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
`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`

Feature	Description
	• `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*
`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."

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 [160]:

```
%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 [161]:

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

In [162]:

```
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 [163]:

```
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[163]:

	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

In [164]:

```
# 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[164]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	Date	project_grade_cate
55660	8393	p205479	2bf07ba08945e5d8b2a3f269b2b3cfe5	Mrs.	CA	2016-04-27 00:27:36	Grades PreK-2
76127	37728	p043609	3f60494c61921b3b43ab61bdde2904df	Ms.	UT	2016-04-27 00:31:25	Grades 3-5

In [165]:

```
project_grade_category = []

for i in range(len(project_data)):
    a = project_data["project_grade_category"][i].replace(" ", "_")
    project_grade_category.append(a)
```

In [166]:

```
project_grade_category[0:5]
```

Out[166]:

```
['Grades_PreK-2', 'Grades_6-8', 'Grades_6-8', 'Grades_PreK-2', 'Grades_PreK-2']
```

In [167]:

```
project_data.drop(['project_grade_category'], axis=1, inplace=True)
```

```
project_data.drop(['project_grade_category'], axis=1, inplace=True)
```

In [168]:

```
project_data["project_grade_category"] = project_grade_category
```

In [169]:

```
project_data.head(5)
```

Out[169]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	Date	project_subject_ca
55660	8393	p205479	2bf07ba08945e5d8b2a3f269b2b3cfe5	Mrs.	CA	2016-04-27 00:27:36	Math & Science
76127	37728	p043609	3f60494c61921b3b43ab61bdde2904df	Ms.	UT	2016-04-27 00:31:25	Special Needs
51140	74477	p189804	4a97f3a390bfe21b99cf5e2b81981c73	Mrs.	CA	2016-04-27 00:46:53	Literacy & Language
473	100660	p234804	cbc0e38f522143b86d372f8b43d4cff3	Mrs.	GA	2016-04-27 00:53:00	Applied Learning
41558	33679	p137682	06f6e62e17de34fcf81020c77549e1d5	Mrs.	WA	2016-04-27 01:05:25	Literacy & Language

1.2 Preprocessing of `project_subject_categories`

In [170]:

```
catogories = 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 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('&','_') # we are replacing the & value into
    cat_list.append(temp.strip())

project_data['clean_categories'] = cat_list
```

```
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 [171]:

```
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]))
```

1.4 Clean Titles (Text preprocessing)

In [172]:

```
# 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 [173]:

```
# 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 [174]:

```
clean_titles = []

for titles in tqdm(project_data["project_title"]):
    title = decontracted(titles)
    title = title.replace('\\r', ' ')
    title = title.replace('\\"', ' ')
    title = title.replace('\\n', ' ')
    title = re.sub('[^A-Za-z0-9]+', ' ', title)
    title = ' '.join(f for f in title.split() if f not in stopwords)
    clean_titles.append(title.lower().strip())
```

```
100%|██████████████████████████████████████████████████████████████████████████| 109248/109248
[00:04<00:00, 22001.47it/s]
```

In [175]:

```
project_data["clean_titles"] = clean_titles
```

In [176]:

```
project_data.drop(['project_title'], axis=1, inplace=True)
```

1.5 Introducing new feature "Number of Words in Title"

In [177]:

```
title_word_count = []
```

In [178]:

```
for a in project_data["clean_titles"] :
    b = len(a.split())
    title word count.append(b)
```

In [179]:

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

In [180]:

```
project_data.head(5)
```

Out[180]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	Date	project_essay_1	p
55660	8393	p205479	2bf07ba08945e5d8b2a3f269b2b3cfe5	Mrs.	CA	2016-04-27 00:27:36	I have been fortunate enough to use the Fairy ...	M c v b
76127	37728	p043609	3f60494c61921b3b43ab61bdde2904df	Ms.	UT	2016-04-27 00:31:25	Imagine being 8-9 years old. You're in your th...	M s a a
51140	74477	p189804	4a97f3a390bfe21b99cf5e2b81981c73	Mrs.	CA	2016-04-27 00:46:53	Having a class of 24 students comes with diver...	I t k s
473	100660	p234804	cbc0e38f522143b86d372f8b43d4cff3	Mrs.	GA	2016-04-27 00:53:00	I recently read an article about giving studen...	I i s
41558	33679	p137682	06f6e62e17de34fcf81020c77549e1d5	Mrs.	WA	2016-04-27 01:05:25	My students crave challenge, they eat obstacle...	W p e s

1.6 Combine 4 Project essays into 1 Essay

In [181]:

```
# 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)
```

1.7 Clean Essays (Text preprocessing)

In [182]:

```
clean_essay = []

for ess in tqdm(project_data["essay"]):
    ess = decontracted(ess)
    ess = ess.replace('\\r', ' ')
    ess = ess.replace('\\"', ' ')
    ess = ess.replace('\\n', ' ')
    ess = re.sub('[^A-Za-z0-9]+', ' ', ess)
    ess = ' '.join(f for f in ess.split() if f not in stopwords)
    clean_essay.append(ess.lower().strip())
```

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```
[02:20<00:00, 775.27it/s]
```

In [183]:

```
project_data["clean_essays"] = clean_essay
```

In [184]:

```
project_data.drop(['essay'], axis=1, inplace=True)
```

1.8 Introducing new feature "Number of Words in Essay"

In [185]:

```
essay_word_count = []
```

In [186]:

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

In [187]:

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

In [188]:

```
project_data.head(5)
```

Out[188]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	Date	project_essay_1	p
55660	8393	p205479	2bf07ba08945e5d8b2a3f269b2b3cfe5	Mrs.	CA	2016-04-27 00:27:36	I have been fortunate enough to use the Fairy ...	M c v b
76127	37728	p043609	3f60494c61921b3b43ab61bdde2904df	Ms.	UT	2016-04-27 00:31:25	Imagine being 8-9 years old. You're in your th...	M s a a
51140	74477	p189804	4a97f3a390bfe21b99cf5e2b81981c73	Mrs.	CA	2016-04-27 00:46:53	Having a class of 24 students comes with diver...	I t k s
473	100660	p234804	cbc0e38f522143b86d372f8b43d4cff3	Mrs.	GA	2016-04-27 00:53:00	I recently read an article about giving studen...	I i s
41558	33679	p137682	06f6e62e17de34fcf81020c77549e1d5	Mrs.	WA	2016-04-27 01:05:25	My students crave challenge, they eat obstacle...	W p e s

