• nan</li> <li>• Dr.</li> <li>• Mr.</li> <li>• Mrs.</li> <li>• Ms.</li> <li>• Teacher.</li> </ul>
teacher_number_of_previously_posted_projects	Number of project applications previously submitted by the teacher. <b>Example:</b> 2

\* 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 <code>train.csv</code> file. <b>Example:</b> p036502
description	Description of the resource. <b>Example:</b> Tenor Saxophone Reeds, Box of 25
quantity	Quantity of the resource required. <b>Example:</b> 3
price	Price of the resource required. <b>Example:</b> 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 [309]:

```
%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 plotly 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 [310]:

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

In [311]:

```
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 (109248, 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 [312]:

```
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[312]:

	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 [313]:

```
categories = list(project_data['project_subject_categories'].values)
# 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
cat_list = []
for i in categories:
    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 category based on space "Math & Science"=> "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 replacing all the ' ' (space) with '' (empty) ex: "Math & Science"=> "Math&Science"
            temp+=j.strip()+" " # " abc ".strip() will return "abc", remove the trailing spaces
        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 [314]:

```
sub_categories = list(project_data['project_subject_subcategories'].values)
# 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

sub_cat_list = []
for i in sub_categories:
    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 category based on space "Math & Science" => "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 replacing all the ' ' (space) with '' (empty) ex: "Math & Science" => "Math&Science"
            temp += j.strip() + " #" "abc ".strip() will return "abc", remove the trailing spaces
        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/22898595/4084039
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]))
```

## 1.3 Text preprocessing

In [315]:

```
# 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)
```

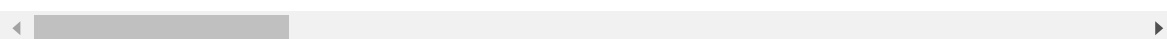


In [316]:

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

Out[316]:

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



In [317]:

```
#### 1.4.2.3 Using Pretrained Models: TFIDF weighted W2V
```

In [318]:

```
#to drop a row having nan https://stackoverflow.com/questions/13413590
project_data=project_data.dropna(subset=['teacher_prefix'])
```

In [319]:

```
# printing some random reviews
print(project_data['essay'].values[0])
print("="*50)
print(project_data['essay'].values[150])
print("="*50)
print(project_data['essay'].values[1000])
print("="*50)
print(project_data['essay'].values[20000])
print("="*50)
print(project_data['essay'].values[99999])
print("="*50)
```

My students are English learners that are working on English as their second or third languages. We are a melting pot of refugees, immigrants, and native-born Americans bringing the gift of language to our school. \r\n\r\n We have over 24 languages represented in our English Learner program with students at every level of mastery. We also have over 40 countries represented with the families within our school. Each student brings a wealth of knowledge and experiences to us that open our eyes to new cultures, beliefs, and respect.\r\n\r\nThe limits of your language are the limits of your world.\r\n\r\n-Ludwig Wittgenstein Our English learner's have a strong support system at home that begs for more resources. Many times our parents are learning to read and speak English along side of their children. Sometimes this creates barriers for parents to be able to help their child learn phonetics, letter recognition, and other reading skills.\r\n\r\n\r\nBy providing these dvd's and players, students are able to continue their mastery of the English language even if no one at home is able to assist. All families with students within the Level 1 proficiency status, will be offered to be a part of this program. These educational videos will be specially chosen by the English Learner Teacher and will be sent home regularly to watch. The videos are to help the child develop early reading skills.\r\n\r\n\r\nParents that do not have access to a dvd player will have the opportunity to check out a dvd player to use for the year. The plan is to use these videos and educational dvd's for the years to come for other EL students.\r\n\r\nnannan

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The 51 fifth grade students that will cycle through my classroom this year all love learning, at least most of the time. At our school, 97.3% of the students receive free or reduced price lunch. Of the 560 students, 97.3% are minority students. \r\n\r\nThe school has a vibrant community that loves to get together and celebrate. Around Halloween there is a whole school parade to show off the beautiful costumes that students wear. On Cinco de Mayo we put on a big festival with crafts made by the students, dances, and games. At the end of the year the school hosts a carnival to celebrate the hard work put in during the school year, with a dunk tank being the most popular activity. My students will use these five brightly colored Hokki stools in place of regular, stationary, 4-legged chairs. As I will only have a total of ten in the classroom and not enough for each student to have an individual one, they will be used in a variety of ways. During independent reading time they will be used as special chairs students will each use on occasion. I will utilize them in place of chairs at my small group tables during math and reading times. The rest of the day they will be used by the students who need the highest amount of movement in their life in order to stay focused on school.\r\n\r\n\r\nWhenever asked what the classroom is missing, my students always say more Hokki Stools. They can't get their fill of the 5 stools we already have. When the students are sitting in group with me on the Hokki Stools, they are always moving, but at the same time doing their work. Anytime the students get to pick where they can sit, the Hokki Stools are the first to be taken. There are always students who head over to the kidney table to get one of the stools who are disappointed as there are not enough of them. \r\n\r\n\r\nWe ask a lot of students to sit for 7 hours a day. The Hokki stools will be a compromise that allow my students to do desk work and move at the same time. These stools will help students to meet their 60 minutes a day of movement by allowing them to activate their core muscles for balance while they sit. For many of my students, these chairs will take away the barrier that exists in schools for a child who can't sit still. nannan

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How do you remember your days of school? Was it in a sterile environment with plain walls, rows of desks, and a teacher in front of the room? A typical day in our room is nothing like that. I work hard to create a warm inviting themed room for my students look forward to coming to each day.\r\n\r\n\r\nMy class is made up of 28 wonderfully unique boys and girls of mixed r

aces in Arkansas.\r\nThey attend a Title I school, which means there is a high enough percentage of free and reduced-price lunch to qualify. Our school is an "open classroom" concept, which is very unique as there are no walls separating the classrooms. These 9 and 10 year-old students are very eager learners; they are like sponges, absorbing all the information and experiences and keep on wanting more. With these resources such as the comfy red throw pillows and the whimsical nautical hanging decor and the blue fish nets, I will be able to help create the mood in our classroom setting to be one of a themed nautical environment. Creating a classroom environment is very important in the success in each and every child's education. The nautical photo props will be used with each child as they step foot into our classroom for the first time on Meet the Teacher evening. I'll take pictures of each child with them, have them developed, and then hung in our classroom ready for their first day of 4th grade. This kind gesture will set the tone before even the first day of school! The nautical thank you cards will be used throughout the year by the students as they create thank you cards to their team groups.\r\n\r\nYour generous donations will help me to help make our classroom a fun, inviting, learning environment from day one.\r\n\r\nIt costs lost of money out of my own pocket on resources to get our classroom ready. Please consider helping with this project to make our new school year a very successful one. Thank you!nannan

=====  
My wonderful students are 3, 4, and 5 years old. We are located in a small town outside of Charlotte, NC. All of my 22 students are children of school district employees.\r\n\r\nMy students are bright, energetic, and they love to learn! They love hands-on activities that get them moving. Like most preschoolers, they enjoy music and creating different things. \r\n\r\nAll of my students come from wonderful families that are very supportive of our classroom. Our parents enjoy watching their children's growth as much as we do! These materials will help me teach my students all about the life cycle of a butterfly. We will watch as the Painted Lady caterpillars grow bigger and build their chrysalis. After a few weeks they will emerge from the chrysalis as beautiful butterflies! We already have a net for the chrysalises, but we still need the caterpillars and feeding station.\r\n\r\nThis will be an unforgettable experience for my students. My student absolutely love hands-on materials. They learn so much from getting to touch and manipulate different things. The supporting materials I have selected will help my students understand the life cycle through exploration.nannan

=====  
The students in my classroom are learners, readers, writers, explorers, scientists, and mathematicians! The potential in these first graders is endless! Each day they come in grinning from ear-to-ear and ready to learn more. \r\n\r\nI choose curriculum that is real and relevant to the students, but it will also prepare them for their futures. These kids are encouraged to investigate concepts that are exciting for them and I hope we can keep this momentum going! These kids deserve the best, please help me give that to them! Thank you! :) These kits include a wide variety of science, technology, engineering, and mechanics for my students to dive into at the beginning of the year. I want them to hit the ground running this upcoming year and these kits always encourage high interest.\r\n\r\nWho wouldn't want to build their own roller coaster, design a car, or even think critically to make a bean bag bounce as far as it can go?? These kits will also shows students potential careers that they may have never heard of before!\r\n\r\nAny donations would be greatly appreciated and my students will know exactly who to thank for them!nannan

