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.

DonorsChoose

About the DonorsChoose Data Set

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

Feature	Description
`project_id`	A unique identifier for the proposed project. **Example:** `p036502`
`project_title`	Title of the project. **Examples:** • `Art Will Make You Happy!` • `First Grade Fun`
`project_grade_category`	Grade level of students for which the project is targeted. One of the following enumerated values: • `Grades PreK-2` • `Grades 3-5` • `Grades 6-8` • `Grades 9-12`
`project_subject_categories`	One or more (comma-separated) subject categories for the project from the following enumerated list of values: • `Applied Learning` • `Care & Hunger` • `Health & Sports` • `History & Civics` • `Literacy & Language` • `Math & Science` • `Music & The Arts` • `Special Needs` • `Warmth` **Examples:** • `Music & The Arts` • `Literacy & Language, Math & Science`
`school_state`	State where school is located (Two-letter U.S. postal code). **Example:** `WY`
`project_subject_subcategories`	One or more (comma-separated) subject subcategories for the project. **Examples:** • `Literacy` • `Literature & Writing, Social Sciences`
`project_resource_summary`	An explanation of the resources needed for the project. **Example:** • `My students need hands on literacy materials to manage sensory needs!`
`project_essay_1`	First application essay*
`project_essay_2`	Second application essay*
`project_essay_3`	Third application essay*

Feature	Description
`project_essay_4`	Fourth application essay
`project_submitted_datetime`	Datetime when project application was submitted. **Example:** `2016-04-28 12:43:56.245`
`teacher_id`	A unique identifier for the teacher of the proposed project. **Example:** `bdf8baa8fedef6bfeec7ae4ff1c15c56`
`teacher_prefix`	Teacher's title. One of the following enumerated values: • `nan` • `Dr.` • `Mr.` • `Mrs.` • `Ms.` • `Teacher.`
`teacher_number_of_previously_posted_projects`	Number of project applications previously submitted by the same teacher. **Example:** `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 `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 [1]:

```
%matplotlib inline
import warnings
warnings.filterwarnings("ignore")

import sqlite3
import pandas as pd
import numpy as np
import nltk
import string
import math
```

```
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

import dill #To store session variables
#https://stackoverflow.com/questions/34342155/how-to-pickle-or-store-jupyter-ipython-notebook-session-for-later
```

1.1 Reading Data

In [2]:

```
from google.colab import drive
drive.mount('/content/drive', force_remount=True)
```

```
Mounted at /content/drive
```

In [3]:

```
ls "drive/My Drive/Colab Notebooks"
```

```
3_DonorsChoose_KNN_final.ipynb  glove.6B.50d.txt    knn.sess
4_DonorsChoose_NB_final.ipynb   glove_vectors_30    resources.csv
5_DonorsChoose_LR_final.ipynb   glove_vectors_300d  train_data.csv
```

In [0]:

```
project_data = pd.read_csv('drive/My Drive/Colab Notebooks/train_data.csv')
resource_data = pd.read_csv('drive/My Drive/Colab Notebooks/resources.csv')
```

In [5]:

```
project_data_1=project_data[project_data['project_is_approved']==1]
project_data_0=project_data[project_data['project_is_approved']==0]

print(project_data_1.shape)
print(project_data_0.shape)

#Creating a dataset of 0.2k points containg points from both the classes
project_data = project_data_1[0:33458].append(project_data_0[0:16542])
print(project_data['project_is_approved'].value_counts())
print(project_data.shape)
```

```
(92706, 17)
(16542, 17)
1    33458
0    16542
Name: project_is_approved, dtype: int64
(50000, 17)
```

In [6]:

```
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 (50000, 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 [7]:

```
# how to replace elements in list python: https://stackoverflow.com/a/2582163/4084039
cols = ['Date' if x=='project_submitted_datetime' else x for x in list(project_data.columns)]

#sort dataframe based on time pandas python: https://stackoverflow.com/a/49702492/4084039
project_data['Date'] = pd.to_datetime(project_data['project_submitted_datetime'])
project_data.drop('project_submitted_datetime', axis=1, inplace=True)
project_data.sort_values(by=['Date'], inplace=True)

# how to reorder columns pandas python: https://stackoverflow.com/a/13148611/4084039
project_data = project_data[cols]

project_data.head(2)
```

Out[7]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	Date	project_grade_category	project_s
473	100660	p234804	cbc0e38f522143b86d372f8b43d4cff3	Mrs.	GA	2016-04-27 00:53:00	Grades PreK-2	
29891	146723	p099708	c0a28c79fe8ad5810da49de47b3fb491	Mrs.	CA	2016-04-27 01:10:09	Grades 3-5	Math &

In [8]:

```
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[8]:

	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 [0]:

```
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 & H
unger"]
        if 'The' in j.split(): # this will split each of the catogory based on space "Math & Scienc
e"=> "Math","&", "Science"
            j=j.replace('The','') # if we have the words "The" we are going to replace it with ''(i
.e removing 'The')
        j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty) ex:"Math &
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 [0]:

```
sub_catogories = 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_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", "Warmth", "Care & H
unger"]
        if 'The' in j.split(): # this will split each of the catogory based on space "Math & Scienc
e"=> "Math","&", "Science"
            j=j.replace('The','') # if we have the words "The" we are going to replace it with ''(i
.e removing 'The')
        j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty) ex:"Math &
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 [0]:

```
# 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 [12]:

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

Out[12]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	Date	project_grade_category	project_
473	100660	p234804	cbc0e38f522143b86d372f8b43d4cff3	Mrs.	GA	2016-04-27 00:53:00	Grades PreK-2	Flex Seating Flex Lear
29891	146723	p099708	c0a28c79fe8ad5810da49de47b3fb491	Mrs.	CA	2016-04-27 01:10:09	Grades 3-5	Brea Box to Ig Engagem

In [13]:

```
# 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])
```

```
I recently read an article about giving students a choice about how they learn. We already set goa
ls; why not let them choose where to sit, and give them options of what to sit on?I teach at a low
-income (Title 1) school. Every year, I have a class with a range of abilities, yet they are all t
he same age. They learn differently, and they have different interests. Some have ADHD, and some a
re fast learners. Yet they are eager and active learners that want and need to be able to move aro
und the room, yet have a place that they can be comfortable to complete their work.We need a class
room rug that we can use as a class for reading time, and students can use during other learning t
imes. I have also requested four Kore Kids wobble chairs and four Back Jack padded portable chairs
so that students can still move during whole group lessons without disrupting the class. Having th
ese areas will provide these little ones with a way to wiggle while working.Benjamin Franklin once
said, \"Tell me and I forget, teach me and I may remember, involve me and I learn.\" I want these
children to be involved in their learning by having a choice on where to sit and how to learn, all
by giving them options for comfortable flexible seating.
==================================================
A unit that has captivated my students and one that has forced them to seek out further resources
on their own, is the Holocaust unit. This unit not only brought their critical thinking skills to
life, but it brought out their passion, love, dislikes, and fears about wars and prejudices to lig
ht.My 8th graders students live in a high-poverty school district and live in a large, urban area.
They are reluctant readers unless introduced to life-changing books. This book made my students wo
rk hard in improving their reading and writing skills. The Holocaust unit brought compassion and h
istory to life. The students wanted to read ahead and learn about tolerance and
discrimination.These materials will be used in-class. We were read, discuss, and think critically
about the world event that still affects us. The Holocaust is part of our history and its victims
and survivors deserve our knowledge and recognition of the hardships they endured. We will be rese
arching the victims and survivors of the Holocaust, read non-fictional text, watch documentaries,
and overall broaden our education on this historic event. This project will greatly benefit my
```

and overall broaden our education on this historic event.This project will greatly benefit my students. It will not only help them academically and help prepare them for high school, but it wi ll make them well-rounded individuals who better understand the power of tolerance and war. Please know that you have made a positive impact on my students and we sincerely thank you in advance.
==
Why learn coding in the 5th grade? I teach science through STEM. Instead of using only spaghetti a nd marshmallows for engineering, I want the students to use coding. It is time to use interactive approaches to solving problems and testing ideas using real-life skills students may use in the fu ture.My school is located in Jupiter, Florida, and we are an intermediate center, servicing only 3 rd-5th grades. I teach 3 classes of science to 5th grade students. My students are a mix of gifted and advanced 10 and 11 year olds, of at which 20% have some type of learning challenge, such as AD D or autism. They all have insatiable thirsts for science. Most come to me with limited knowledge of science, but a tremendous understanding of technology. Most have a computer in their home and a re familiar with tablets and smartphones. At least 1/3 of my students know Scratch and JavaScript programming.\r\nMy goal is to pair my students incredible knowledge of technology with science concepts to deepen their understandings of that concept. I also want to expose all of my students with coding since research has shown that more computer coders will be needed for future jobs than ever before.\r\nWhat I envision is the students working in groups using the specific coding device , Raspberry Pi, to create codes to manipulate the sensors. These will be attached to laptops at ea ch table. In the beginning, I will use the device to teach basic coding to solve a problem. The s tudents will be required to learn how to set up the motherboard during this process. Then I will m ove on to using it with my science content. One activity I found intriguing is the weather station sensors. The students work together to find a way to code for each of these sensors to turn on and off and collect, store, and manipulate the data. This will become a part of my weather unit.By pai ring this type of technology with science, I feel my lesson then is reflecting how science works i n the real world. Technology and science go hand in hand and I want my students to experience that one influences the other. I want them to experience that scientists use technology as a tool to fu rther deepen their understanding of concepts. I also want both my boys and girls to learn and understanding coding as a viable future career.

In [0]:

```
# 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 [15]:

```
sent = decontracted(project_data['essay'].values[2000])
print(sent)
print("="*50)
```

My school is in a low socio-economic area with a high ELL population. The students in my classroom do not have a lot of academic practice outside of the school day. They love coming to school every day and are eager to learn. They work very hard and are so excited when they master new concepts. \r\n   At my school site we strive to make the most of every minute during the school day in order to ensure students are able to learn and feel successful. We know that the time we have with them is very precious!I am asking for the mini white boards and reusable write and wipe pockets in orde r to help me monitor my students thinking and learning. Often times, when work is done on worksheets the feedback to students is not meaningful because it can take awhile to give each stud ent individual feed back. The white boards and write and wipe pockets will give students a way to show written responses while we are gathered at the carpet together. This will allow me to give im mediate feedback to students and then can modify their responses right then and there. This will l ead to more meaningful learning and processing.nannan
==

In [16]:

```
# \r \n \t remove from string python: http://texthandler.com/info/remove-line-breaks-python/
```

```
sent = sent.replace('\\r', ' ')
sent = sent.replace('\\"', ' ')
sent = sent.replace('\\n', ' ')
print(sent)
```

```
My school is in a low socio-economic area with a high ELL population. The students in my classroom
do not have a lot of academic practice outside of the school day. They love coming to school every
day and are eager to learn. They work very hard and are so excited when they master new concepts.
At my school site we strive to make the most of every minute during the school day in order to ens
ure students are able to learn and feel successful. We know that the time we have with them is ver
y precious!I am asking for the mini white boards and reusable write and wipe pockets in order to h
elp me monitor my students thinking and learning. Often times, when work is done on worksheets the
feedback to students is not meaningful because it can take awhile to give each student individual
feed back. The white boards and write and wipe pockets will give students a way to show written re
sponses while we are gathered at the carpet together. This will allow me to give immediate
feedback to students and then can modify their responses right then and there. This will lead to m
ore meaningful learning and processing.nannan
```

In [17]:

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

```
My school is in a low socio economic area with a high ELL population The students in my classroom
do not have a lot of academic practice outside of the school day They love coming to school everyd
ay and are eager to learn They work very hard and are so excited when they master new concepts At
my school site we strive to make the most of every minute during the school day in order to ensure
students are able to learn and feel successful We know that the time we have with them is very pre
cious I am asking for the mini white boards and reusable write and wipe pockets in order to help m
e monitor my students thinking and learning Often times when work is done on worksheets the
feedback to students is not meaningful because it can take awhile to give each student individual
feed back The white boards and write and wipe pockets will give students a way to show written res
ponses while we are gathered at the carpet together This will allow me to give immediate feedback
to students and then can modify their responses right then and there This will lead to more meanin
gful learning and processing nannan
```

In [0]:

```
# https://gist.github.com/sebleier/554280
# we are removing the words from the stop words list: 'no', 'nor', 'not'
stopwords= ['i', 'me', 'my', 'myself', 'we', 'our', 'ours', 'ourselves', 'you', "you're", "you've",
\
            "you'll", "you'd", 'your', 'yours', 'yourself', 'yourselves', 'he', 'him', 'his',
'himself', \
            'she', "she's", 'her', 'hers', 'herself', 'it', "it's", 'its', 'itself', 'they', 'them',
'their',\
            'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'that', "that'll",
'these', 'those', \
            'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'has', 'had', 'having',
'do', 'does', \
            'did', 'doing', 'a', 'an', 'the', 'and', 'but', 'if', 'or', 'because', 'as', 'until', '
while', 'of', \
            'at', 'by', 'for', 'with', 'about', 'against', 'between', 'into', 'through', 'during',
'before', 'after',\
            'above', 'below', 'to', 'from', 'up', 'down', 'in', 'out', 'on', 'off', 'over', 'under'
, 'again', 'further',\
            'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'all', 'any', 'both', 'e
ach', 'few', 'more',\
            'most', 'other', 'some', 'such', 'only', 'own', 'same', 'so', 'than', 'too', 'very', \
            's', 't', 'can', 'will', 'just', 'don', "don't", 'should', "should've", 'now', 'd', 'll'
, 'm', 'o', 're', \
            've', 'y', 'ain', 'aren', "aren't", 'couldn', "couldn't", 'didn', "didn't", 'doesn', "d
esn't", 'hadn',\
            "hadn't", 'hasn', "hasn't", 'haven', "haven't", 'isn', "isn't", 'ma', 'mightn',
"mightn't", 'mustn',\
            "mustn't", 'needn', "needn't", 'shan', "shan't", 'shouldn', "shouldn't", 'wasn',
"wasn't", 'weren', "weren't", \
            'won', "won't", 'wouldn', "wouldn't"]
```

In [19]:

```
# Combining all the above stundents
```

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

```
100%|██████████| 50000/50000 [00:26<00:00, 1853.74it/s]
```

In [20]:

```
#adding a new column for the processed essay text
project_data['clean_essay']=preprocessed_essays
print(project_data.columns)

# after preprocesing
preprocessed_essays[2000]
```

```
Index(['Unnamed: 0', 'id', 'teacher_id', 'teacher_prefix', 'school_state',
       'Date', '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', 'essay', 'clean_essay'],
      dtype='object')
```