1.9 Calculate Sentiment Scores for the essays

In [35]:

```
import nltk
nltk.downloader.download('vader_lexicon')
from nltk.sentiment.vader import SentimentIntensityAnalyzer
```

```
[nltk_data] Downloading package vader_lexicon to
[nltk_data]     C:\Users\sidda.p\AppData\Roaming\nltk_data...
```

In [36]:

```
analyser = SentimentIntensityAnalyzer()
```

In [37]:

```
neg = []
pos = []
neu = []
compound = []

for a in tqdm(project_data["clean_essays"]) :
    b = analyser.polarity_scores(a)['neg']
    c = analyser.polarity_scores(a)['pos']
    d = analyser.polarity_scores(a)['neu']
    e = analyser.polarity_scores(a)['compound']
    neg.append(b)
    pos.append(c)
    neu.append(d)
    compound.append(e)
```

```
100%|██████████████████████████████████████████████████████████████████████████████| 109248/109248 [36:12<00:00, 50.29it/s]
```

In [ ]:

```
project_data["pos"] = pos
```

In [37]:

```
project_data["neg"] = neg
```

In [38]:

```
project_data["neu"] = neu
```

In [39]:

```
project_data["compound"] = compound
```

In [189]:

```
project_data.head(5)
```

Out[189]:

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	Date	project_essay_1	p
55660	8393	p205479	2bf07ba08945e5d8b2a3f269b2b3cfe5	Mrs.	CA	2016-04-27 00:27:36	I have been fortunate enough to use the Fairy ...	M c v b
76127	37728	p043609	3f60494c61921b3b43ab61bdde2904df	Ms.	UT	2016-04-27 00:31:25	Imagine being 8-9 years old. You're in your	M s a

	Unnamed: 0	id	teacher_id	teacher_prefix	school_state	Date	th... project_essay_1	a p
51140	74477	p189804	4a97f3a390bfe21b99cf5e2b81981c73	Mrs.	CA	2016-04-27 00:46:53	Having a class of 24 students comes with diver...	H tw ki st
473	100660	p234804	cbc0e38f522143b86d372f8b43d4cff3	Mrs.	GA	2016-04-27 00:53:00	I recently read an article about giving studen...	I t in so
41558	33679	p137682	06f6e62e17de34fcf81020c77549e1d5	Mrs.	WA	2016-04-27 01:05:25	My students crave challenge, they eat obstacle...	W pu el so

1.10 Test - Train Split

In [190]:

```
# train test split

from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(project_data,
project_data['project_is_approved'],test_size=0.33, stratify = project_data['project_is_approved']
)
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train, test_size=0.33, stratify=y_train)
```

In [191]:

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

Project_grade preprocessing

In [192]:

```
project_data['project_grade_category'][:4]
```

Out[192]:

```
55660    Grades_PreK-2
76127       Grades_6-8
51140       Grades_6-8
473      Grades_PreK-2
Name: project_grade_category, dtype: object
```

In [193]:

```
project_data['project_grade_category'] = project_data['project_grade_category'].str.replace(" ", "_
")
project_data['project_grade_category'].value_counts()
```

Out[193]:

```
Grades_PreK-2    44225
Grades_3-5       37137
Grades_6-8       16923
Grades_9-12      10963
Name: project_grade_category, dtype: int64
```

teacher_prefix preprocessing

In [194]:

```
project_data['teacher_prefix'][0:4]
```

Out[194]:

```
55660    Mrs.
76127     Ms.
51140    Mrs.
473      Mrs.
Name: teacher_prefix, dtype: object
```

In [196]:

```
project_data['teacher_prefix']=project_data['teacher_prefix'].str.replace(".","")
project_data['teacher_prefix']=project_data['teacher_prefix'].str.replace("nan","")
project_data['teacher_prefix'].value_counts()
```

Out[196]:

```
Mrs        57269
Ms         38955
Mr         10648
Teacher     2360
Dr            13
Name: teacher_prefix, dtype: int64
```

Preparing data for models

In [197]:

```
project_data.columns
```

Out[197]:

```
Index(['Unnamed: 0', 'id', 'teacher_id', 'teacher_prefix', 'school_state',
       'Date', 'project_essay_1', 'project_essay_2', 'project_essay_3',
       'project_essay_4', 'project_resource_summary',
       'teacher_number_of_previously_posted_projects', 'project_is_approved',
       'project_grade_category', 'clean_categories', 'clean_subcategories',
       'clean_titles', 'title_word_count', 'clean_essays', 'essay_word_count'],
      dtype='object')
```

we are going to consider

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

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

- quantity : numerical (optional)
- teacher_number_of_previously_posted_projects : numerical
- price : numerical
- title_word_count : numerical
- essay_word_count : numerical
- essay sentiment [positive] : numerical
- essay sentiment [negative] : numerical
- essay sentiment [neutral] : numerical
- essay sentiment [compound] : numerical
```

2.1 Vectorizing Categorical data

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

One Hot Encode - Clean Categories of Projects

In [198]:

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

from sklearn.feature_extraction.text import CountVectorizer

vectorizer_proj = CountVectorizer(vocabulary=list(sorted_cat_dict.keys()), lowercase=False, binary
=True)
vectorizer_proj.fit(X_train['clean_categories'].values)

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

print(vectorizer_proj.get_feature_names())

print("Shape of matrix of Train data after one hot encoding ",categories_one_hot_train.shape)
print("Shape of matrix of Test data after one hot encoding ",categories_one_hot_test.shape)
print("Shape of matrix of CV data after one hot encoding ",categories_one_hot_cv.shape)
```

```
['Warmth', 'Care_Hunger', 'History_Civics', 'Music_Arts', 'AppliedLearning', 'SpecialNeeds',
'Health_Sports', 'Math_Science', 'Literacy_Language']
Shape of matrix of Train data after one hot encoding  (49041, 9)
Shape of matrix of Test data after one hot encoding  (36052, 9)
Shape of matrix of CV data after one hot encoding  (24155, 9)
```

One Hot Encode - Clean Sub-Categories of Projects

In [199]:

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

vectorizer_sub_proj = CountVectorizer(vocabulary=list(sorted_sub_cat_dict.keys()), lowercase=False
, binary=True)
vectorizer_sub_proj.fit(X_train['clean_subcategories'].values)

sub_categories_one_hot_train = vectorizer_sub_proj.transform(X_train['clean_subcategories'].values
)
sub_categories_one_hot_test = vectorizer_sub_proj.transform(X_test['clean_subcategories'].values)
sub_categories_one_hot_cv = vectorizer_sub_proj.transform(X_cv['clean_subcategories'].values)


print(vectorizer_sub_proj.get_feature_names())

print("Shape of matrix of Train data after one hot encoding ",sub_categories_one_hot_train.shape)
print("Shape of matrix of Test data after one hot encoding ",sub_categories_one_hot_test.shape)
print("Shape of matrix of Cross Validation data after one hot encoding ",sub_categories_one_hot_cv
.shape)
```

```
['Economics', 'CommunityService', 'FinancialLiteracy', 'ParentInvolvement', 'Extracurricular',
'Civics_Government', 'ForeignLanguages', 'NutritionEducation', '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 of Train data after one hot encoding  (49041, 30)
Shape of matrix of Test data after one hot encoding  (36052, 30)
Shape of matrix of Cross Validation data after one hot encoding  (24155, 30)
```

One Hot Encode - School States

In [200]:

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

In [201]:

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

In [202]:

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

vectorizer_states = CountVectorizer(vocabulary=list(sorted_school_state_cat_dict.keys()),
lowercase=False, binary=True)
vectorizer_states.fit(X_train['school_state'].values)

school_state_categories_one_hot_train = vectorizer_states.transform(X_train['school_state'].values
)
school_state_categories_one_hot_test = vectorizer_states.transform(X_test['school_state'].values)
school_state_categories_one_hot_cv = vectorizer_states.transform(X_cv['school_state'].values)

print(vectorizer_states.get_feature_names())

print("Shape of matrix of Train data after one hot encoding
",school_state_categories_one_hot_train.shape)
print("Shape of matrix of Test data after one hot encoding ",school_state_categories_one_hot_test.
shape)
print("Shape of matrix of Cross Validation data after one hot encoding
",school_state_categories_one_hot_cv.shape)
```

```
['VT', 'WY', 'ND', 'MT', 'RI', 'SD', 'NE', 'DE', 'AK', 'NH', 'WV', 'ME', 'HI', 'DC', 'NM', 'KS', 'I
A', '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 of Train data after one hot encoding  (49041, 51)
Shape of matrix of Test data after one hot encoding  (36052, 51)
Shape of matrix of Cross Validation data after one hot encoding  (24155, 51)
```

One Hot Encode - Project Grade Category

In [203]:

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

In [204]:

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

In [205]:

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

vectorizer_grade = CountVectorizer(vocabulary=list(sorted_project_grade_cat_dict.keys()),
lowercase=False, binary=True)
vectorizer_grade.fit(X_train['project_grade_category'].values)

project_grade_categories_one_hot_train =
vectorizer_grade.transform(X_train['project_grade_category'].values)
project_grade_categories_one_hot_test = vectorizer_grade.transform(X_test['project_grade_category'
].values)
project_grade_categories_one_hot_cv = vectorizer_grade.transform(X_cv['project_grade_category'].va
lues)
```

```
print(vectorizer_grade.get_feature_names())

print("Shape of matrix of Train data after one hot encoding
",project_grade_categories_one_hot_train.shape)
print("Shape of matrix of Test data after one hot encoding ",project_grade_categories_one_hot_test
.shape)
print("Shape of matrix of Cross Validation data after one hot encoding
",project_grade_categories_one_hot_cv.shape)
```

```
['Grades_9-12', 'Grades_6-8', 'Grades_3-5', 'Grades_PreK-2']
Shape of matrix of Train data after one hot encoding  (49041, 4)
Shape of matrix of Test data after one hot encoding  (36052, 4)
Shape of matrix of Cross Validation data after one hot encoding  (24155, 4)
```

One Hot Encode - Teacher Prefix

In [206]:

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

In [207]:

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

In [208]:

```
vectorizer = CountVectorizer()
vectorizer.fit(X_train['teacher_prefix'].values.astype('U')) # 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.astype('U'))
X_cv_teacher_ohe = vectorizer.transform(X_cv['teacher_prefix'].values.astype('U'))
X_test_teacher_ohe = vectorizer.transform(X_test['teacher_prefix'].values.astype('U'))

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
(49041, 6) (49041,)
(24155, 6) (24155,)
(36052, 6) (36052,)
['dr', 'mr', 'mrs', 'ms', 'nan', 'teacher']
====================================================================================================
```

2.2 Vectorizing Text data

A) Bag of Words (BOW) with bi-grams with min_df=10 and max_features=5000

Bag of words - Train Data - Essays

In [140]:

```
# We are considering only the words which appeared in at least 10 documents(rows or projects).
```

```
vectorizer_bow_essay = CountVectorizer(ngram_range=(2,2), min_df=10, max_features = 5000)

vectorizer_bow_essay.fit(X_train["clean_essays"])

text_bow_train = vectorizer_bow_essay.transform(X_train["clean_essays"])

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

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

Bag of words - Test Data - Essays

In [68]:

```
text_bow_test = vectorizer_bow_essay.transform(X_test["clean_essays"])
print("Shape of matrix after one hot encoding ",text_bow_test.shape)
```

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

Bag of words - Cross Validation Data - Essays

In [69]:

```
text_bow_cv = vectorizer_bow_essay.transform(X_cv["clean_essays"])
print("Shape of matrix after one hot encoding ",text_bow_cv.shape)
```

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

Bag of words - Train Data - Titles

In [70]:

```
vectorizer_bow_title = CountVectorizer(ngram_range=(2,2), min_df=10, max_features = 5000)

vectorizer_bow_title.fit(X_train["clean_titles"])

title_bow_train = vectorizer_bow_title.transform(X_train["clean_titles"])
print("Shape of matrix after one hot encoding ",title_bow_train.shape)
```

```
('Shape of matrix after one hot encoding ', (49041, 1683))
```

Bag of words - Test Data - Titles

In [71]:

```
title_bow_test = vectorizer_bow_title.transform(X_test["clean_titles"])
print("Shape of matrix after one hot encoding ",title_bow_test.shape)
```

```
('Shape of matrix after one hot encoding ', (36052, 1683))
```

Bag of words - Cross Validation Data - Titles

In [72]:

```
title_bow_cv = vectorizer_bow_title.transform(X_cv["clean_titles"])
print("Shape of matrix after one hot encoding ",title_bow_cv.shape)
```

```
('Shape of matrix after one hot encoding ', (24155, 1683))
```