=====

In [320]:

```
# 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 [321]:

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

My wonderful students are 3, 4, and 5 years old. We are located in a small town outside of Charlotte, NC. All of my 22 students are children of school district employees.\r\nMy students are bright, energetic, and they love to learn! They love hands-on activities that get them moving. Like most preschoolers, they enjoy music and creating different things. \r\nAll of my students come from wonderful families that are very supportive of our classroom. Our parents enjoy watching their children is growth as much as we do!These materials will help me teach my students all about the life cycle of a butterfly. We will watch as the Painted Lady caterpillars grow bigger and build their chrysalis. After a few weeks they will emerge from the chrysalis as beautiful butterflies! We already have a net for the chrysalises, but we still need the caterpillars and feeding station.\r\nThis will be an unforgettable experience for my students. My student absolutely love hands-on materials. They learn so much from getting to touch and manipulate different things. The supporting materials I have selected will help my students understand the life cycle through exploration.nannan  
=====

In [322]:

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

My wonderful students are 3, 4, and 5 years old. We are located in a small town outside of Charlotte, NC. All of my 22 students are children of school district employees. My students are bright, energetic, and they love to learn! They love hands-on activities that get them moving. Like most preschoolers, they enjoy music and creating different things. All of my students come from wonderful families that are very supportive of our classroom. Our parents enjoy watching their children's growth as much as we do! These materials will help me teach my students all about the life cycle of a butterfly. We will watch as the Painted Lady caterpillars grow bigger and build their chrysalis. After a few weeks they will emerge from the chrysalis as beautiful butterflies! We already have a net for the chrysalises, but we still need the caterpillars and feeding station. This will be an unforgettable experience for my students. My student absolutely love hands-on materials. They learn so much from getting to touch and manipulate different things. The supporting materials I have selected will help my students understand the life cycle through exploration.nannan

In [323]:

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

My wonderful students are 3 4 and 5 years old We are located in a small town outside of Charlotte NC All of my 22 students are children of school district employees My students are bright energetic and they love to learn They love hands on activities that get them moving Like most preschoolers they enjoy music and creating different things All of my students come from wonderful families that are very supportive of our classroom Our parents enjoy watching their children's growth as much as we do These materials will help me teach my students all about the life cycle of a butterfly We will watch as the Painted Lady caterpillars grow bigger and build their chrysalis After a few weeks they will emerge from the chrysalis as beautiful butterflies We already have a net for the chrysalises but we still need the caterpillars and feeding station This will be an unforgettable experience for my students My student absolutely love hands on materials They learn so much from getting to touch and manipulate different things The supporting materials I have selected will help my students understand the life cycle through exploration nannan

In [324]:

```
# 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'r
e", "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', 't
hey', 'them', 'their',\
            'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'that', "th
at'll", 'these', 'those', \
            'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'has', 'ha
d', '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', 'ov
er', 'under', 'again', 'further',\
            'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'all', 'an
y', 'both', 'each', 'few', 'more',\
            'most', 'other', 'some', 'such', 'only', 'own', 'same', 'so', 'than', 'too'
, 'very', \
            's', 't', 'can', 'will', 'just', 'don', "don't", 'should', "should've", 'no
w', 'd', 'll', 'm', 'o', 're', \
            've', 'y', 'ain', 'aren', "aren't", 'couldn', "couldn't", 'didn', "didn't",
'doesn', "doesn't", 'hadn',\
            "hadn't", 'hasn', "hasn't", 'haven', "haven't", 'isn', "isn't", 'ma', 'migh
tn', "mighntn't", 'mustn',\
            "mustn't", 'needn', "needn't", 'shan', "shan't", 'shouldn', "shouldn't", 'w
asn', "wasn't", 'weren', "weren't", \
            'won', "won't", 'wouldn', "wouldn't"]
```

In [325]:

```
# Combining all the above stundents
from tqdm import tqdm
preprocessed_essays = []
# tqdm is for printing the status bar
for sentence in tqdm(project_data['essay'].values):
    sent = decontracted(sentence)
    sent = sent.replace('\r', ' ')
    sent = sent.replace('\n', ' ')
    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())
```

```
100%|████████████████████████████████████████████████████████████████████████████████| 109245/109245 [01:33<00:00, 1166.07it/s]
```

In [326]:

```
# after preprocessing
preprocessed_essays[20000]
```

Out[326]:

```
'my wonderful students 3 4 5 years old we located small town outside charl
otte nc all 22 students children school district employees my students bri
ght energetic love learn they love hands activities get moving like presch
oolers enjoy music creating different things all students come wonderful f
amilies supportive classroom our parents enjoy watching children growth mu
ch these materials help teach students life cycle butterfly we watch paint
ed lady caterpillars grow bigger build chrysalis after weeks emerge chrysa
lis beautiful butterflies we already net chrysalises still need caterpilla
rs feeding station this unforgettable experience students my student absol
utely love hands materials they learn much getting touch manipulate differ
ent things the supporting materials i selected help students understand li
fe cycle exploration nannan'
```

## 1.4 Preprocessing of `project\_title`

In [327]:

```
# printing some random reviews
print(project_data['project_title'].values[0])
print("="*50)
print(project_data['project_title'].values[150])
print("="*50)
print(project_data['project_title'].values[1000])
print("="*50)
print(project_data['project_title'].values[20000])
print("="*50)
print(project_data['project_title'].values[99999])
print("="*50)
```

```
Educational Support for English Learners at Home
=====
More Movement with Hokki Stools
=====
Sailing Into a Super 4th Grade Year
=====
The Beautiful Life of a Butterfly
=====
Hands-On, Brains On!
=====
```





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 (optional)
  
- quantity : numerical (optional)
- teacher\_number\_of\_previously\_posted\_projects : numerical
- price : numerical

### 1.5.1 Vectorizing Categorical data

- <https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/handling-categorical-and-numerical-features/> (<https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/handling-categorical-and-numerical-features/>)

In [331]:

```
# we use count vectorizer to convert the values into one
from sklearn.feature_extraction.text import CountVectorizer
vectorizer = CountVectorizer(vocabulary=list(sorted_cat_dict.keys()), lowercase=False,
binary=True)
categories_one_hot = vectorizer.fit_transform(project_data['clean_categories'].values)
print(vectorizer.get_feature_names())
print("Shape of matrix after one hot encoding ",categories_one_hot.shape)
```

```
['Warmth', 'Care_Hunger', 'History_Civics', 'Music_Arts', 'AppliedLearnin
g', 'SpecialNeeds', 'Health_Sports', 'Math_Science', 'Literacy_Language']
Shape of matrix after one hot encoding (109245, 9)
```

In [332]:

```
# we use count vectorizer to convert the values into one
vectorizer = CountVectorizer(vocabulary=list(sorted_sub_cat_dict.keys()), lowercase=False, binary=True)
sub_categories_one_hot = vectorizer.fit_transform(project_data['clean_subcategories'].values)
print(vectorizer.get_feature_names())
print("Shape of matrix after one hot encoding ", sub_categories_one_hot.shape)
```

```
['Economics', 'CommunityService', 'FinancialLiteracy', 'ParentInvolvement', 'Extracurricular', 'Civics_Government', 'ForeignLanguages', 'Nutrition Education', 'Warmth', 'Care_Hunger', 'SocialSciences', 'PerformingArts', 'CharacterEducation', 'TeamSports', 'Other', 'College_CareerPrep', 'Music', 'History_Geography', 'Health_LifeScience', 'EarlyDevelopment', 'ESL', 'Gym_Fitness', 'EnvironmentalScience', 'VisualArts', 'Health_Wellness', 'AppliedSciences', 'SpecialNeeds', 'Literature_Writing', 'Mathematics', 'Literacy']
Shape of matrix after one hot encoding (109245, 30)
```

In [333]:

```
#Vectorizing Categorical data:State

# count of all the words in corpus python: https://stackoverflow.com/a/22898595/4084039
from collections import Counter
my_counter = Counter()
for word in project_data['school_state'].values:
    my_counter.update(word.split())

# dict sort by value python: https://stackoverflow.com/a/613218/4084039
state_dict = dict(my_counter)
sorted_state_dict = dict(sorted(state_dict.items(), key=lambda kv: kv[1]))

# we use count vectorizer to convert the values into one hot encoded features
from sklearn.feature_extraction.text import CountVectorizer
vectorizer1 = CountVectorizer(vocabulary=list(sorted_state_dict.keys()), lowercase=False, binary=True)
vectorizer1.fit(project_data['school_state'].values)
print(vectorizer1.get_feature_names())

state_one_hot = vectorizer1.transform(project_data['school_state'].values)

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

['VT', 'WY', 'ND', 'MT', 'RI', 'SD', 'NE', 'DE', 'AK', 'NH', 'WV', 'ME', 'HI', 'DC', 'NM', 'KS', 'IA', 'ID', 'AR', 'CO', 'MN', 'OR', 'KY', 'MS', 'NV', 'MD', 'CT', 'TN', 'UT', 'AL', 'WI', 'VA', 'AZ', 'NJ', 'OK', 'WA', 'MA', 'LA', 'OH', 'MO', 'IN', 'PA', 'MI', 'SC', 'GA', 'IL', 'NC', 'FL', 'NY', 'TX', 'CA']
Shape of matrix after one hot encoding (109245, 51)
```

In [334]:

```
#Vectorizing Categorical data:teacher_prefix

def partition(i):
    return i.replace('.', '')

prefix = project_data['teacher_prefix']
actual_prefix = prefix.map(partition)
project_data['teacher_prefix'] = actual_prefix

# count of all the words in corpus python: https://stackoverflow.com/a/22898595/4084039
my_counter = Counter()
my_counter.update(project_data['teacher_prefix'])

#dict sort by value python: https://stackoverflow.com/a/613218/4084039
teacher_dict = dict(my_counter)
sorted_teacher_dict = dict(sorted(teacher_dict.items(), key=lambda kv: kv[1]))

#we use count vectorizer to convert the values into one hot encoded features

vectorizer1 = CountVectorizer(vocabulary=list(sorted_teacher_dict.keys()), lowercase=False, binary=True)
vectorizer1.fit(project_data['teacher_prefix'].values)
print(vectorizer1.get_feature_names())

prefix_one_hot = vectorizer1.transform(project_data['teacher_prefix'].values)

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

['Dr', 'Teacher', 'Mr', 'Ms', 'Mrs']
Shape of matrix after one hot encoding (109245, 5)
```

In [335]:

```
def partition(i):
    return i.replace('-', '_')

prefix = project_data['project_grade_category']
actual_prefix = prefix.map(partition)
project_data['project_grade_category'] = actual_prefix

# count of all the words in corpus python: https://stackoverflow.com/a/22898595/4084039
my_counter = Counter()
for word in project_data['project_grade_category'].values:
    my_counter.update(word.split())

# dict sort by value python: https://stackoverflow.com/a/613218/4084039
grade_dict = dict(my_counter)
sorted_grade_dict = dict(sorted(grade_dict.items(), key=lambda kv: kv[1]))

#https://thispointer.com/different-ways-to-remove-a-key-from-dictionary-in-python/
if "Grades" in sorted_grade_dict:
    del sorted_grade_dict["Grades"]

#Vectorizing Categorical data:project_grade_category

# we use count vectorizer to convert the values into one hot encoded features
vectorizer3 = CountVectorizer(vocabulary=list(sorted_grade_dict.keys()), lowercase=False, binary=True)
vectorizer3.fit(project_data['project_grade_category'].values)
print(vectorizer3.get_feature_names())

grade_one_hot = vectorizer3.transform(project_data['project_grade_category'].values)
print("Shape of matrix after one hot encodig ",grade_one_hot.shape)
```

```
['9_12', '6_8', '3_5', 'PreK_2']
Shape of matrix after one hot encodig (109245, 4)
```

## 1.5.2 Vectorizing Text data

### 1.5.2.1 Bag of words

In [336]:

```
# We are considering only the words which appeared in at least 10 documents(rows or projects).
vectorizer = CountVectorizer(min_df=10)
text_bow = vectorizer.fit_transform(preprocessed_essays)
print("Shape of matrix after one hot encodig ",text_bow.shape)
```

```
Shape of matrix after one hot encodig (109245, 16623)
```

### 1.5.2.2 TFIDF vectorizer

In [337]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
vectorizer = TfidfVectorizer(min_df=10)
text_tfidf = vectorizer.fit_transform(preprocessed_essays)
print("Shape of matrix after one hot encoding ",text_tfidf.shape)
```

Shape of matrix after one hot encoding (109245, 16623)

### 1.5.2.3 Using Pretrained Models: Avg W2V

In [338]:

```
'''
# 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-save-and-load-variables-in-python/

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

'''
```

Out[338]:

```
'\n# Reading glove vectors in python: https://stackoverflow.com/a/3823034
9/4084039\ndef loadGloveModel(gloveFile):\n    print ("Loading Glove Mode
l")\n    f = open(gloveFile,\r', encoding="utf8")\n    model = {}\n    f
or line in tqdm(f):\n        splitLine = line.split()\n        word = spli
tLine[0]\n        embedding = np.array([float(val) for val in splitLine
[1:]])\n        model[word] = embedding\n    print ("Done.",len(model)," w
ords loaded!")\n    return model\nmodel = loadGloveModel('glove.42B.300d.
txt')\n\n# =====\nOutput:\n    \nLoading Glove Mod
el\n1917495it [06:32, 4879.69it/s]\nDone. 1917495 words loaded!\n\n# ====
=====
\n\nwords = []\nfor i in preproced_texts:\n    wor
ds.extend(i.split(' '))\n\nfor i in preproced_titles:\n    words.extend
(i.split(' '))\n\nprint("all the words in the coupus", len(words))\n\nwords
= set(words)\n\nprint("the unique words in the coupus", len(words))\n\ninter
_words = set(model.keys()).intersection(words)\n\nprint("The number of words
that are present in both glove vectors and our coupus", len(inter_wo
rds), "("np.round(len(inter_words)/len(words)*100,3),"%")\n\nwords_courpu
s = {}\n\nwords_glove = set(model.keys())\n\nfor i in words:\n    if i in word
s_glove:\n        words_courpus[i] = model[i]\n\nprint("word 2 vec length",
len(words_courpus))\n\n\n# stronging variables into pickle files python: h
ttp://www.jessicayung.com/how-to-use-pickle-to-save-and-load-variables-in-
python/\n\nimport pickle\n\nwith open('glove_vectors', 'wb') as f:\n
pickle.dump(words_courpus, f)\n\n\n'
```

In [339]:

```
# stronging variables into pickle files python: http://www.jessicayung.com/how-to-use-p
ickle-to-save-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 [340]:

```
# average Word2Vec
# compute average word2vec for each review.
avg_w2v_vectors = []; # the avg-w2v for each sentence/review is stored in this list
for sentence in tqdm(preprocessed_essays): # 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)

print(len(avg_w2v_vectors))
print(len(avg_w2v_vectors[0]))
```

```
100%|████████████████████████████████████████████████████████████████████████████████|
109245/109245 [00:53<00:00, 2032.37it/s]
```

```
109245
300
```









In [347]:

```
# check this one: https://www.youtube.com/watch?v=0H0q0cLn3Z4&t=530s
# standardization sklearn: https://scikit-learn.org/stable/modules/generated/sklearn.preprocessing.StandardScaler.html
from sklearn.preprocessing import StandardScaler

# price_standardized = standardScaler.fit(project_data['price'].values)
# this will rise the error
# ValueError: Expected 2D array, got 1D array instead: array=[725.05 213.03 329. ...
# 399. 287.73 5.5 ].
# Reshape your data either using array.reshape(-1, 1)

price_scalar = StandardScaler()
price_scalar.fit(project_data['price'].values.reshape(-1,1)) # finding the mean and standard deviation of this data
print(f"Mean : {price_scalar.mean_[0]}, Standard deviation : {np.sqrt(price_scalar.var_[0])}")

# Now standardize the data with above mean and variance.
price_standardized = price_scalar.transform(project_data['price'].values.reshape(-1, 1))
```

Mean : 298.1152448166964, Standard deviation : 367.49642545627506

In [348]:

```
price_standardized
```

Out[348]:

```
array([[ -0.39052147],
       [ 0.00240752],
       [ 0.5952024 ],
       ...,
       [-0.1582471 ],
       [-0.61242839],
       [-0.51215531]])
```

## 1.5.4 Merging all the above features

- we need to merge all the numerical vectors i.e categorical, text, numerical vectors

In [349]:

```
print(categories_one_hot.shape)
print(sub_categories_one_hot.shape)
print(text_bow.shape)
print(price_standardized.shape)
```

```
(109245, 9)
(109245, 30)
(109245, 16623)
(109245, 1)
```

In [350]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039
from scipy.sparse import hstack
# with the same hstack function we are concatenating a sparse matrix and a dense matrix
:)
X = hstack((categories_one_hot, sub_categories_one_hot, text_bow, price_standardized))
X.shape
```

Out[350]:

(109245, 16663)

## Assignment 4: Naive Bayes

## 1. Apply Multinomial NaiveBayes on these feature sets

- Set 1: categorical, numerical features + project\_title(BOW) + preprocessed\_eassay (BOW)
- Set 2: categorical, numerical features + project\_title(TFIDF)+ preprocessed\_eassay (TFIDF)

## 2. The hyper paramter tuning(find best Alpha)

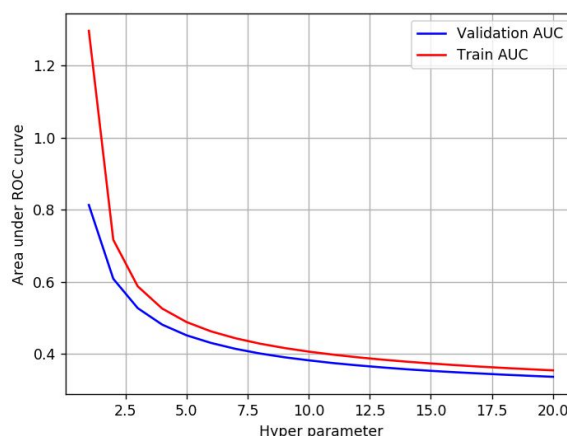
- Find the best hyper parameter which will give the maximum AUC (<https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/receiver-operating-characteristic-curve-roc-curve-and-auc-1/>) value
- Consider a wide range of alpha values for hyperparameter tuning, start as low as 0.00001
- Find 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