Out[20]:

```
'school low socio economic area high ell population students classroom not lot academic practice o
utside school day love coming school everyday eager learn work hard excited master new concepts sc
hool site strive make every minute school day order ensure students able learn feel successful kno
w time precious asking mini white boards reusable write wipe pockets order help monitor students t
hinking learning often times work done worksheets feedback students not meaningful take awhile giv
e student individual feed back white boards write wipe pockets give students way show written
responses gathered carpet together allow give immediate feedback students modify responses right l
ead meaningful learning processing nannan'
```

1.4.1 Preprocessing of `project_title`

In [21]:

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

Out[21]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	Date	project_grade_category	project_
473	100660	p234804	cbc0e38f522143b86d372f8b43d4cff3	Mrs.	GA	2016-04-27 00:53:00	Grades PreK-2	Flex Seatin Flex Lear
29891	146723	p099708	c0a28c79fe8ad5810da49de47b3fb491	Mrs.	CA	2016-04-27 01:10:09	Grades 3-5	Brea Box to Ig Engagem

In [22]:

```
#Printing a few random review summaries

for i in range(1,3000,1000):
    sent = project_data['project_title'].values[i]
    print(sent,'--- Row No:',i)
    print("="*50)
```

```
Breakout Box to Ignite Engagement! --- Row No: 1
==================================================
Cozy Classroom Carpet for Learning --- Row No: 1001
==================================================
Community Circle Carpet: A Place to Call Home! --- Row No: 2001
==================================================
```

In [23]:

```
# The above random records show that there are no URLs or HTML tags, but we will remove incase if
there are any

from tqdm import tqdm #for status bar
from bs4 import BeautifulSoup #for html tags

preprocessed_title=[]

for title in tqdm(project_data['project_title'].values):
    # To remove urls - https://stackoverflow.com/a/40823105/4084039
    title = re.sub(r"http\S+", "", title)

    # To remove all HTML tags
    #https://stackoverflow.com/questions/16206380/python-beautifulsoup-how-to-remove-all-tags-from
-an-element
    title = BeautifulSoup(title, 'lxml').get_text()

    # To split contractions - refer decontracted function defined above
    title = decontracted(title)

    # To remove alphanumerics (words with numbers in them) -
https://stackoverflow.com/a/18082370/4084039
    title = re.sub("\S*\d\S*", "", title).strip()

    # To remove special characters - https://stackoverflow.com/a/5843547/4084039
    title = re.sub('[^A-Za-z]+', ' ', title)

    # To remove stop words from the summaries and convert to lowercase
    title = ' '.join(e.lower() for e in title.split() if e.lower() not in stopwords)
    preprocessed_title.append(title.strip())

#adding a new column for cleaned titles
project_data['clean_title']=preprocessed_title
print(project_data.columns)
```

```
100%|██████████| 50000/50000 [00:10<00:00, 4607.19it/s]
```

```
Index(['Unnamed: 0', 'id', 'teacher_id', 'teacher_prefix', 'school_state',
       'Date', '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', 'essay', 'clean_essay',
       'clean_title'],
      dtype='object')
```

1.4.2 Preprocessing of `teacher_prefix`

In [0]:

```
#replacing Nan values with 'Unknown'
project_data['teacher_prefix']=project_data['teacher_prefix'].replace(np.nan,'Unknown')
```

1.4.3 Combining resource_data with project_data

In [0]:

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

1.5 Preparing data for models

In [26]:

```
project_data.columns
```

Out[26]:

```
Index(['Unnamed: 0', 'id', 'teacher_id', 'teacher_prefix', 'school_state',
       'Date', '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', 'essay', 'clean_essay',
       'clean_title', 'price', 'quantity'],
      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
```

2. Naive Bayes

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

In [27]:

```
from sklearn.model_selection import train_test_split

import warnings
warnings.filterwarnings("ignore", category=DeprecationWarning)

#Checking if there are any values other than 0 and 1
project_data['project_is_approved'].unique()

#https://answers.dataiku.com/2352/split-dataset-by-stratified-sampling
df_train, df_test = train_test_split(project_data, test_size = 0.3, stratify=project_data['project_
is_approved'])
print(df_train.shape,df_test.shape)
```

```
(35000, 22) (15000, 22)
```

2.2 Make Data Model Ready: encoding numerical, categorical features

2.2.1 Vectorizing Categorical data

2.2.1.1 Feature encoding for categories

In [28]:

```
# 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_train = vectorizer.fit_transform(df_train['clean_categories'].values)
categories_one_hot_test = vectorizer.transform(df_test['clean_categories'].values)
print(vectorizer.get_feature_names())
print("Shape of matrices after one hot encoding ",categories_one_hot_train.shape,
categories_one_hot_test.shape)

# Store feature names in a list
feature_names = []
feature_names = vectorizer.get_feature_names()
print(len(feature_names))
```

```
['Warmth', 'Care_Hunger', 'History_Civics', 'Music_Arts', 'AppliedLearning', 'SpecialNeeds',
'Health_Sports', 'Math_Science', 'Literacy_Language']
Shape of matrices after one hot encoding  (35000, 9) (15000, 9)
9
```

2.2.1.2 Feature encoding for subcategories

In [29]:

```
# 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_train = vectorizer.fit_transform(df_train['clean_subcategories'].values)
sub_categories_one_hot_test = vectorizer.transform(df_test['clean_subcategories'].values)
print(vectorizer.get_feature_names())
print("Shape of matrices after one hot encoding ",sub_categories_one_hot_train.shape,
sub_categories_one_hot_test.shape)

# Store feature names in a list
feature_names.extend(vectorizer.get_feature_names())
print(len(feature_names))
```

```
['Economics', 'CommunityService', 'FinancialLiteracy', 'ParentInvolvement', 'Extracurricular',
'Civics_Government', 'ForeignLanguages', 'Warmth', 'Care_Hunger', 'NutritionEducation',
'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 matrices after one hot encoding  (35000, 30) (15000, 30)
39
```

2.2.1.3 Feature encoding for state

In [30]:

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

#https://cmdlinetips.com/2018/01/how-to-get-unique-values-from-a-column-in-pandas-data-frame/
#To get unique values from school_state column

school_state_lst=project_data['school_state'].unique()

vectorizer = CountVectorizer(vocabulary = school_state_lst, lowercase=False, binary=True)

school_state_one_hot_train = vectorizer.fit_transform(df_train['school_state'].values)
```

```
school_state_one_hot_test = vectorizer.transform(df_test['school_state'].values)
print(vectorizer.get_feature_names())
print("Shape of matrices after one hot encoding
",school_state_one_hot_train.shape,school_state_one_hot_test.shape)

# Store feature names in a list
feature_names.extend(vectorizer.get_feature_names())
print(len(feature_names))
```

```
['GA', 'CA', 'OH', 'FL', 'MD', 'TX', 'NJ', 'OK', 'PA', 'WV', 'NC', 'CO', 'VA', 'AZ', 'MA', 'ID', 'M
I', 'ME', 'WA', 'SC', 'LA', 'TN', 'MS', 'IN', 'KS', 'NY', 'KY', 'WI', 'MO', 'IA', 'SD', 'UT', 'IL',
'CT', 'NV', 'AL', 'MN', 'AR', 'DC', 'OR', 'NH', 'RI', 'HI', 'NE', 'NM', 'AK', 'ND', 'DE', 'MT', 'VI
', 'WY']
Shape of matrices after one hot encoding  (35000, 51) (15000, 51)
90
```

2.2.1.4 Feature encoding for teacher_prefix

In [31]:

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

#https://cmdlinetips.com/2018/01/how-to-get-unique-values-from-a-column-in-pandas-data-frame/
#https://stackoverflow.com/questions/48090658/sklearn-how-to-incorporate-missing-data-when-one-hot
-encoding

#fetching unique values
teacher_prefix_lst=project_data['teacher_prefix'].unique()

vectorizer = CountVectorizer(vocabulary = teacher_prefix_lst, lowercase=False, binary=True)

teacher_prefix_one_hot_train = vectorizer.fit_transform(df_train['teacher_prefix'].values)
teacher_prefix_one_hot_test = vectorizer.transform(df_test['teacher_prefix'].values)
print(vectorizer.get_feature_names())
print("Shape of matrices after one hot encoding
",teacher_prefix_one_hot_train.shape,teacher_prefix_one_hot_test.shape)

# Store feature names in a list
feature_names.extend(vectorizer.get_feature_names())
print(len(feature_names))
```

```
['Mrs.', 'Ms.', 'Mr.', 'Teacher', 'Unknown', 'Dr.']
Shape of matrices after one hot encoding  (35000, 6) (15000, 6)
96
```