B) TFIDF vectorizer with bigrams with min_df=10 and max_features=5000

B) TFIDF vectorizer with bi-grams with min_df=10 and max_features=5000

TFIDF - Train Data - Essays

In [73]:

```
from sklearn.feature_extraction.text import TfidfVectorizer

vectorizer_tfidf_essay = TfidfVectorizer(ngram_range=(2,2), min_df=10, max_features = 5000)
vectorizer_tfidf_essay.fit(X_train["clean_essays"])

text_tfidf_train = vectorizer_tfidf_essay.transform(X_train["clean_essays"])
print("Shape of matrix after one hot encoding ",text_tfidf_train.shape)
```

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

TFIDF - Test Data - Essays

In [74]:

```
text_tfidf_test = vectorizer_tfidf_essay.transform(X_test["clean_essays"])
print("Shape of matrix after one hot encoding ",text_tfidf_test.shape)
```

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

TFIDF - Cross Validation Data - Essays

In [75]:

```
text_tfidf_cv = vectorizer_tfidf_essay.transform(X_cv["clean_essays"])
print("Shape of matrix after one hot encoding ",text_tfidf_cv.shape)
```

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

TFIDF - Train Data - Titles

In [76]:

```
vectorizer_tfidf_titles = TfidfVectorizer(ngram_range=(2,2), min_df=10, max_features = 5000)

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

```
('Shape of matrix after one hot encoding ', (49041, 1683))
```

TFIDF - Test Data - Titles

In [77]:

```
title_tfidf_test = vectorizer_tfidf_titles.transform(X_test["clean_titles"])
print("Shape of matrix after one hot encoding ",title_tfidf_test.shape)
```

```
('Shape of matrix after one hot encoding ', (36052, 1683))
```

TFIDF - Cross Validation Data - Titles

In [78]:

```
title_tfidf_cv = vectorizer_tfidf_titles.transform(X_cv["clean_titles"])
print("Shape of matrix after one hot encoding ",title_tfidf_cv.shape)
```

```
('Shape of matrix after one hot encoding ', (24155, 1683))
```

C) Using Pretrained Models : AVG W2V

In [79]:

```
# Reading glove vectors in python: https://stackoverflow.com/a/38230349/4084039

def loadGloveModel(gloveFile):

    print ("Loading Glove Model")

    f = open(gloveFile,'r')

    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
```

In [80]:

```
model = loadGloveModel('glove.42B.300d.txt')
```

```
1796it [00:00, 8789.48it/s]
```

```
Loading Glove Model
```

```
1917495it [03:34, 8940.65it/s]
```

```
('Done.', 1917495, ' words loaded!')
```

In [83]:

```
words_train_essays = []

for i in X_train["clean_essays"] :
    words_train_essays.extend(i.split(' '))
```

In [84]:

```
## Find the total number of words in the Train data of Essays.

print("All the words in the corpus", len(words_train_essays))
```

```
('All the words in the corpus', 7429957)
```

In [85]:

```
## Find the unique words in this set of words

words_train_essay = set(words_train_essays)
print("the unique words in the corpus", len(words_train_essay))
```

```
('the unique words in the corpus', 41340)
```

In [86]:

```
## Find the words present in both Glove Vectors as well as our corpus.

inter_words = set(model.keys()).intersection(words_train_essay)

print("The number of words that are present in both glove vectors and our corpus are {} which \
is nearly {}% ".format(len(inter_words), np.round((float(len(inter_words))/len(words_train_essay))
*100)))
```

```
The number of words that are present in both glove vectors and our corpus are 37928 which is
nearly 92.0%
```

In [87]:

```
words_corpus_train_essay = {}

words_glove = set(model.keys())

for i in words_train_essay:
    if i in words_glove:
        words_corpus_train_essay[i] = model[i]

print("word 2 vec length", len(words_corpus_train_essay))
```

```
('word 2 vec length', 37928)
```

In [88]:

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

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

In [89]:

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

Train - Essays

In [92]:

```
# average Word2Vec
# compute average word2vec for each review.

avg_w2v_vectors_train = [];

for sentence in tqdm(X_train["clean_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_train.append(vector)

print(len(avg_w2v_vectors_train))
print(len(avg_w2v_vectors_train[0]))
```

```
100%|██████████| 49041/49041 [00:14<00:00, 3284.61it/s]

49041
300
```

Test - Essays

In [93]:

```
# average Word2Vec
# compute average word2vec for each review.

avg_w2v_vectors_test = [];

for sentence in tqdm(X_test["clean_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_test.append(vector)

print(len(avg_w2v_vectors_test))
print(len(avg_w2v_vectors_test[0]))
```

```
100%|██████████| 36052/36052 [00:10<00:00, 3321.58it/s]
```

```
36052
300
```

Cross-Validation - Essays

In [94]:

```
avg_w2v_vectors_cv = [];

for sentence in tqdm(X_cv["clean_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_cv.append(vector)

print(len(avg_w2v_vectors_cv))
print(len(avg_w2v_vectors_cv[0]))
```

```
100%|██████████| 24155/24155 [00:07<00:00, 3387.14it/s]
```

```
24155
300
```

Train - Titles

In [95]:

```
# Similarly you can vectorize for title also

avg_w2v_vectors_titles_train = []; # the avg-w2v for each sentence/review is stored in this list
for sentence in tqdm(X_train["clean_titles"]): # for each title
    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_titles_train.append(vector)

print(len(avg_w2v_vectors_titles_train))
print(len(avg_w2v_vectors_titles_train[0]))
```

```
100%|██████████| 49041/49041 [00:00<00:00, 51372.38it/s]
```

```
49041
300
```

Test - Titles

In [96]:

```
# Similarly you can vectorize for title also

avg_w2v_vectors_titles_test = []; # the avg-w2v for each sentence/review is stored in this list
for sentence in tqdm(X_test["clean_titles"]): # for each title
    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_titles_test.append(vector)

print(len(avg_w2v_vectors_titles_test))
print(len(avg_w2v_vectors_titles_test[0]))
```

```
100%|██████████| 36052/36052 [00:00<00:00, 50408.92it/s]
```

```
36052
300
```

Cross-Validation - Titles

In [97]:

```
# Similarly you can vectorize for title also

avg_w2v_vectors_titles_cv = []; # the avg-w2v for each sentence/review is stored in this list
for sentence in tqdm(X_cv["clean_titles"]): # for each title
    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_titles_cv.append(vector)

print(len(avg_w2v_vectors_titles_cv))
print(len(avg_w2v_vectors_titles_cv[0]))
```