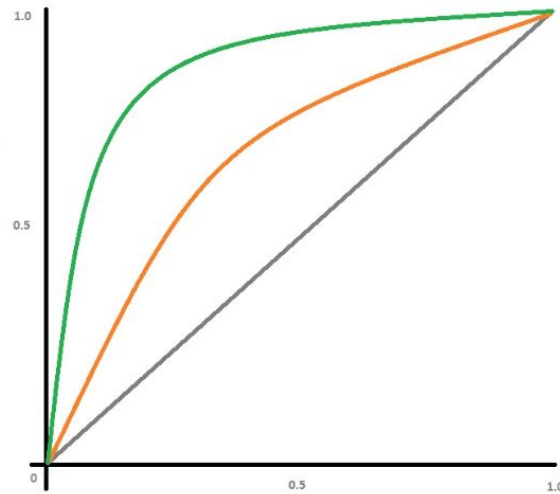
- Find the top 10 features of positive class and top 10 features of negative class for both feature sets Set 1 and Set 2 using values of `feature\_log\_prob\_` parameter of MultinomialNB ([https://scikit-learn.org/stable/modules/generated/sklearn.naive\\_bayes.MultinomialNB.html](https://scikit-learn.org/stable/modules/generated/sklearn.naive_bayes.MultinomialNB.html)) 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 (<https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/confusion-matrix-tpr-fpr-fnr-tnr-1/>) with predicted and original labels of test data points. Please visualize your confusion matrices using seaborn heatmaps.

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

(<https://seaborn.pydata.org/generated/seaborn.heatmap.html>)

(<https://seaborn.pydata.org/generated/seaborn.heatmap.html>)

(<https://seaborn.pydata.org/generated/seaborn.heatmap.html>)

(<https://seaborn.pydata.org/generated/seaborn.heatmap.html>)

## 5. **Conclusion** (<https://seaborn.pydata.org/generated/seaborn.heatmap.html>)

(<https://seaborn.pydata.org/generated/seaborn.heatmap.html>)

- 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. (<https://seaborn.pydata.org/generated/seaborn.heatmap.html>) link (<http://zetcode.com/python/prettytable/>)

Vectorizer	Model	Hyper parameter	AUC
BOW	Brute	7	0.78
TFIDF	Brute	12	0.79
W2V	Brute	10	0.78
TFIDFW2V	Brute	6	0.78

## 2. Naive Bayes

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

In [351]:

```
project_data1 = project_data
project_data1.head(3)
```

Out[351]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs	IN
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr	FL
2	21895	p182444	3465aaf82da834c0582ebd0ef8040ca0	Ms	AZ

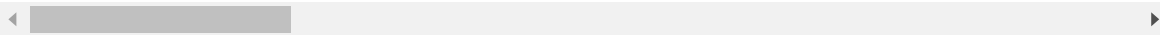


In [352]:

```
y = project_data1['project_is_approved'].values
project_data1.drop(['project_is_approved'], axis=1, inplace=True)
project_data1.head(1)
```

Out[352]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_sta
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs	IN



In [353]:

```
X = project_data1
# train test split
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.33, stratify=y)
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train, test_size=0.33, stratify=y_train)
```

## 2.2 Make Data Model Ready: encoding numerical, categorical features

### 2.2.1 Normalizing the numerical features: Price

In [354]:

```
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))

X_train_price_norm = normalizer.transform(X_train['price'].values.reshape(-1,1))
X_cv_price_norm = normalizer.transform(X_cv['price'].values.reshape(-1,1))
X_test_price_norm = normalizer.transform(X_test['price'].values.reshape(-1,1))

print("After vectorizations")
print(X_train_price_norm.shape, y_train.shape)
print(X_cv_price_norm.shape, y_cv.shape)
print(X_test_price_norm.shape, y_test.shape)
print("="*100)
```

After vectorizations

(49039, 1) (49039,)

(24155, 1) (24155,)

(36051, 1) (36051,)

=====

=====

In [355]:

```
features_name = ['price']
```

## 2.2.2 Normalizing the numerical features: teacher\_number\_of\_previously\_posted\_projects

In [356]:

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

X_train_tnppp_norm = normalizer.transform(X_train['teacher_number_of_previously_posted_projects'].values.reshape(-1,1))
X_cv_tnppp_norm = normalizer.transform(X_cv['teacher_number_of_previously_posted_projects'].values.reshape(-1,1))
X_test_tnppp_norm = normalizer.transform(X_test['teacher_number_of_previously_posted_projects'].values.reshape(-1,1))

print("After vectorizations")
print(X_train_tnppp_norm.shape, y_train.shape)
print(X_cv_tnppp_norm.shape, y_cv.shape)
print(X_test_tnppp_norm.shape, y_test.shape)
print("="*100)
```

After vectorizations

(49039, 1) (49039,)

(24155, 1) (24155,)

(36051, 1) (36051,)

=====

In [357]:

```
features_name.extend(['tnpp'])
```

## 2.2.3 one hot encoding the catogorical features:clean\_categories

In [358]:

```
from sklearn.feature_extraction.text import CountVectorizer
vectorizer = CountVectorizer(vocabulary=list(sorted_cat_dict.keys()), lowercase=False,
binary=True)
vectorizer.fit(X_train['clean_categories'].values)

X_train_categories_ohe = vectorizer.transform(X_train['clean_categories'].values)
X_cv_categories_ohe = vectorizer.transform(X_cv['clean_categories'].values)
X_test_categories_ohe = vectorizer.transform(X_test['clean_categories'].values)
print("After vectorizations")
print(X_train_categories_ohe.shape, y_train.shape)
print(X_cv_categories_ohe.shape, y_cv.shape)
print(X_test_categories_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

After vectorizations

(49039, 9) (49039,)

(24155, 9) (24155,)

(36051, 9) (36051,)

['Warmth', 'Care\_Hunger', 'History\_Civics', 'Music\_Arts', 'AppliedLearning', 'SpecialNeeds', 'Health\_Sports', 'Math\_Science', 'Literacy\_Language']

=====

In [359]:

```
features_name1 = vectorizer.get_feature_names()
features_name.extend(features_name1)
```

## 2.2.4 one hot encoding the catogorical features: clean\_subcategories

In [360]:

```
vectorizer = CountVectorizer(vocabulary=list(sorted_sub_cat_dict.keys()), lowercase=False, binary=True)
vectorizer.fit(X_train['clean_subcategories'].values)
X_train_sub_categories_ohe = vectorizer.transform(X_train['clean_subcategories'].values)
X_cv_sub_categories_ohe = vectorizer.transform(X_cv['clean_subcategories'].values)
X_test_sub_categories_ohe = vectorizer.transform(X_test['clean_subcategories'].values)
print("After vectorizations")
print(X_train_sub_categories_ohe.shape, y_train.shape)
print(X_cv_sub_categories_ohe.shape, y_cv.shape)
print(X_test_sub_categories_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

After vectorizations

(49039, 30) (49039,)

(24155, 30) (24155,)

(36051, 30) (36051,)

['Economics', 'CommunityService', 'FinancialLiteracy', 'ParentInvolvement', 'Extracurricular', 'Civics\_Government', 'ForeignLanguages', 'Nutrition Education', 'Warmth', 'Care\_Hunger', 'SocialSciences', 'PerformingArts', 'CharacterEducation', 'TeamSports', 'Other', 'College\_CareerPrep', 'Music', 'History\_Geography', 'Health\_LifeScience', 'EarlyDevelopment', 'ESL', 'Gym\_Fitness', 'EnvironmentalScience', 'VisualArts', 'Health\_Wellness', 'AppliedSciences', 'SpecialNeeds', 'Literature\_Writing', 'Mathematics', 'Literacy']

=====

In [361]:

```
features_name.extend(vectorizer.get_feature_names())
```

## 2.2.5 one hot encoding the catogorical features: school\_state

In [362]:

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

# we use the fitted CountVectorizer to convert the text to vector
X_train_state_ohe = vectorizer.transform(X_train['school_state'].values)
X_cv_state_ohe = vectorizer.transform(X_cv['school_state'].values)
X_test_state_ohe = vectorizer.transform(X_test['school_state'].values)

print("After vectorizations")
print(X_train_state_ohe.shape, y_train.shape)
print(X_cv_state_ohe.shape, y_cv.shape)
print(X_test_state_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
After vectorizations
(49039, 51) (49039,)
(24155, 51) (24155,)
(36051, 51) (36051,)
['ak', 'al', 'ar', 'az', 'ca', 'co', 'ct', 'dc', 'de', 'fl', 'ga', 'hi',
'ia', 'id', 'il', 'in', 'ks', 'ky', 'la', 'ma', 'md', 'me', 'mi', 'mn', 'm
o', 'ms', 'mt', 'nc', 'nd', 'ne', 'nh', 'nj', 'nm', 'nv', 'ny', 'oh', 'o
k', 'or', 'pa', 'ri', 'sc', 'sd', 'tn', 'tx', 'ut', 'va', 'vt', 'wa', 'w
i', 'wv', 'wy']
=====
=====
```