2.2.1.5 Feature encoding for project_grade_category

In [32]:

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

#https://cmdlinetips.com/2018/01/how-to-get-unique-values-from-a-column-in-pandas-data-frame/
#To get unique values from project_grade_category column
grade_cat_lst=project_data['project_grade_category'].unique()

vectorizer = CountVectorizer(vocabulary = grade_cat_lst, lowercase=False, binary=True)

grade_cat_one_hot_train = vectorizer.fit_transform(df_train['project_grade_category'].values)
grade_cat_one_hot_test = vectorizer.transform(df_test['project_grade_category'].values)
print(vectorizer.get_feature_names())
print("Shape of matrix after one hot encoding ",grade_cat_one_hot_train.shape,
grade_cat_one_hot_test.shape)

# Store feature names in a list
feature_names.extend(vectorizer.get_feature_names())
print(len(feature_names))
```

```
['Grades PreK-2', 'Grades 3-5', 'Grades 6-8', 'Grades 9-12']
Shape of matrix after one hot encoding  (35000, 4) (15000, 4)
100
```

2.2.2 Vectorizing Numerical features

2.2.2.1 Vectorizing price

In [33]:

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

# price_standardized = standardScalar.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)
print(df_train.columns)
price_scalar = StandardScaler(with_mean=False) #with_mean=False uses mean value as zero, which
helps in avoiding negative values
print(price_scalar)
price_scalar.fit(df_train['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 maen and variance.
price_train_standardized = price_scalar.transform(df_train['price'].values.reshape(-1, 1))
price_test_standardized = price_scalar.transform(df_test['price'].values.reshape(-1, 1))

# Store feature names in a list
feature_names.append('price')
print(len(feature_names))
```

```
Index(['Unnamed: 0', 'id', 'teacher_id', 'teacher_prefix', 'school_state',
       'Date', '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', 'essay', 'clean_essay',
       'clean_title', 'price', 'quantity'],
      dtype='object')
StandardScaler(copy=True, with_mean=False, with_std=True)
Mean : 311.86518714285717, Standard deviation : 381.568204243382
101
```

2.2.2.2 Vectorizing no. of previously posted projects

In [34]:

```
# check this one: https://www.youtube.com/watch?v=0HOqOcln3Z4&t=530s
# standardization sklearn: https://scikit-
learn.org/stable/modules/generated/sklearn.preprocessing.StandardScaler.html
from sklearn.preprocessing import StandardScaler
import warnings
warnings.filterwarnings("ignore")

prev_proj_scalar = StandardScaler(with_mean=False) #with_mean=False uses mean value as zero, which
helps in avoiding negative values
prev_proj_scalar.fit(df_train['teacher_number_of_previously_posted_projects'].values.reshape(-1,1))
# finding the mean and standard deviation of this data
print(f"Mean : {prev_proj_scalar.mean_[0]}, Standard deviation :
{np.sqrt(prev_proj_scalar.var_[0])}")

# Now standardize the data with above mean and variance.
prev_proj_train_standardized = prev_proj_scalar.transform(df_train['price'].values.reshape(-1, 1))
prev_proj_test_standardized = prev_proj_scalar.transform(df_test['price'].values.reshape(-1, 1))

# Store feature names in a list
feature_names.append('previously posted projects')
feature_names_tfidf = feature_names.copy()
feature_names_bow = feature_names.copy()
```

```
print(len(feature_names_tfidf), len(feature_names_bow))
```

```
Mean : 10.498342857142857, Standard deviation : 27.062927676006062
102 102
```

2.3 Make Data Model Ready: encoding essay, and project_title</h2>

2.3.1 Vectorizing Text data

2.3.1.1 Bag of words for essay text

In [35]:

```
# We are considering only the words which appeared in at least 10 documents(rows or projects).
vectorizer = CountVectorizer(min_df=10)
text_train_bow = vectorizer.fit_transform(df_train['clean_essay'])
text_test_bow = vectorizer.transform(df_test['clean_essay'])
print("Shape of matrix after one hot encoding ",text_train_bow.shape, text_test_bow.shape)

# Store feature names in a list
feature_names_bow.extend(vectorizer.get_feature_names())
print(len(feature_names_bow))
```

```
Shape of matrix after one hot encoding  (35000, 10462) (15000, 10462)
10564
```

In [36]:

```
# you can vectorize the title also
# before you vectorize the title make sure you preprocess it

vectorizer = CountVectorizer(min_df=10)
title_train_bow = vectorizer.fit_transform(df_train['clean_title'])
title_test_bow = vectorizer.transform(df_test['clean_title'])
print("Shape of matrix after one hot encoding ", title_train_bow.shape, title_test_bow.shape)

# Store feature names in a list
feature_names_bow.extend(vectorizer.get_feature_names())
print(len(feature_names_bow))
```

```
Shape of matrix after one hot encoding  (35000, 1580) (15000, 1580)
12144
```

2.3.1.2 TFIDF vectorizer for essay text

In [37]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
vectorizer = TfidfVectorizer(min_df=10)

text_train_tfidf = vectorizer.fit_transform(df_train['clean_essay'])
text_test_tfidf = vectorizer.transform(df_test['clean_essay'])
print("Shape of matrix after one hot encoding ",text_train_tfidf.shape, text_test_tfidf.shape)

# Store feature names in a list
feature_names_tfidf.extend(vectorizer.get_feature_names())
print(len(feature_names_tfidf))
```

```
Shape of matrix after one hot encoding  (35000, 10462) (15000, 10462)
10564
```

In [38]:

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

```
vectorizer = TfidfVectorizer(min_df=10)

title_train_tfidf = vectorizer.fit_transform(df_train['clean_title'])
title_test_tfidf = vectorizer.transform(df_test['clean_title'])

print("Shape of matrix after one hot encodig ",title_train_tfidf.shape, title_test_tfidf.shape)

# Store feature names in a list
feature_names_tfidf.extend(vectorizer.get_feature_names())
print(len(feature_names_tfidf))
```

```
Shape of matrix after one hot encodig  (35000, 1580) (15000, 1580)
12144
```

2.4 Applying Naive Bayes on different kinds of featurizations

2.4.1 Applying Multinomial Naive Bayes on BOW, SET 1

Hyper paramter tuning method: GridSearch

In [39]:

```
#https://www.digitalocean.com/community/tutorials/how-to-plot-data-in-python-3-using-matplotlib
#https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_auc_score.html
#https://scikit-learn.org/stable/modules/model_evaluation.html#scoring-parameter

from scipy.sparse import hstack
from sklearn.model_selection import GridSearchCV
from sklearn.naive_bayes import MultinomialNB
import matplotlib.patches as mpatches
from sklearn.metrics import roc_auc_score

print(type(categories_one_hot_train), type(sub_categories_one_hot_train),
type(grade_cat_one_hot_train),
                  type(teacher_prefix_one_hot_train), type(school_state_one_hot_train), type(price_
train_standardized),
                  type(prev_proj_train_standardized), type(text_train_bow), type(title_train_bow))

x_train = hstack((categories_one_hot_train, sub_categories_one_hot_train,
school_state_one_hot_train,
                  teacher_prefix_one_hot_train, grade_cat_one_hot_train, price_train_standardized,
                  prev_proj_train_standardized, text_train_bow, title_train_bow))
y_train = df_train['project_is_approved']

x_test = hstack((categories_one_hot_test, sub_categories_one_hot_test, school_state_one_hot_test,
                  teacher_prefix_one_hot_test, grade_cat_one_hot_test, price_test_standardized,
                  prev_proj_test_standardized, text_test_bow, title_test_bow))
y_test = df_test['project_is_approved']

print(x_train.shape, type(x_train), y_train.shape, type(y_train))
print(x_test.shape, type(x_test), y_test.shape, type(y_test))
```

```
<class 'scipy.sparse.csr.csr_matrix'> <class 'scipy.sparse.csr.csr_matrix'> <class
'scipy.sparse.csr.csr_matrix'> <class 'scipy.sparse.csr.csr_matrix'> <class
'scipy.sparse.csr.csr_matrix'> <class 'numpy.ndarray'> <class 'numpy.ndarray'> <class
'scipy.sparse.csr.csr_matrix'> <class 'scipy.sparse.csr.csr_matrix'>
(35000, 12144) <class 'scipy.sparse.coo.coo_matrix'> (35000,) <class 'pandas.core.series.Series'>
(15000, 12144) <class 'scipy.sparse.coo.coo_matrix'> (15000,) <class 'pandas.core.series.Series'>
```

In [40]:

```
#https://stackabuse.com/cross-validation-and-grid-search-for-model-selection-in-python/
#https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.GridSearchCV.html

#Initialising Classifier
classifier = MultinomialNB(class_prior=[0.5,0.5])

#Brute force approach for finding best K value
parameters = {'alpha':[0.00001,0.0001,0.001,0.01,1,10,100,1000,10000]}
```

```
#Training the model on train data
MNB_BoW = GridSearchCV(classifier, parameters, cv=10, scoring='roc_auc', n_jobs=-1)
MNB_BoW.fit(x_train, y_train)
```

Out[40]:

```
GridSearchCV(cv=10, error_score='raise-deprecating',
       estimator=MultinomialNB(alpha=1.0, class_prior=[0.5, 0.5], fit_prior=True),
       fit_params=None, iid='warn', n_jobs=-1,
       param_grid={'alpha': [1e-05, 0.0001, 0.001, 0.01, 1, 10, 100, 1000, 10000]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
       scoring='roc_auc', verbose=0)
```

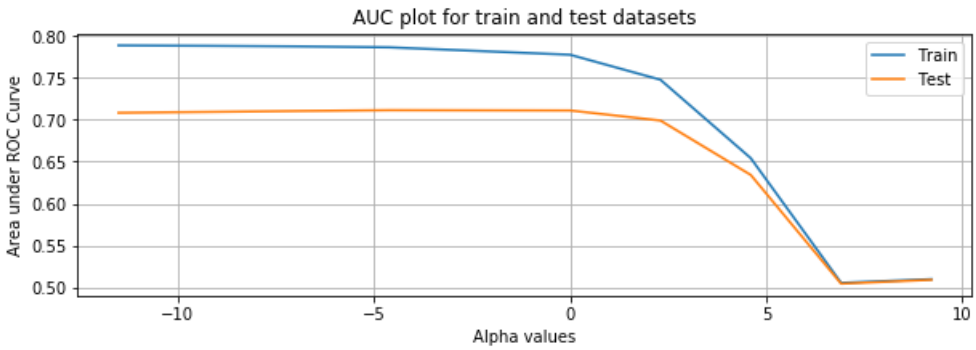
In [0]:

```
import dill
#dill.dump_session('sess_knn.pckl')
#dill.load_session('sess_knn.pckl')
```

In [42]:

```
#https://matplotlib.org/api/_as_gen/matplotlib.pyplot.plot.html

print(MNB_BoW.best_params_) #Gives the best value of K from the given neighbor range
print(MNB_BoW.cv_results_['mean_train_score'])
print(MNB_BoW.cv_results_['mean_test_score'])
print(parameters['alpha'])

log_params = []
for i in parameters['alpha']:
  log_params.append(math.log(i))

print(log_params)

plt.figure(figsize=(10,3))
plt.plot(log_params,MNB_BoW.cv_results_['mean_train_score'], label="Train")
plt.plot(log_params,MNB_BoW.cv_results_['mean_test_score'], label="Test")
plt.title('AUC plot for train and test datasets')
plt.xlabel('Alpha values')
plt.ylabel('Area under ROC Curve')
plt.legend()
plt.grid()
plt.show()
plt.close()
```

```
{'alpha': 0.01}
[0.78867121 0.78820869 0.78749613 0.78638633 0.77756267 0.74772221
 0.65418477 0.50546424 0.50988099]
[0.70833562 0.70936168 0.71044844 0.71140283 0.7110712  0.69907235
 0.63416119 0.50444176 0.50907605]
[1e-05, 0.0001, 0.001, 0.01, 1, 10, 100, 1000, 10000]
[-11.512925464970229, -9.210340371976182, -6.907755278982137, -4.605170185988091, 0.0,
2.302585092994046, 4.605170185988092, 6.907755278982137, 9.210340371976184]
```



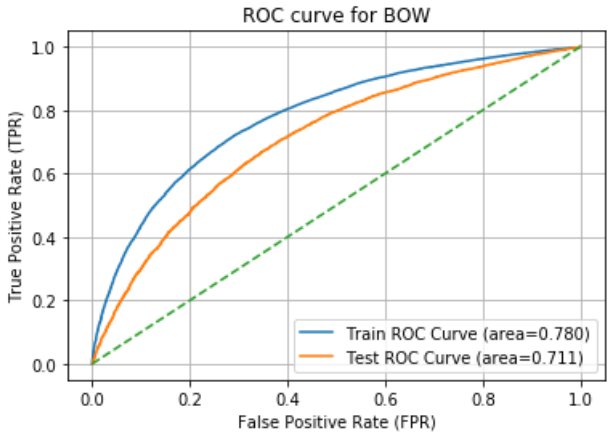
In [0]:

```
#https://datascience.stackexchange.com/questions/22762/understanding-predict-proba-from-
multioutputclassifier
```

```
#https://stackoverflow.com/questions/34894587/should-we-plot-the-roc-curve-for-each-class

from sklearn.metrics import roc_curve, auc

#training the model on the best K value found in the above result
final_MNB_BoW = MultinomialNB(alpha=0.01, class_prior=[0.5,0.5])
final_MNB_BoW.fit(x_train,y_train)

x_train_csr=x_train.tocsr()
x_test_csr=x_test.tocsr()

y_train_pred=[]
y_test_pred=[]

#ROC curve function takes the actual values and the predicted probabilities of the positive class
for i in range(0,x_train.shape[0]):
    y_train_pred.extend(final_MNB_BoW.predict_proba(x_train_csr[i])[:,1]) #[:,1] gives the probabil
ity for class 1

for i in range(0,x_test.shape[0]):
    y_test_pred.extend(final_MNB_BoW.predict_proba(x_test_csr[i])[:,1])
```

In [62]:

```
#https://matplotlib.org/api/_as_gen/matplotlib.pyplot.plot.html
#https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html
#https://www.programcreek.com/python/example/81207/sklearn.metrics.roc_curve
#https://scikit-learn.org/stable/modules/generated/sklearn.metrics.auc.html

#Calculating FPR and TPR for train and test data
train_fpr, train_tpr, train_thresholds = roc_curve(y_train, y_train_pred)
test_fpr, test_tpr, test_thresholds = roc_curve(y_test, y_test_pred)

#Calculating AUC for train and test curves
roc_auc_train=auc(train_fpr,train_tpr)
roc_auc_test=auc(test_fpr,test_tpr)

plt.plot(train_fpr, train_tpr, label="Train ROC Curve (area=%0.3f)" % roc_auc_train)
plt.plot(test_fpr, test_tpr, label="Test ROC Curve (area=%0.3f)" % roc_auc_test)
plt.plot([0,1],[0,1],linestyle='--')
plt.legend()
plt.xlabel("False Positive Rate (FPR)")
plt.ylabel("True Positive Rate (TPR)")
plt.title("ROC curve for BOW")
plt.grid()

plt.show()
plt.close()
```



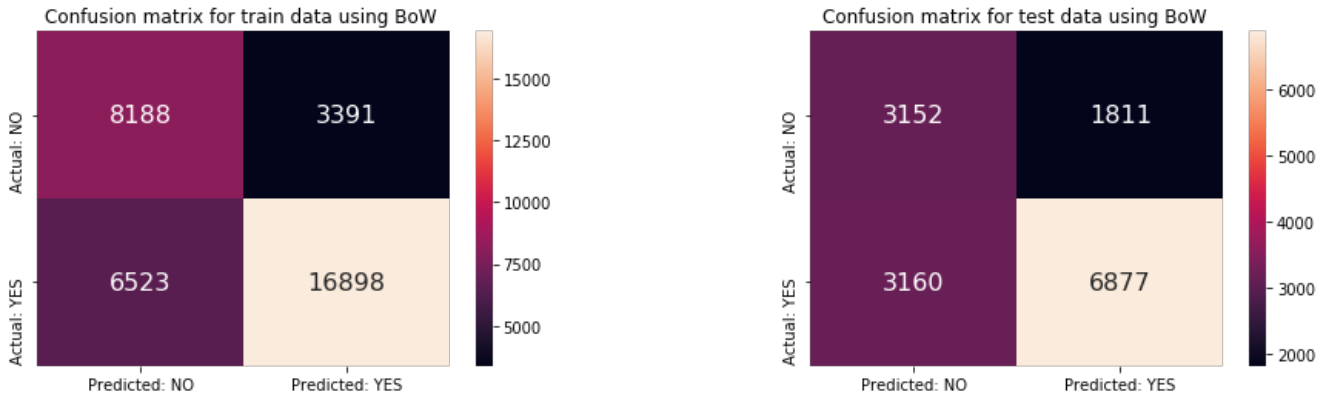
In [0]:

```
#https://stackoverflow.com/questions/35572000/how-can-i-plot-a-confusion-matrix
#https://scikit-learn.org/stable/modules/generated/sklearn.metrics.confusion_matrix.html
#https://datatofish.com/confusion-matrix-python/

from sklearn.metrics import confusion_matrix as cf_mx
```

```
expected_train = y_train.values
predicted_train = final_MNB_BoW.predict(x_train)

expected_test = y_test.values
predicted_test = final_MNB_BoW.predict(x_test)
```

In [64]:

```
plt.subplots(figsize=(15,4))
plt.subplot(1,2,1)
cmdf_train=cf_mx(expected_train, predicted_train)
df_cm_train = pd.DataFrame(cmdf_train, range(2),range(2))
df_cm_train.columns = ['Predicted: NO','Predicted: YES']
df_cm_train = df_cm_train.rename({0: 'Actual: NO', 1: 'Actual: YES'})
sns.heatmap(df_cm_train, annot=True,annot_kws={"size": 16}, fmt='g')
plt.title('Confusion matrix for train data using BoW ')

plt.subplot(1,2,2)
cmdf_test=cf_mx(expected_test, predicted_test)
df_cm_test = pd.DataFrame(cmdf_test, range(2),range(2))
df_cm_test.columns = ['Predicted: NO','Predicted: YES']
df_cm_test = df_cm_test.rename({0: 'Actual: NO', 1: 'Actual: YES'})
sns.heatmap(df_cm_test, annot=True,annot_kws={"size": 16}, fmt='g')
plt.title('Confusion matrix for test data using BoW ')
plt.subplots_adjust(wspace=0.5)
plt.show()
plt.close()
```



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

In [65]:

```
# Computing log probabilities for each of the features(in the order mentioned in hstack)

log_prob_pred_bow = []

feat_cnt=len(feature_names_bow)

print(len(feature_names_bow))

for i in range(feat_cnt):
    log_prob_pred_bow.append(final_MNB_BoW.feature_log_prob_[1][i]) #[1] gives the probability for
class 1

print(len(feature_names_bow), len(log_prob_pred_bow))

top10_bow_1 = pd.DataFrame({'Feature':feature_names_bow, 'Log_Probability':log_prob_pred_bow})

top10_bow_1 = top10_bow_1.sort_values('Log_Probability',ascending=False)

print(top10_bow_1[:10])
```

```
12144
12144 12144
                       Feature  Log_Probability
101   previously posted projects        -2.674692
9155                    students        -3.053412
```

```
8325                    school        -4.195063
5529                  learning        -4.567294
1856                 classroom        -4.588665
6430                       not        -4.855144
5525                     learn        -4.911208
4579                      help        -4.940753
5848                      many        -5.071632
6284                    nannan        -5.089561
```

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

In [66]:

```
# Computing log probabilities for each of the features(in the order mentioned in hstack)

log_prob_pred_bow = []

for i in range(feat_cnt):
    log_prob_pred_bow.append(final_MNB_BoW.feature_log_prob_[0][i]) #[0] gives the probability for
class 0

print(len(feature_names_bow), len(log_prob_pred_bow))

top10_bow_0 = pd.DataFrame({'Feature':feature_names_bow, 'Log_Probability':log_prob_pred_bow})

top10_bow_0 = top10_bow_0.sort_values('Log_Probability',ascending=False)

print(top10_bow_0[:10])
```

```
12144 12144
                       Feature  Log_Probability
101   previously posted projects        -2.431473
9155                    students        -3.088936
8325                      school        -4.183340
5529                    learning        -4.499058
1856                   classroom        -4.667664
6430                         not        -4.843214
5525                       learn        -4.861252
4579                        help        -4.902275
6284                      nannan        -5.057097
100                        price        -5.077597
```

2.4.2 Applying Naive Bayes on TFIDF, SET 2

Hyper paramter tuning method: GridSearch

In [49]:

```
#https://www.digitalocean.com/community/tutorials/how-to-plot-data-in-python-3-using-matplotlib
#https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_auc_score.html
#https://scikit-learn.org/stable/modules/model_evaluation.html#scoring-parameter

from scipy.sparse import hstack
from sklearn.model_selection import GridSearchCV
from sklearn.naive_bayes import MultinomialNB
import matplotlib.patches as mpatches
from sklearn.metrics import roc_auc_score

x_train_tfidf = hstack((categories_one_hot_train, sub_categories_one_hot_train,
grade_cat_one_hot_train,
                  teacher_prefix_one_hot_train, school_state_one_hot_train,
price_train_standardized,
                  prev_proj_train_standardized, text_train_tfidf, title_train_tfidf))
y_train_tfidf = df_train['project_is_approved']

x_test_tfidf = hstack((categories_one_hot_test, sub_categories_one_hot_test,
grade_cat_one_hot_test,
                  teacher_prefix_one_hot_test, school_state_one_hot_test, price_test_standardized,
                  prev_proj_test_standardized, text_test_tfidf, title_test_tfidf))
y_test_tfidf = df_test['project_is_approved']
```

```
print(x_train_tfidf.shape, type(x_train_tfidf), y_train_tfidf.shape, type(y_train_tfidf))
print(x_test_tfidf.shape, type(x_test_tfidf), y_test_tfidf.shape, type(y_test_tfidf))
```

```
(35000, 12144) <class 'scipy.sparse.coo.coo_matrix'> (35000,) <class 'pandas.core.series.Series'>
(15000, 12144) <class 'scipy.sparse.coo.coo_matrix'> (15000,) <class 'pandas.core.series.Series'>
```

In [50]:

```
#https://stackabuse.com/cross-validation-and-grid-search-for-model-selection-in-python/
#https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.GridSearchCV.html

#Initialising Classifier
classifier = MultinomialNB(class_prior=[0.5,0.5])

#Brute force approach for finding best K value
parameters = {'alpha':[0.00001,0.0001,0.001,0.01,1,10,100,1000,10000]}

#Training the model on train data
MNB_tfidf = GridSearchCV(classifier, parameters, cv=10, scoring='roc_auc', n_jobs=-1)
MNB_tfidf.fit(x_train_tfidf, y_train_tfidf)
```

Out[50]:

```
GridSearchCV(cv=10, error_score='raise-deprecating',
       estimator=MultinomialNB(alpha=1.0, class_prior=[0.5, 0.5], fit_prior=True),
       fit_params=None, iid='warn', n_jobs=-1,
       param_grid={'alpha': [1e-05, 0.0001, 0.001, 0.01, 1, 10, 100, 1000, 10000]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
       scoring='roc_auc', verbose=0)
```

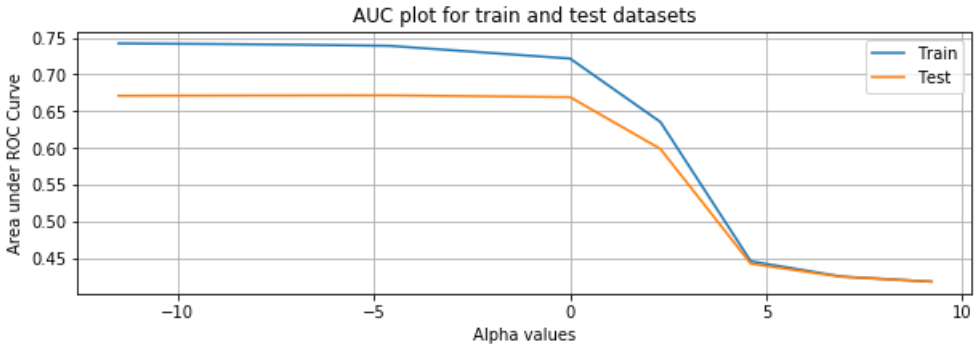
In [0]:

```
import dill
#dill.dump_session('sess_knn.pckl')
#dill.load_session('sess_knn.pckl')
```

In [52]:

```
#https://matplotlib.org/api/_as_gen/matplotlib.pyplot.plot.html

print(MNB_tfidf.best_params_) #Gives the best value of K from the given neighbor range
print(MNB_tfidf.cv_results_['mean_train_score'])
print(MNB_tfidf.cv_results_['mean_test_score'])
print(parameters['alpha'])

log_params = []
for i in parameters['alpha']:
  log_params.append(math.log(i))

print(log_params)

plt.figure(figsize=(10,3))
plt.plot(log_params,MNB_tfidf.cv_results_['mean_train_score'], label="Train")
plt.plot(log_params,MNB_tfidf.cv_results_['mean_test_score'], label="Test")
plt.title('AUC plot for train and test datasets')
plt.xlabel('Alpha values')
plt.ylabel('Area under ROC Curve')
plt.legend()
plt.grid()
plt.show()
plt.close()
```

```
{'alpha': 0.01}
[0.74212412 0.74138198 0.74037618 0.7388522  0.72151066 0.63520649
 0.44566702 0.42498151 0.41787934]
[0.67089247 0.67116761 0.67135976 0.67148636 0.66900025 0.59850255
 0.44232707 0.42453841 0.4179122 ]
[1e-05, 0.0001, 0.001, 0.01, 1, 10, 100, 1000, 10000]
[-11.512925464970229, -9.210340371976182, -6.907755278982137, -4.605170185988091, 0.0,
2.302585092994046, 4.605170185988092, 6.907755278982137, 9.210340371976184]
```

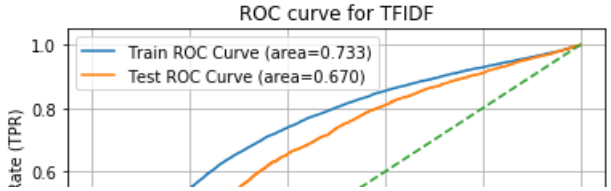


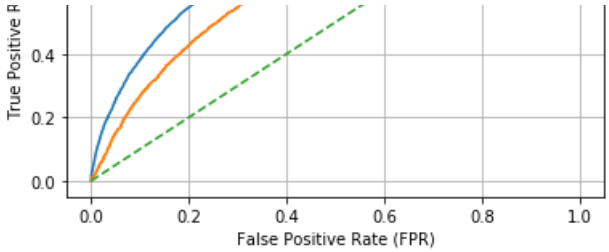
In [0]:

```
#https://datascience.stackexchange.com/questions/22762/understanding-predict-proba-from-
multioutputclassifier
#https://stackoverflow.com/questions/34894587/should-we-plot-the-roc-curve-for-each-class

from sklearn.metrics import roc_curve, auc

#training the model on the best K value found in the above result
final_MNB_tfidf = MultinomialNB(alpha=0.01, class_prior=[0.5,0.5])
final_MNB_tfidf.fit(x_train_tfidf,y_train_tfidf)

x_train_tfidf_csr=x_train_tfidf.tocsr()
x_test_tfidf_csr=x_test_tfidf.tocsr()

y_train_tfidf_pred=[]
y_test_tfidf_pred=[]

#ROC curve function takes the actual values and the predicted probabilities of the positive class
for i in range(0,x_train_tfidf.shape[0]):
    y_train_tfidf_pred.extend(final_MNB_tfidf.predict_proba(x_train_tfidf_csr[i])[:,1]) #[:,1] give
s the probability for class 1

for i in range(0,x_test_tfidf.shape[0]):
    y_test_tfidf_pred.extend(final_MNB_tfidf.predict_proba(x_test_tfidf_csr[i])[:,1])
```

In [54]:

```
#https://matplotlib.org/api/_as_gen/matplotlib.pyplot.plot.html
#https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html
#https://www.programcreek.com/python/example/81207/sklearn.metrics.roc_curve
#https://scikit-learn.org/stable/modules/generated/sklearn.metrics.auc.html

#Calculating FPR and TPR for train and test data
train_fpr, train_tpr, train_thresholds = roc_curve(y_train_tfidf, y_train_tfidf_pred)
test_fpr, test_tpr, test_thresholds = roc_curve(y_test_tfidf, y_test_tfidf_pred)