```
100%|██████████| 24155/24155 [00:00<00:00, 47649.01it/s]
```

```
24155
300
```

D) Using Pretrained Models: TFIDF weighted W2V

Train - Essays

In [98]:

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

In [99]:

```
# average Word2Vec
# compute average word2vec for each review.
tfidf_w2v_vectors_train = []; # the avg-w2v for each sentence/review is stored in this list
for sentence in tqdm(X_train["clean_essays"]): # for each review/sentence
    vector = np.zeros(300) # as word vectors are of zero length
    tf_idf_weight =0; # num of words with a valid vector in the sentence/review
    for word in sentence.split(): # for each word in a review/sentence
        if (word in glove_words) and (word in tfidf_words):
            vec = model[word] # getting the vector for each word
            # here we are multiplying idf value(dictionary[word]) and the tf
value((sentence.count(word)/len(sentence.split())))
            tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split())) # getting the tf
idf value for each word
            vector += (vec * tf_idf) # calculating tfidf weighted w2v
            tf_idf_weight += tf_idf
    if tf_idf_weight != 0:
        vector /= tf_idf_weight
    tfidf_w2v_vectors_train.append(vector)

print(len(tfidf_w2v_vectors_train))
print(len(tfidf_w2v_vectors_train[0]))
```

```
100%|██████████| 49041/49041 [01:42<00:00, 476.35it/s]
```

```
49041
300
```

Test - Essays

In [100]:

```
# compute average word2vec for each review.

tfidf_w2v_vectors_test = []; # the avg-w2v for each sentence/review is stored in this list
for sentence in tqdm(X_test["clean_essays"]): # for each review/sentence
    vector = np.zeros(300) # as word vectors are of zero length
    tf_idf_weight =0; # num of words with a valid vector in the sentence/review
    for word in sentence.split(): # for each word in a review/sentence
        if (word in glove_words) and (word in tfidf_words):
            vec = model[word] # getting the vector for each word
            # here we are multiplying idf value(dictionary[word]) and the tf
value((sentence.count(word)/len(sentence.split())))
            tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split())) # getting the tf
idf value for each word
            vector += (vec * tf_idf) # calculating tfidf weighted w2v
            tf_idf_weight += tf_idf
    if tf_idf_weight != 0:
        vector /= tf_idf_weight
    tfidf_w2v_vectors_test.append(vector)

print(len(tfidf_w2v_vectors_test))
print(len(tfidf_w2v_vectors_test[0]))
```

```
100%|██████████| 36052/36052 [01:13<00:00, 490.33it/s]
```

```
100%|██████████| 36052/36052 [01:13<00:00, 488.33it/s]
```

```
36052
300
```

Cross-Validation - Essays

In [101]:

```
# compute average word2vec for each review.

tfidf_w2v_vectors_cv = []; # the avg-w2v for each sentence/review is stored in this list
for sentence in tqdm(X_cv["clean_essays"]): # for each review/sentence
    vector = np.zeros(300) # as word vectors are of zero length
    tf_idf_weight =0; # num of words with a valid vector in the sentence/review
    for word in sentence.split(): # for each word in a review/sentence
        if (word in glove_words) and (word in tfidf_words):
            vec = model[word] # getting the vector for each word
            # here we are multiplying idf value(dictionary[word]) and the tf
value((sentence.count(word)/len(sentence.split())))
            tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split())) # getting the tf
idf value for each word
            vector += (vec * tf_idf) # calculating tfidf weighted w2v
            tf_idf_weight += tf_idf
    if tf_idf_weight != 0:
        vector /= tf_idf_weight
    tfidf_w2v_vectors_cv.append(vector)

print(len(tfidf_w2v_vectors_cv))
print(len(tfidf_w2v_vectors_cv[0]))
```

```
100%|██████████| 24155/24155 [00:49<00:00, 492.74it/s]
```

```
24155
300
```

Train - Titles

In [102]:

```
tfidf_model = TfidfVectorizer()
tfidf_model.fit(X_train["clean_titles"])
# we are converting a dictionary with word as a key, and the idf as a value
dictionary = dict(zip(tfidf_model.get_feature_names(), list(tfidf_model.idf_)))
tfidf_words = set(tfidf_model.get_feature_names())
```

In [103]:

```
# compute average word2vec for each review.

tfidf_w2v_vectors_titles_train = [];

for sentence in tqdm(X_train["clean_titles"]): # for each review/sentence
    vector = np.zeros(300) # as word vectors are of zero length
    tf_idf_weight =0; # num of words with a valid vector in the sentence/review
    for word in sentence.split(): # for each word in a review/sentence
        if (word in glove_words) and (word in tfidf_words):
            vec = model[word] # getting the vector for each word
            # here we are multiplying idf value(dictionary[word]) and the tf
value((sentence.count(word)/len(sentence.split())))
            tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split())) # getting the tf
idf value for each word
            vector += (vec * tf_idf) # calculating tfidf weighted w2v
            tf_idf_weight += tf_idf
    if tf_idf_weight != 0:
        vector /= tf_idf_weight
    tfidf_w2v_vectors_titles_train.append(vector)

print(len(tfidf_w2v_vectors_titles_train))
```

```
print(len(tfidf_w2v_vectors_titles_train[0]))
```

```
100%|██████████| 49041/49041 [00:01<00:00, 25933.76it/s]
```

```
49041
300
```

Test - Titles

In [104]:

```
# compute average word2vec for each review.

tfidf_w2v_vectors_titles_test = [];

for sentence in tqdm(X_test["clean_titles"]): # for each review/sentence
    vector = np.zeros(300) # as word vectors are of zero length
    tf_idf_weight =0; # num of words with a valid vector in the sentence/review
    for word in sentence.split(): # for each word in a review/sentence
        if (word in glove_words) and (word in tfidf_words):
            vec = model[word] # getting the vector for each word
            # here we are multiplying idf value(dictionary[word]) and the tf
value((sentence.count(word)/len(sentence.split())))
            tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split())) # getting the tf
idf value for each word
            vector += (vec * tf_idf) # calculating tfidf weighted w2v
            tf_idf_weight += tf_idf
    if tf_idf_weight != 0:
        vector /= tf_idf_weight
    tfidf_w2v_vectors_titles_test.append(vector)

print(len(tfidf_w2v_vectors_titles_test))
print(len(tfidf_w2v_vectors_titles_test[0]))
```

```
100%|██████████| 36052/36052 [00:01<00:00, 26332.51it/s]
```

```
36052
300
```

Cross-Validation - Titles

In [105]:

```
# compute average word2vec for each review.

tfidf_w2v_vectors_titles_cv = [];

for sentence in tqdm(X_cv["clean_titles"]): # for each review/sentence
    vector = np.zeros(300) # as word vectors are of zero length
    tf_idf_weight =0; # num of words with a valid vector in the sentence/review
    for word in sentence.split(): # for each word in a review/sentence
        if (word in glove_words) and (word in tfidf_words):
            vec = model[word] # getting the vector for each word
            # here we are multiplying idf value(dictionary[word]) and the tf
value((sentence.count(word)/len(sentence.split())))
            tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split())) # getting the tf
idf value for each word
            vector += (vec * tf_idf) # calculating tfidf weighted w2v
            tf_idf_weight += tf_idf
    if tf_idf_weight != 0:
        vector /= tf_idf_weight
    tfidf_w2v_vectors_titles_cv.append(vector)

print(len(tfidf_w2v_vectors_titles_cv))
print(len(tfidf_w2v_vectors_titles_cv[0]))
```

```
100%|██████████| 24155/24155 [00:00<00:00, 28046.61it/s]
```

```
24155
300
```

2.3 Vectorizing Numerical features

In [106]:

```
# https://stackoverflow.com/questions/22407798/how-to-reset-a-dataframes-indexes-for-all-groups-in-one-step
price_data = resource_data.groupby('id').agg({'price':'sum', 'quantity':'sum'}).reset_index()
price_data.head(2)
```

Out[106]:

	id	price	quantity
0	p000001	459.56	7
1	p000002	515.89	21

In [107]:

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

A) Price

In [108]:

```
from sklearn.preprocessing import Normalizer

normalizer = Normalizer()

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

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

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

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

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

B) Quantity

In [109]:

```
normalizer = Normalizer()
```

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

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

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

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

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

C) Number of Projects previously proposed by Teacher

In [110]:

```
normalizer = Normalizer()

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

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

prev_projects_train = normalizer.transform(X_train['teacher_number_of_previously_posted_projects']
.values.reshape(-1,1))
prev_projects_cv =
normalizer.transform(X_cv['teacher_number_of_previously_posted_projects'].values.reshape(-1,1))
prev_projects_test = normalizer.transform(X_test['teacher_number_of_previously_posted_projects'].v
alues.reshape(-1,1))

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

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

D) Title word Count

In [111]:

```
normalizer = Normalizer()

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

title_word_count_train = normalizer.transform(X_train['title_word_count'].values.reshape(-1,1))
```

```
title_word_count_cv = normalizer.transform(X_cv['title_word_count'].values.reshape(-1,1))
title_word_count_test = normalizer.transform(X_test['title_word_count'].values.reshape(-1,1))

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

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

E) Essay word Count

In [112]:

```
normalizer = Normalizer()

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

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

print("After vectorizations")
print(essay_word_count_train.shape, y_train.shape)
print(essay_word_count_cv.shape, y_cv.shape)
print(essay_word_count_test.shape, y_test.shape)
print("="*100)
```

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

F) Essay Sentiments - pos

In [190]:

```
normalizer = Normalizer()

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

essay_sent_pos_train = normalizer.transform(X_train['pos'].values.reshape(-1,1))
essay_sent_pos_cv = normalizer.transform(X_cv['pos'].values.reshape(-1,1))
essay_sent_pos_test = normalizer.transform(X_test['pos'].values.reshape(-1,1))

print("After vectorizations")
print(essay_sent_pos_train.shape, y_train.shape)
print(essay_sent_pos_cv.shape, y_cv.shape)
print(essay_sent_pos_test.shape, y_test.shape)
print("="*100)
```

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

G) Essay Sentiments - neg

In [191]:

In [191]:

```
normalizer = Normalizer()

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

essay_sent_neg_train = normalizer.transform(X_train['neg'].values.reshape(-1,1))
essay_sent_neg_cv = normalizer.transform(X_cv['neg'].values.reshape(-1,1))
essay_sent_neg_test = normalizer.transform(X_test['neg'].values.reshape(-1,1))

print("After vectorizations")
print(essay_sent_neg_train.shape, y_train.shape)
print(essay_sent_neg_cv.shape, y_cv.shape)
print(essay_sent_neg_test.shape, y_test.shape)
print("="*100)
```

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

H) Essay Sentiments - neu

In [192]:

```
normalizer = Normalizer()

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

essay_sent_neu_train = normalizer.transform(X_train['neu'].values.reshape(-1,1))
essay_sent_neu_cv = normalizer.transform(X_cv['neu'].values.reshape(-1,1))
essay_sent_neu_test = normalizer.transform(X_test['neu'].values.reshape(-1,1))

print("After vectorizations")
print(essay_sent_neu_train.shape, y_train.shape)
print(essay_sent_neu_cv.shape, y_cv.shape)
print(essay_sent_neu_test.shape, y_test.shape)
print("="*100)
```

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

I) Essay Sentiments - compound

In [193]:

```
normalizer = Normalizer()

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

essay_sent_comp_train = normalizer.transform(X_train['compound'].values.reshape(-1,1))
essay_sent_comp_cv = normalizer.transform(X_cv['compound'].values.reshape(-1,1))
essay_sent_comp_test = normalizer.transform(X_test['compound'].values.reshape(-1,1))

print("After vectorizations")
print(essay_sent_comp_train.shape, y_train.shape)
print(essay_sent_comp_cv.shape, y_cv.shape)
print(essay_sent_comp_test.shape, y_test.shape)
print("="*100)
```

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

Assignment 5: Logistic Regression

1. **[Task-1] Logistic Regression(either SGDClassifier with log loss, or LogisticRegression) on these feature sets**
    - Set 1: categorical, numerical features + project_title(BOW) + preprocessed_eassay (`BOW with bi-grams` with `min_df=10` and `max_features=5000`)
    - Set 2: categorical, numerical features + project_title(TFIDF)+ preprocessed_eassay (`TFIDF with bi-grams` with `min_df=10` and `max_features=5000`)
    - Set 3: categorical, numerical features + project_title(AVG W2V)+ preprocessed_eassay (AVG W2V)
    - Set 4: categorical, numerical features + project_title(TFIDF W2V)+ preprocessed_essay (TFIDF W2V)

2. **Hyper paramter tuning (find best hyper parameters corresponding the algorithm that you choose)**
    - Find the best hyper parameter which will give the maximum AUC value
    - 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. **Representation of results**
    - You need to plot the performance of model both on train data and cross validation data for each hyper parameter, like shown in the figure.
    - Once after you found the best hyper parameter, you need to train your model with it, and find the AUC on test data and plot the ROC curve on both train and test.
    - Along with plotting ROC curve, you need to print the confusion matrix with predicted and original labels of test data points. Please visualize your confusion matrices using seaborn heatmaps.