In [363]:

```
features_name.extend(vectorizer.get_feature_names())
```

## 2.2.6 one hot encoding the catogorical features: teacher\_prefix

In [364]:

```
vectorizer.fit(X_train['teacher_prefix'].values) # fit has to happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
X_train_teacher_ohe = vectorizer.transform(X_train['teacher_prefix'].values)
X_cv_teacher_ohe = vectorizer.transform(X_cv['teacher_prefix'].values)
X_test_teacher_ohe = vectorizer.transform(X_test['teacher_prefix'].values)

print("After vectorizations")
print(X_train_teacher_ohe.shape, y_train.shape)
print(X_cv_teacher_ohe.shape, y_cv.shape)
print(X_test_teacher_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)
```

```
After vectorizations
(49039, 5) (49039,)
(24155, 5) (24155,)
(36051, 5) (36051,)
['dr', 'mr', 'mrs', 'ms', 'teacher']
=====
=====
```

In [365]:

```
features_name.extend(vectorizer.get_feature_names())
```

## 2.2.7 one hot encoding the catogorical features: project\_grade\_category

In [366]:

```
#one hot encoding of project_grade_category for X_train
# count of all the words in corpus python: https://stackoverflow.com/a/22898595/4084039
from collections import Counter
my_counter = Counter()
for word in X_train['project_grade_category'].values:
    my_counter.update(word.split())

# dict sort by value python: https://stackoverflow.com/a/613218/4084039
grade_dict = dict(my_counter)
sorted_grade_dict = dict(sorted(grade_dict.items(), key=lambda kv: kv[1]))

#https://thispointer.com/different-ways-to-remove-a-key-from-dictionary-in-python/
if "Grades" in sorted_grade_dict:
    del sorted_grade_dict["Grades"]

#Vectorizing Categorical data:project_grade_category

# we use count vectorizer to convert the values into one hot encoded features
vectorizer = CountVectorizer(vocabulary=list(sorted_grade_dict.keys()), lowercase=False
, binary=True)
vectorizer.fit(X_train['project_grade_category'].values)
print(vectorizer.get_feature_names())

X_train_grade_ohe = vectorizer.transform(X_train['project_grade_category'].values)
print(X_train_grade_ohe.shape, y_train.shape)

['9_12', '6_8', '3_5', 'PreK_2']
(49039, 4) (49039,)
```

In [367]:

```
features_name.extend(vectorizer.get_feature_names())
```

In [368]:

```
#one hot encoding of project_grade_category for X_cv
my_counter = Counter()
for word in X_cv['project_grade_category'].values:
    my_counter.update(word.split())

# dict sort by value python: https://stackoverflow.com/a/613218/4084039
grade_dict = dict(my_counter)
sorted_grade_dict = dict(sorted(grade_dict.items(), key=lambda kv: kv[1]))

#https://thispointer.com/different-ways-to-remove-a-key-from-dictionary-in-python/
if "Grades" in sorted_grade_dict:
    del sorted_grade_dict["Grades"]

#Vectorizing Categorical data:project_grade_category

# we use count vectorizer to convert the values into one hot encoded features
vectorizer = CountVectorizer(vocabulary=list(sorted_grade_dict.keys()), lowercase=False
, binary=True)
vectorizer.fit(X_cv['project_grade_category'].values)
print(vectorizer.get_feature_names())

X_cv_grade_ohe = vectorizer.transform(X_cv['project_grade_category'].values)
print(X_cv_grade_ohe.shape, y_cv.shape)

['9_12', '6_8', '3_5', 'PreK_2']
(24155, 4) (24155,)
```

In [369]:

```
#one hot encoding of project_grade_category for X_test
my_counter = Counter()
for word in X_test['project_grade_category'].values:
    my_counter.update(word.split())

# dict sort by value python: https://stackoverflow.com/a/613218/4084039
grade_dict = dict(my_counter)
sorted_grade_dict = dict(sorted(grade_dict.items(), key=lambda kv: kv[1]))

#https://thispointer.com/different-ways-to-remove-a-key-from-dictionary-in-python/
if "Grades" in sorted_grade_dict:
    del sorted_grade_dict["Grades"]

#Vectorizing Categorical data:project_grade_category

# we use count vectorizer to convert the values into one hot encoded features
vectorizer = CountVectorizer(vocabulary=list(sorted_grade_dict.keys()), lowercase=False,
                             binary=True)
vectorizer.fit(X_test['project_grade_category'].values)
print(vectorizer.get_feature_names())

X_test_grade_ohe = vectorizer.transform(X_test['project_grade_category'].values)
print(X_test_grade_ohe.shape, y_test.shape)

['9_12', '6_8', '3_5', 'PreK_2']
(36051, 4) (36051,)
```

In [370]:

```
print("After vectorizations")
print(X_train_grade_ohe.shape, y_train.shape)
print(X_cv_grade_ohe.shape, y_cv.shape)
print(X_test_grade_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("=="*100)
```

```
After vectorizations
(49039, 4) (49039,)
(24155, 4) (24155,)
(36051, 4) (36051,)
['9_12', '6_8', '3_5', 'PreK_2']
=====
=====
```

## 2.3 Make Data Model Ready: encoding eassay, and project\_title

### 2.3.1.1 Text preprocessing





In [374]:

```
# We are considering only the words which appeared in at least 10 documents(rows or projects).
vectorizer = CountVectorizer(min_df=10)
vectorizer.fit(X_train_preprocessed_essays) # fit has to happen only on train data

X_train_text_bow = vectorizer.transform(X_train_preprocessed_essays)
X_cv_text_bow = vectorizer.transform(X_cv_preprocessed_essays)
X_test_text_bow = vectorizer.transform(X_test_preprocessed_essays)

print("After vectorizations")
print(X_train_text_bow.shape, y_train.shape)
print(X_cv_text_bow.shape, y_cv.shape)
print(X_test_text_bow.shape, y_test.shape)
print("=="*100)
```

```
After vectorizations
(49039, 12085) (49039,)
(24155, 12085) (24155,)
(36051, 12085) (36051,)
=====
=====
```

In [375]:

```
features_name_bow = features_name
features_name_tfidf = features_name
features_name_bow.extend(vectorizer.get_feature_names())
```

### 2.3.1.3 Vectorizing Text data: tfidf

In [376]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
vectorizer = TfidfVectorizer(min_df=10)
vectorizer.fit(X_train_preprocessed_essays) # fit has to happen only on train data
X_train_text_tfidf = vectorizer.transform(X_train_preprocessed_essays)
X_cv_text_tfidf = vectorizer.transform(X_cv_preprocessed_essays)
X_test_text_tfidf = vectorizer.transform(X_test_preprocessed_essays)

print("After vectorizations")
print(X_train_text_tfidf.shape, y_train.shape)
print(X_cv_text_tfidf.shape, y_cv.shape)
print(X_test_text_tfidf.shape, y_test.shape)
print("=="*100)
```

```
After vectorizations
(49039, 12085) (49039,)
(24155, 12085) (24155,)
(36051, 12085) (36051,)
=====
=====
```

In [377]:

```
features_name_tfidf.extend(vectorizer.get_feature_names())
```

### 2.3.2.1 Title preprocessing

In [378]:

```
#Title preprocessing on X_train datasets
from tqdm import tqdm
X_train_preprocessed_titles = []
# tqdm is for printing the status bar
for sentence in tqdm(X_train['project_title'].values):
    sent = decontracted(sentence)
    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)
    X_train_preprocessed_titles.append(sent.lower().strip())
```

```
100%|████████████████████████████████████████████████████████████████████████████████|
████████████████████████████████████████████████████████████████████████████████| 49039/49039 [00:02<00:00, 23997.15it/s]
```

In [379]:

```
#title preprocessing on X_train datasets
from tqdm import tqdm
X_cv_preprocessed_titles = []
# tqdm is for printing the status bar
for sentence in tqdm(X_cv['project_title'].values):
    sent = decontracted(sentence)
    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)
    X_cv_preprocessed_titles.append(sent.lower().strip())
```

```
100%|████████████████████████████████████████████████████████████████████████████████|
████████████████████████████████████████████████████████████████████████████████| 24155/24155 [00:01<00:00, 20789.45it/s]
```

In [380]:

```
#title preprocessing on X_train datasets
from tqdm import tqdm
X_test_preprocessed_titles = []
# tqdm is for printing the status bar
for sentence in tqdm(X_test['project_title'].values):
    sent = decontracted(sentence)
    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)
    X_test_preprocessed_titles.append(sent.lower().strip())
```