#Calculating AUC for train and test curves
roc_auc_train=auc(train_fpr,train_tpr)
roc_auc_test=auc(test_fpr,test_tpr)

plt.plot(train_fpr, train_tpr, label="Train ROC Curve (area=%0.3f)" % roc_auc_train)
plt.plot(test_fpr, test_tpr, label="Test ROC Curve (area=%0.3f)" % roc_auc_test)
plt.plot([0,1],[0,1],linestyle='--')
plt.legend()
plt.xlabel("False Positive Rate (FPR)")
plt.ylabel("True Positive Rate (TPR)")
plt.title("ROC curve for TFIDF")
plt.grid()

plt.show()
plt.close()
```



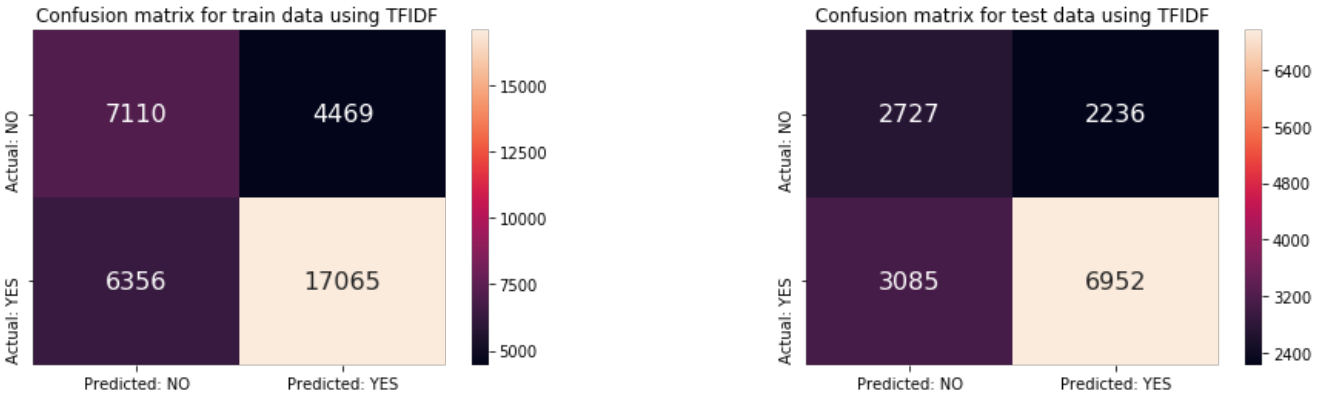


In [0]:

```
#https://stackoverflow.com/questions/35572000/how-can-i-plot-a-confusion-matrix
#https://scikit-learn.org/stable/modules/generated/sklearn.metrics.confusion_matrix.html
#https://datatofish.com/confusion-matrix-python/

from sklearn.metrics import confusion_matrix as cf_mx

expected_train_tfidf = y_train_tfidf.values
predicted_train_tfidf = final_MNB_tfidf.predict(x_train_tfidf)

expected_test_tfidf = y_test_tfidf.values
predicted_test_tfidf = final_MNB_tfidf.predict(x_test_tfidf)
```

In [56]:

```
plt.subplots(figsize=(15,4))
plt.subplot(1,2,1)
cmdf_train=cf_mx(expected_train_tfidf, predicted_train_tfidf)
df_cm_train = pd.DataFrame(cmdf_train, range(2),range(2))
df_cm_train.columns = ['Predicted: NO','Predicted: YES']
df_cm_train = df_cm_train.rename({0: 'Actual: NO', 1: 'Actual: YES'})
sns.heatmap(df_cm_train, annot=True,annot_kws={"size": 16}, fmt='g')
plt.title('Confusion matrix for train data using TFIDF ')

plt.subplot(1,2,2)
cmdf_test=cf_mx(expected_test_tfidf, predicted_test_tfidf)
df_cm_test = pd.DataFrame(cmdf_test, range(2),range(2))
df_cm_test.columns = ['Predicted: NO','Predicted: YES']
df_cm_test = df_cm_test.rename({0: 'Actual: NO', 1: 'Actual: YES'})
sns.heatmap(df_cm_test, annot=True,annot_kws={"size": 16}, fmt='g')
plt.title('Confusion matrix for test data using TFIDF')
plt.subplots_adjust(wspace=0.5)
plt.show()
plt.close()
```



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

In [57]:

```
# Computing log probabilities for each of the features(in the order mentioned in hstack)

log_prob_pred_tfidf  = []

for i in range(feat_cnt):
    log_prob_pred_tfidf.append(final_MNB_tfidf.feature_log_prob_[1][i]) #[1] gives the probability
```

```
for class 1

print(len(feature_names_tfidf), len(log_prob_pred_tfidf))

top10_tfidf_1 = pd.DataFrame({'Feature':feature_names_tfidf, 'Log_Probability':log_prob_pred_tfidf
})

top10_tfidf_1 = top10_tfidf_1.sort_values('Log_Probability',ascending=False)

print(top10_tfidf_1[:10])
```

```
12144 12144
                        Feature  Log_Probability
101   previously posted projects        -0.877998
100                        price        -3.524123
8              Literacy_Language        -3.965544
7                   Math_Science        -4.238369
38                       Literacy        -4.387511
37                    Mathematics        -4.617956
36             Literature_Writing        -4.835860
50                             CO        -5.223306
9155                     students        -5.265257
6                  Health_Sports        -5.283257
```

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

In [58]:

```
# Computing log probabilities for each of the features(in the order mentioned in hstack)

log_prob_pred_tfidf  = []

for i in range(feat_cnt):
    log_prob_pred_tfidf.append(final_MNB_tfidf.feature_log_prob_[0][i]) #[0] gives the probability
for class 0

print(len(feature_names_tfidf), len(log_prob_pred_tfidf))

top10_tfidf_0 = pd.DataFrame({'Feature':feature_names_tfidf, 'Log_Probability':log_prob_pred_tfidf
})

top10_tfidf_0 = top10_tfidf_0.sort_values('Log_Probability',ascending=False)

print(top10_tfidf_0[:10])
```

```
12144 12144
                        Feature  Log_Probability
101  previously posted projects        -0.761413
100                        price        -3.407537
8              Literacy_Language        -4.196183
7                   Math_Science        -4.263770
37                    Mathematics        -4.689304
38                       Literacy        -4.691633
36             Literature_Writing        -4.993854
35                   SpecialNeeds        -5.331587
5                    SpecialNeeds        -5.331587
50                             CO        -5.364335
```

3. Conclusions

In [68]:

```
#http://zetcode.com/python/prettytable/

from prettytable import PrettyTable

x = PrettyTable()

x.field_names = ["Vectorizer", "Model", "Hyper parameter(K)", "AUC(Train Data)", "AUC(Test Data)"]

x.add_row(["BoW", "Brute", 0.01, 0.780, 0.711])
```

```
x.add_row(["TFIDF", "Brute", 0.01, 0.733, 0.670])

print(x)
```

```
+------------+-------+--------------------+-----------------+----------------+
| Vectorizer | Model | Hyper parameter(K) | AUC(Train Data) | AUC(Test Data) |
+------------+-------+--------------------+-----------------+----------------+
|    BoW     | Brute |        0.01        |       0.78      |     0.711      |
|   TFIDF    | Brute |        0.01        |      0.733      |      0.67      |
+------------+-------+--------------------+-----------------+----------------+
```

The results are better compared to KNN and the train and run times are significantly lower than KNN.