4. **[Task-2] Apply Logistic Regression on the below feature set Set 5 by finding the best hyper parameter as suggested in step 2 and step 3.**
5. Consider these set of features Set 5 :
    - **school_state** : categorical data
    - **clean_categories** : categorical data
    - **clean_subcategories** : categorical data
    - **project_grade_category** :categorical data
    - **teacher_prefix** : categorical data
    - **quantity** : numerical data
    - **teacher_number_of_previously_posted_projects** : numerical data
    - **price** : numerical data
    - **sentiment score's of each of the essay** : numerical data
    - **number of words in the title** : numerical data
    - **number of words in the combine essays** : numerical data

    And apply the Logistic regression on these features by finding the best hyper paramter as suggested in step 2 and step 3

6. **Conclusion**
    - You need to summarize the results at the end of the notebook, summarize it in the table format. To print out a table please refer to this prettytable library link

Note: Data Leakage

1. There will be an issue of data-leakage if you vectorize the entire data and then split it into train/cv/test.
2. To avoid the issue of data-leakage, make sure to split your data first and then vectorize it.
3. While vectorizing your data, apply the method fit_transform() on you train data, and apply the method transform() on cv/test data.
4. For more details please go through this link.

3. Logistic Regression

Set 1: Categorical, Numerical features + Project_title(BOW) +

Preprocessed_essay (BOW with bi-grams with min_df=10 and max_features=5000)

In [115]:

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

X_tr = hstack((categories_one_hot_train, sub_categories_one_hot_train,
school_state_categories_one_hot_train,
               project_grade_categories_one_hot_train, teacher_prefix_categories_one_hot_train, pri
ce_train,
               quantity_train, prev_projects_train, title_word_count_train, essay_word_count_train,
title_bow_train,
               text_bow_train)).tocsr()
X_te = hstack((categories_one_hot_test, sub_categories_one_hot_test,
school_state_categories_one_hot_test,
               project_grade_categories_one_hot_test, teacher_prefix_categories_one_hot_test, price
_test,
               quantity_test, prev_projects_test, title_word_count_test, essay_word_count_test, tit
le_bow_test,
               text_bow_test)).tocsr()
X_cr = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
school_state_categories_one_hot_cv,
               project_grade_categories_one_hot_cv, teacher_prefix_categories_one_hot_cv, price_cv,
quantity_cv,
               prev_projects_cv, title_word_count_cv, essay_word_count_cv, title_bow_cv,
text_bow_cv)).tocsr()
```

In [116]:

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

```
Final Data matrix
((49041, 6788), (49041,))
((24155, 6788), (24155,))
((36052, 6788), (36052,))
====================================================================================================
```

A) GridSearchCV (K fold Cross Validation)

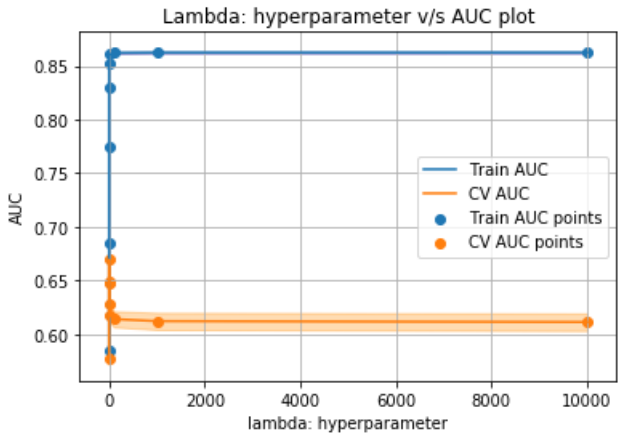
In [118]:

```
from sklearn.model_selection import GridSearchCV
from sklearn.linear_model import LogisticRegression
```

In [119]:

```
lr = LogisticRegression()

parameters = {'C':[10**-4, 10**-3, 10**-2, 10**-1, 10**0, 10**1, 10**2, 10**3, 10**4]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')

clf.fit(X_tr, y_train)

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

plt.plot(parameters['C'], train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],train_auc - train_auc_std,train_auc +
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
```