```
100%|████████████████████████████████████████████████████████████████████████████████|
████████████████████████████████████████████████████████████████████████████████| 36051/36051 [00:01<00:00, 19444.73it/s]
```

### 2.3.2.2 Vectorizing project\_titles data:Bag of words

In [381]:

```
# We are considering only the words which appeared in at least 10 documents(rows or projects).
vectorizer = CountVectorizer(min_df=10)
vectorizer.fit(X_train_preprocessed_titles) # fit has to happen only on train data

X_train_titles_bow = vectorizer.transform(X_train_preprocessed_titles)
X_cv_titles_bow = vectorizer.transform(X_cv_preprocessed_titles)
X_test_titles_bow = vectorizer.transform(X_test_preprocessed_titles)

print("After vectorizations")
print(X_train_titles_bow.shape, y_train.shape)
print(X_cv_titles_bow.shape, y_cv.shape)
print(X_test_titles_bow.shape, y_test.shape)
print("=="*100)
```

```
After vectorizations
(49039, 1986) (49039,)
(24155, 1986) (24155,)
(36051, 1986) (36051,)
=====
=====
```

In [382]:

```
features_name_bow.extend(vectorizer.get_feature_names())
```

### 2.3.2.3 Vectorizing Text data: tfidf

In [383]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
vectorizer = TfidfVectorizer(min_df=10)
vectorizer.fit(X_train_preprocessed_titles) # fit has to happen only on train data
X_train_titles_tfidf = vectorizer.transform(X_train_preprocessed_titles)
X_cv_titles_tfidf = vectorizer.transform(X_cv_preprocessed_titles)
X_test_titles_tfidf = vectorizer.transform(X_test_preprocessed_titles)

print("After vectorizations")
print(X_train_titles_tfidf.shape, y_train.shape)
print(X_cv_titles_tfidf.shape, y_cv.shape)
print(X_test_titles_tfidf.shape, y_test.shape)
print("=="*100)
```

```
After vectorizations
(49039, 1986) (49039,)
(24155, 1986) (24155,)
(36051, 1986) (36051,)
=====
=====
```

In [384]:

```
features_name_tfidf.extend(vectorizer.get_feature_names())
```

## 2.4 Appling NB() on different kind of featurization as mentioned in the instructions

Apply Naive Bayes on different kind of featurization as mentioned in the instructions

For Every model that you work on make sure you do the step 2 and step 3 of instructions

### Concatinating all the features:model1-BOW

In [385]:

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

X_tr_m1 = hstack((X_train_price_norm, X_train_tnppp_norm, X_train_categories_ohe, X_train_sub_categories_ohe, X_train_state_ohe, X_train_teacher_ohe, X_train_grade_ohe, X_train_text_bow, X_train_titles_bow))

X_cv_m1 = hstack((X_cv_price_norm, X_cv_tnppp_norm, X_cv_categories_ohe, X_cv_sub_categories_ohe, X_cv_state_ohe, X_cv_teacher_ohe, X_cv_grade_ohe, X_cv_text_bow, X_cv_titles_bow))

X_te_m1 = hstack((X_test_price_norm, X_test_tnppp_norm, X_test_categories_ohe, X_test_sub_categories_ohe, X_test_state_ohe, X_test_teacher_ohe, X_test_grade_ohe, X_test_text_bow, X_test_titles_bow))

print("Final Data matrix")
print(X_tr_m1.shape, y_train.shape)
print(X_cv_m1.shape, y_cv.shape)
print(X_te_m1.shape, y_test.shape)
print("=="*100)
```

Final Data matrix

(49039, 14172) (49039,)

(24155, 14172) (24155,)

(36051, 14172) (36051,)

=====  
=====

### Concatinating all the features:model2-TFIDF

In [386]:

```
# merge two sparse matrices: https://stackoverflow.com/a/19710648/4084039

X_tr_m2 = hstack((X_train_price_norm, X_train_tnppp_norm, X_train_categories_ohe, X_train_sub_categories_ohe, X_train_state_ohe, X_train_teacher_ohe, X_train_grade_ohe, X_train_text_tfidf, X_train_titles_tfidf))

X_cv_m2 = hstack((X_cv_price_norm, X_cv_tnppp_norm, X_cv_categories_ohe, X_cv_sub_categories_ohe, X_cv_state_ohe, X_cv_teacher_ohe, X_cv_grade_ohe, X_cv_text_tfidf, X_cv_titles_tfidf))

X_te_m2 = hstack((X_test_price_norm, X_test_tnppp_norm, X_test_categories_ohe, X_test_sub_categories_ohe, X_test_state_ohe, X_test_teacher_ohe, X_test_grade_ohe, X_test_text_tfidf, X_test_titles_tfidf))

print("Final Data matrix")
print(X_tr_m2.shape, y_train.shape)
print(X_cv_m2.shape, y_cv.shape)
print(X_te_m2.shape, y_test.shape)
print("="*100)
```

Final Data matrix

(49039, 14172) (49039,)

(24155, 14172) (24155,)

(36051, 14172) (36051,)

=====

## 2.4.1 Applying Naive Bayes on BOW, SET 1

In [387]:

```
from scipy.sparse import hstack
from scipy.sparse import coo_matrix
from scipy.sparse import csr_matrix

X_tr_m1 = csr_matrix(X_tr_m1)
X_cv_m1 = csr_matrix(X_cv_m1)
X_te_m1 = csr_matrix(X_te_m1)
```

In [388]:

```
def batch_predict(clf, data):  
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates  
    # of the positive class  
    # not the predicted outputs  
  
    y_data_pred = []  
    tr_loop = data.shape[0] - data.shape[0]%1000  
    # consider you X_tr shape is 49041, then your tr_loop will be 49041 - 49041%1000 =  
    49000  
    # in this for loop we will iterate until 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
```

In [410]:

```
import matplotlib.pyplot as plt
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import roc_auc_score
import math

train_auc = []
cv_auc = []
para = [0.00001, 0.0001, 0.001, 0.01, 0.1, 1.0, 10.0, 100.0, 1000.0]
for i in para:
    mnb = MultinomialNB(alpha=i, class_prior=[0.5, 0.5])
    mnb.fit(X_tr_m1, y_train)

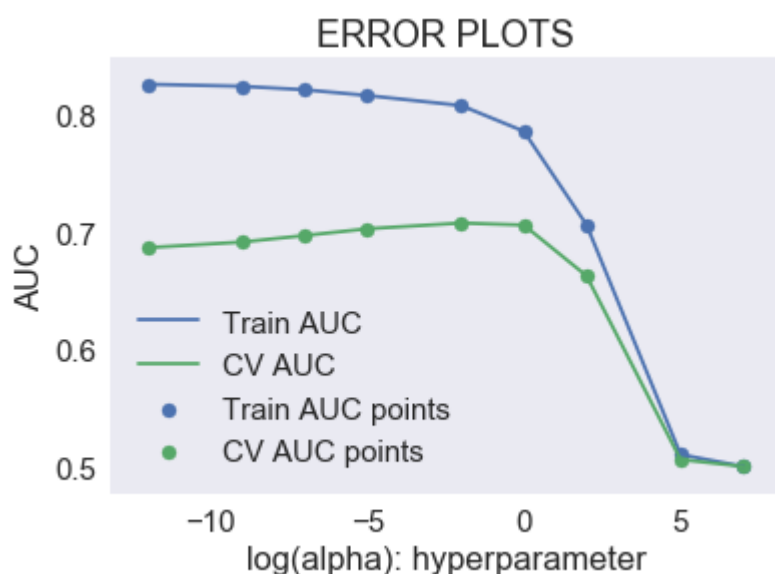
    y_train_pred = batch_predict(mnb, X_tr_m1)
    y_cv_pred = batch_predict(mnb, X_cv_m1)

    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates
    # of the positive class
    # 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))

para1 = [math.log(x) for x in para]
para1 = [round(x) for x in para1]
plt.plot(para1, train_auc, label='Train AUC')
plt.plot(para1, cv_auc, label='CV AUC')

plt.scatter(para1, train_auc, label='Train AUC points')
plt.scatter(para1, cv_auc, label='CV AUC points')

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





In [390]:

```
para1
```

Out[390]:

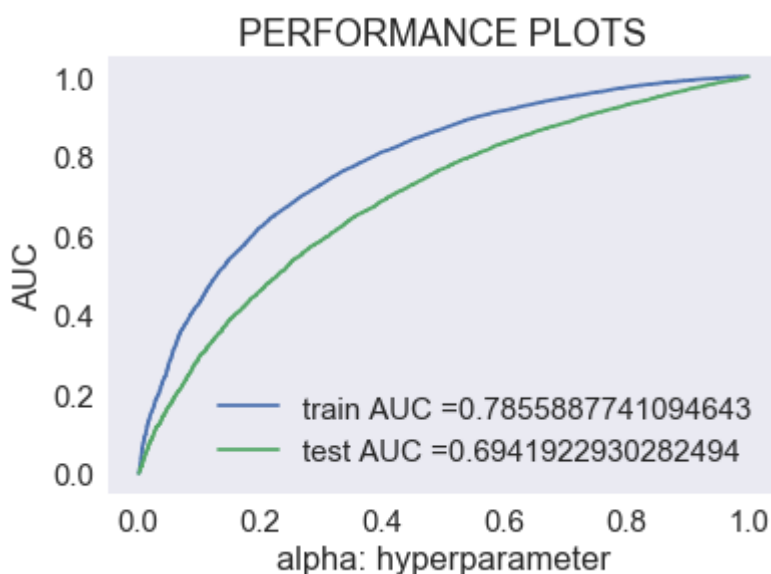
```
[-12, -9, -7, -5, -2, 0, 2, 5, 7]
```

In [391]:

```
#In above plot CV AUC is high for "log(alpha) = 0" and for which corresponding alpha is 1.0  
best_alpha = 1.0
```

In [392]:

```
# https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve  
from sklearn.metrics import roc_curve, auc  
  
mnb = MultinomialNB(alpha=best_alpha, class_prior=[0.5, 0.5])  
mnb.fit(X_tr_m1, y_train)  
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive class  
# not the predicted outputs  
  
y_train_pred = batch_predict(mnb, X_tr_m1)  
y_test_pred = batch_predict(mnb, X_te_m1)  
  
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("alpha: hyperparameter")  
plt.ylabel("AUC")  
plt.title("PERFORMANCE PLOTS")  
plt.grid()  
plt.show()
```



In [393]:

```
# we will pick a threshold that will give the least fpr
def predict(proba, threshold, fpr, tpr):

    t = threshold[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.rou
nd(t,3))
    predictions = []
    for i in proba:
        if i>=t:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

In [394]:

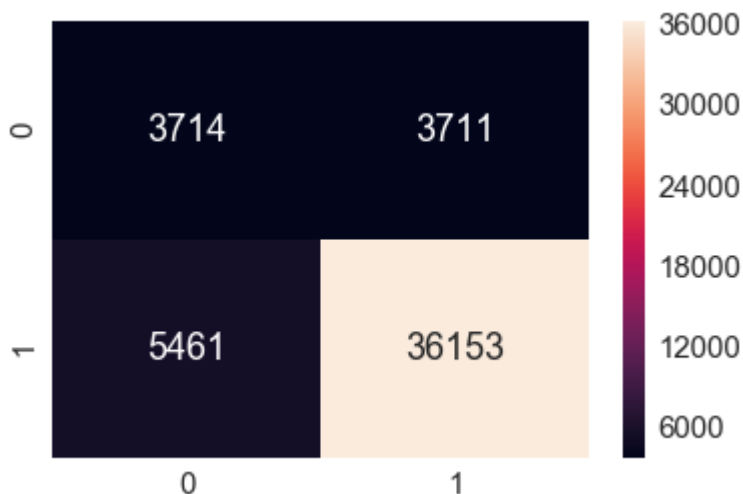
```
import seaborn as sns; sns.set()
from sklearn.metrics import confusion_matrix
print("Train confusion matrix")
conf_mat_data = confusion_matrix(y_train, predict(y_train_pred, tr_thresholds, train_fp
r, train_fpr))
sns.set(font_scale = 1.5)
sns.heatmap(conf_mat_data, annot=True, fmt='g')
```

Train confusion matrix

the maximum value of tpr\*(1-fpr) 0.249999959187838 for threshold 0.03

Out[394]:

<matplotlib.axes.\_subplots.AxesSubplot at 0x2497faeb8>



In [395]:

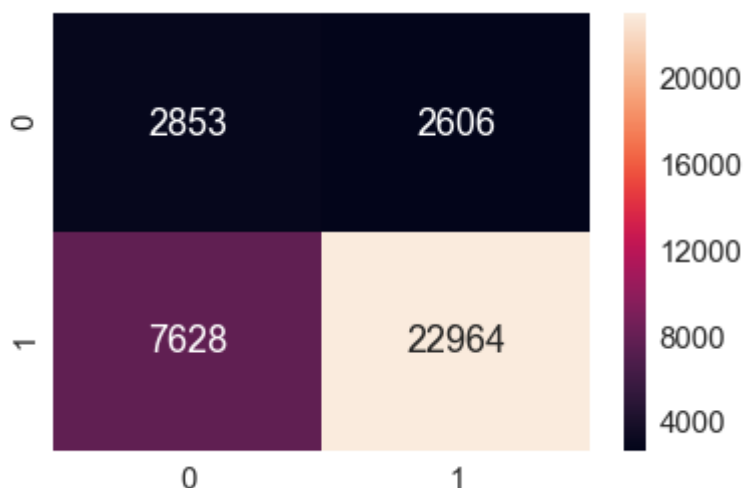
```
print("Test confusion matrix")
sns.set(font_scale = 1.5)
conf_mat_data = confusion_matrix(y_test, predict(y_test_pred, tr_thresholds, test_fpr,
test_fpr))
sns.heatmap(conf_mat_data, annot=True, fmt='g')
```

Test confusion matrix

the maximum value of  $tpr \cdot (1 - fpr)$  0.24999999161092995 for threshold 0.231

Out[395]:

<matplotlib.axes.\_subplots.AxesSubplot at 0x249257809e8>



#### 2.4.1.1 Top 10 important features of positive class from SET 1

In [396]:

```
mnb = MultinomialNB(alpha=best_alpha)

# fitting the model
mnb.fit(X_tr_m1, y_train)

# predict the response
pred = mnb.predict(X_te_m1)
```

In [397]:

```
pos_class_prob_sorted = mnb.feature_log_prob_[1, :].argsort()
print("=====positive bad =====")
print(np.take(features_name_bow, pos_class_prob_sorted[:10]))#first 10 features
print(np.take(features_name_bow, pos_class_prob_sorted[-10:]))#top 10 features

=====positive bad =====
['dr' 'ohana' 'chocolate' 'indians' 'iv' 'employing' 'filmed' 'ethically'
 'alexa' 'invitations']
['nannan' 'many' 'price' 'help' 'learn' 'not' 'classroom' 'learning'
 'school' 'students']
```

#### 2.4.1.2 Top 10 important features of negative class from SET 1

In [398]:

```
neg_class_prob_sorted=mnf.feature_log_prob_[0, :].argsort()
print("=====negative bad =====")
print(np.take(features_name_bow, neg_class_prob_sorted[:10]))#first 10 features
print(np.take(features_name_bow, neg_class_prob_sorted[-10:]))#top 10 features
```

```
=====negative bad =====
['chrysalis' 'replicate' 'diffusers' 'resembles' 'dies' 'assess' 'resort'
 'resounding' 'dicamillo' 'dialects']
['many' 'nannan' 'price' 'help' 'learn' 'not' 'classroom' 'learning'
 'school' 'students']
```

## 2.4.2 Applying Naive Bayes on TFIDF, SET 2

In [399]:

```
from scipy.sparse import hstack
from scipy.sparse import coo_matrix
from scipy.sparse import csr_matrix

X_tr_m2 = csr_matrix(X_tr_m2)
X_cv_m2 = csr_matrix(X_cv_m2)
X_te_m2 = csr_matrix(X_te_m2)
```

In [400]:

```
import matplotlib.pyplot as plt
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import roc_auc_score
import math

train_auc = []
cv_auc = []

para = [0.00001, 0.0001, 0.001, 0.01, 0.1, 1.0, 10.0, 100.0, 1000.0]
for i in para:
    mnb = MultinomialNB(alpha=i, class_prior=[0.5, 0.5])
    mnb.fit(X_tr_m2, y_train)

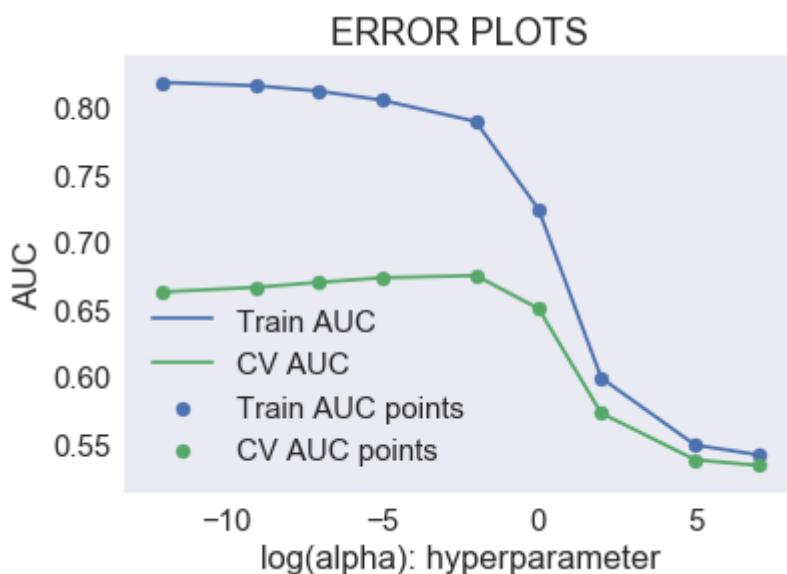
    y_train_pred = batch_predict(mnb, X_tr_m2)
    y_cv_pred = batch_predict(mnb, X_cv_m2)

    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates
    # of the positive class
    # 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))

para1 = [math.log(x) for x in para]
para1 = [round(x) for x in para1]
plt.plot(para1, train_auc, label='Train AUC')
plt.plot(para1, cv_auc, label='CV AUC')

plt.scatter(para1, train_auc, label='Train AUC points')
plt.scatter(para1, cv_auc, label='CV AUC points')

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



In [401]:

```
para1
```

Out[401]:

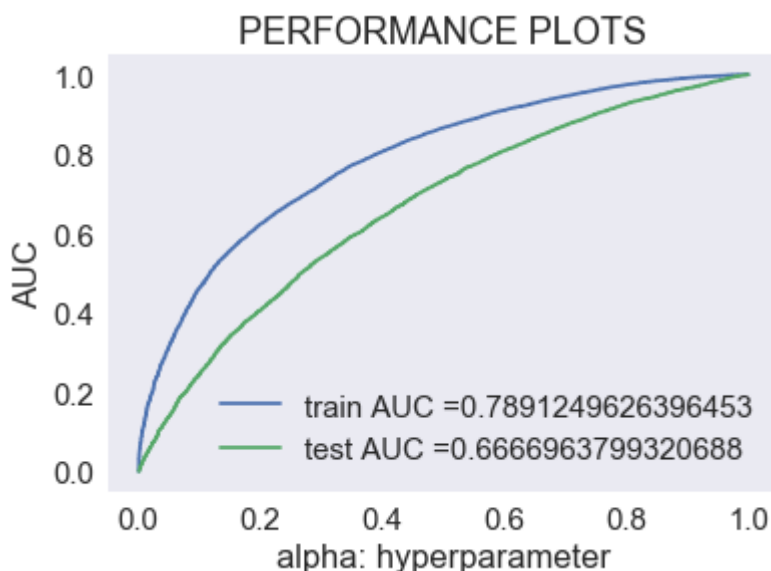
```
[-12, -9, -7, -5, -2, 0, 2, 5, 7]
```

In [402]:

```
#In above plot CV AUC is high for "log(alpha) = -2" and for which corresponding alpha is 0.1  
best_alpha = 0.1
```

In [403]:

```
# https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html#sklearn.metrics.roc_curve  
from sklearn.metrics import roc_curve, auc  
  
mnb = MultinomialNB(alpha=best_alpha, class_prior=[0.5, 0.5])  
mnb.fit(X_tr_m2, y_train)  
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive class  
# not the predicted outputs  
  
y_train_pred = batch_predict(mnb, X_tr_m2)  
y_test_pred = batch_predict(mnb, X_te_m2)  
  
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("alpha: hyperparameter")  
plt.ylabel("AUC")  
plt.title("PERFORMANCE PLOTS")  
plt.grid()  
plt.show()
```



In [404]:

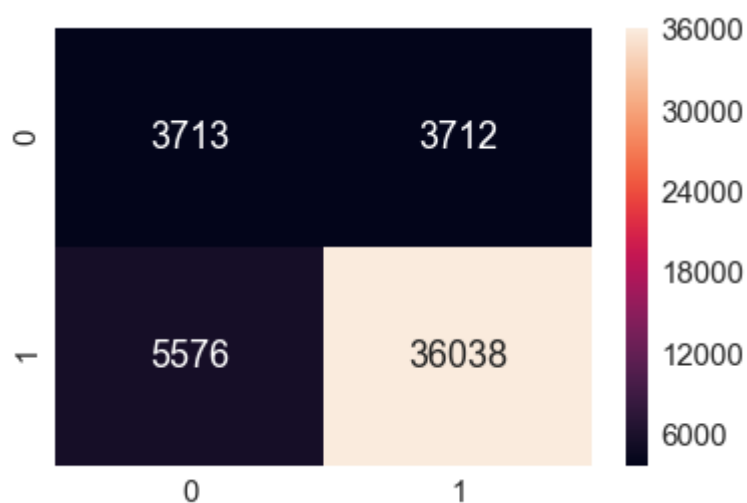
```
import seaborn as sns; sns.set()
from sklearn.metrics import confusion_matrix
print("Train confusion matrix")
conf_mat_data = confusion_matrix(y_train, predict(y_train_pred, tr_thresholds, train_fpr, train_fpr))
sns.set(font_scale = 1.5)
sns.heatmap(conf_mat_data, annot=True, fmt='g')
```

Train confusion matrix

the maximum value of  $tpr \cdot (1 - fpr)$  0.24999999546531537 for threshold 0.356

Out[404]:

<matplotlib.axes.\_subplots.AxesSubplot at 0x249257474a8>



In [405]:

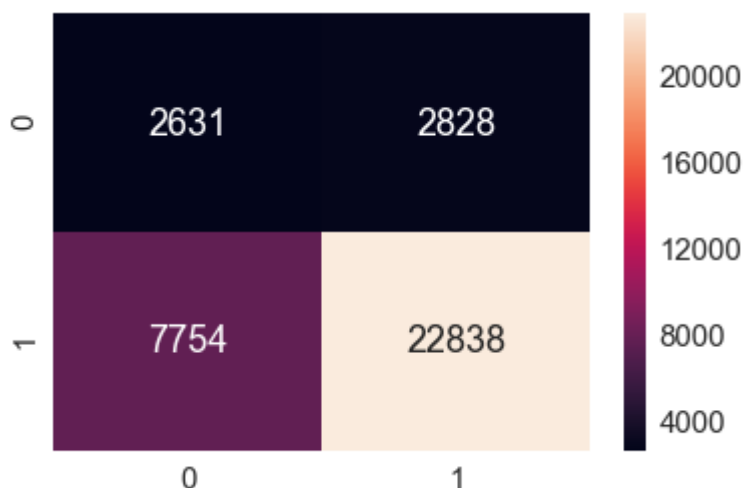
```
print("Test confusion matrix")
conf_mat_data = confusion_matrix(y_test, predict(y_test_pred, tr_thresholds, test_fpr,
test_fpr))
sns.set(font_scale = 1.5)
sns.heatmap(conf_mat_data, annot=True, fmt='g')
```

Test confusion matrix

the maximum value of  $tpr \cdot (1 - fpr)$  0.24999999161092995 for threshold 0.444

Out[405]:

<matplotlib.axes.\_subplots.AxesSubplot at 0x2497dbbecf8>



#### 2.4.2.1 Top 10 important features of positive class from SET 2

In [406]:

```
mnb = MultinomialNB(alpha=best_alpha)

# fitting the model
mnb.fit(X_tr_m2, y_train)

# predict the response
pred = mnb.predict(X_te_m2)
```

In [407]:

```
pos_class_prob_sorted = mnb.feature_log_prob_[1, :].argsort()
print("===== Positive =====")
print(np.take(features_name_tfidf, pos_class_prob_sorted[:10]))#first 10 features
print(np.take(features_name_tfidf, pos_class_prob_sorted[-10:]))#top 10 features

===== Positive =====
['ohana' 'filmed' 'uzbekistan' 'iv' 'breed' 'frost' 'gratefully' 'rubric'
'apparel' 'ethically']
['Mathematics' 'Literacy' '3_5' 'ms' 'Math_Science' 'PreK_2'
'Literacy_Language' 'mrs' 'tnpp' 'price']
```

#### 2.4.2.2 Top 10 important features of negative class from SET 2



In [408]:

```
neg_class_prob_sorted=mnf.feature_log_prob_[0, :].argsort()
print("=====negative bad =====")
print(np.take(features_name_tfidf, neg_class_prob_sorted[:10]))#top 10 features
print(np.take(features_name_tfidf, neg_class_prob_sorted[-10:]))#first 10 features
```

```
=====negative bad =====
['chrysalis' 'samoan' 'sam' 'salmon' 'carved' 'sail' 'cassette' 'casters'
 'saddens' 'catcher']
['Literacy' 'Mathematics' '3_5' 'ms' 'Math_Science' 'PreK_2'
 'Literacy_Language' 'mrs' 'tnpp' 'price']
```

### 3. Conclusions

In [409]:

```
from prettytable import PrettyTable

x = PrettyTable()

x.field_names = ["Vectorizer", "Model", "Hyper Parameter", "AUC"]

x.add_row(["BOW", "Naive Bayes", 0.1, 0.69])
x.add_row(["TFIDF", "Naive Bayes", 0.1, 0.66])
print(x)
```

Vectorizer	Model	Hyper Parameter	AUC
BOW	Naive Bayes	0.1	0.69
TFIDF	Naive Bayes	0.1	0.66