```
plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```



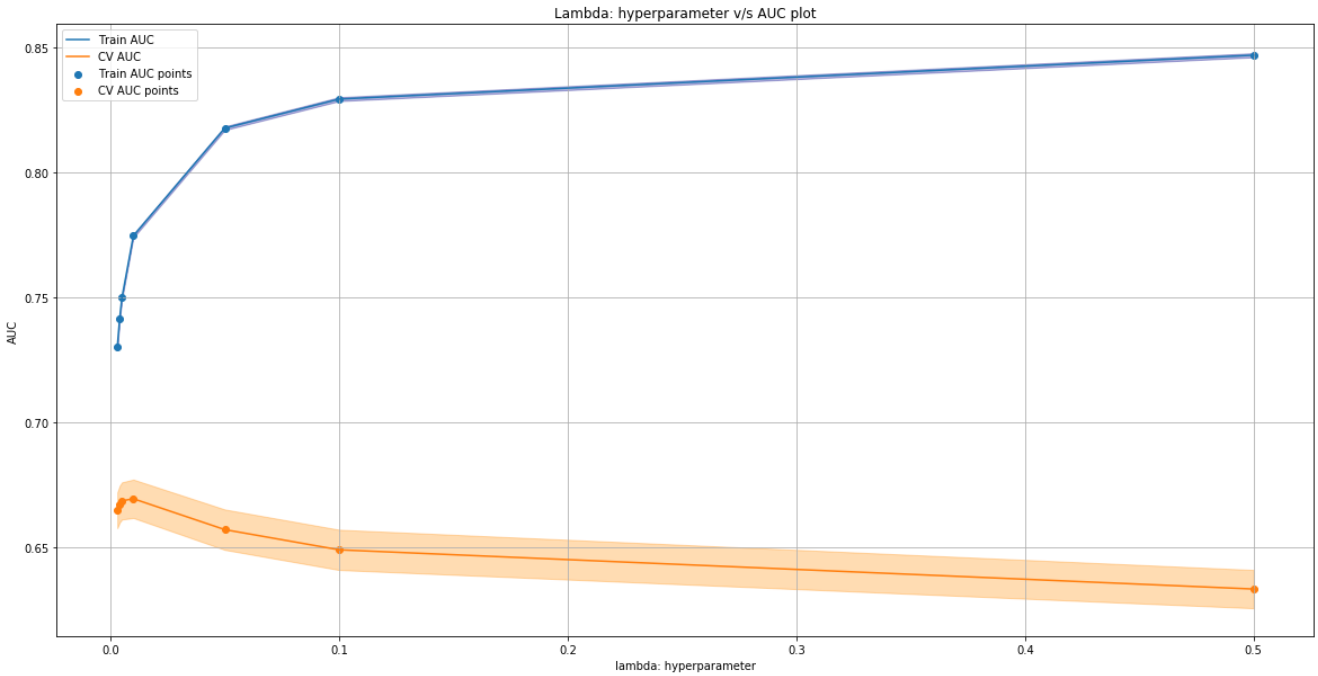
Inference

I was not able to deteremine an appropriate value for my parameter. So, I have re-run the GridSearchCV on a smaller set of parameter values.

In [126]:

```
##https://github.com/harrismohammed/DonorsChoose.org---LogisticRegression
lr = LogisticRegression()

parameters = {'C':[0.5, 0.1, 0.05, 0.01, 0.005, 0.004, 0.003]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')

clf.fit(X_tr, y_train)

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

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

plt.plot(parameters['C'], train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],train_auc - train_auc_std,train_auc +
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
```

```
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```



Inference

0.005 is chosen as the best hyperparameter value.

B) Train the model using the best hyper parameter value

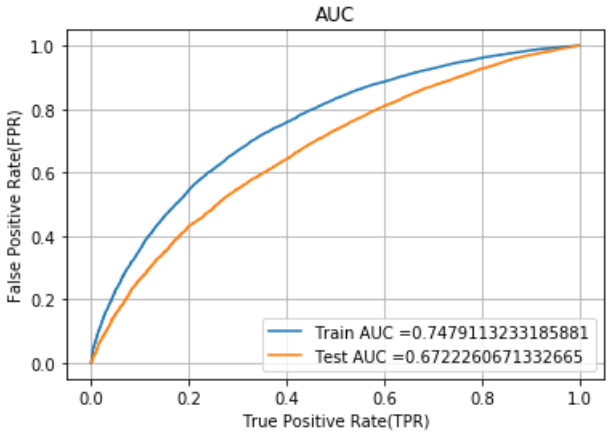
In [127]:

```
def batch_predict(clf, data):
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the posi
tive 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 cr_loop will be 49041 - 49041%1000 = 49000
    # in this for loop we will iterate unti the last 1000 multiplier
    for i in range(0, tr_loop, 1000):
        y_data_pred.extend(clf.predict_proba(data[i:i+1000])[:,1])
    # we will be predicting for the last data points
    y_data_pred.extend(clf.predict_proba(data[tr_loop:])[:,1])

    return y_data_pred
```

In [128]:

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


model = LogisticRegression(C = 0.005)

model.fit(X_tr, y_train)

# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive
class
# not the predicted outputs

y_train_pred = batch_predict(model, X_tr)
y_test_pred = batch_predict(model, X_te)
```

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

plt.plot(train_fpr, train_tpr, label="Train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="Test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("True Positive Rate(TPR)")
plt.ylabel("False Positive Rate(FPR)")
plt.title("AUC")
plt.grid()
plt.show()
```



C) Confusion Matrix

In [129]:

```
def predict(proba, threshould, fpr, tpr):

    t = threshould[np.argmax(fpr*(1-tpr))]

    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high

    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for threshold", np.round(t,3))
    predictions = []
    for i in proba:
        if i>=t:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

Train Data

In [130]:

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

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

Train confusion matrix
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.805)
[[ 3713  3713]
 [ 6955 34660]]
```

In [131]:

```
conf_matr_df_train_1 = pd.DataFrame(confusion_matrix(y_train, predict(y_train_pred, tr_thresholds,
train_fpr, train_fpr)), range(2),range(2))
```

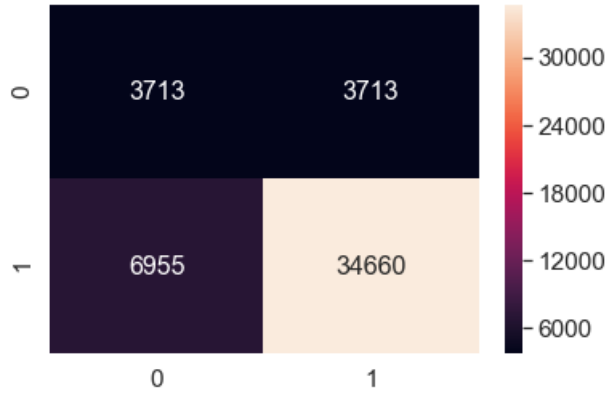
```
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.805)
```

In [212]:

```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_train_1, annot=True,annot_kws={"size": 16}, fmt='g')
```

Out[212]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa4974190>
```



Test Data

In [132]:

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

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

Test confusion matrix
('the maximum value of tpr*(1-fpr)', 0.24999999161092998, 'for threshold', 0.83)
[[ 2962  2497]
 [ 9245 21348]]
```

In [133]:

```
conf_matr_df_test_1 = pd.DataFrame(confusion_matrix(y_test, predict(y_test_pred, tr_thresholds, tes
t_fpr, test_fpr)), range(2),range(2))
```

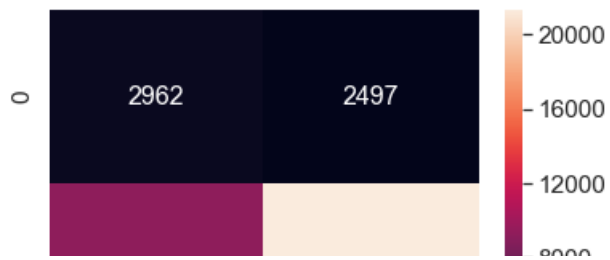
```
('the maximum value of tpr*(1-fpr)', 0.24999999161092998, 'for threshold', 0.83)
```

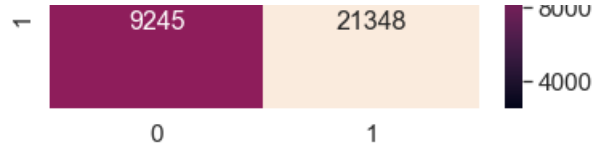
In [211]:

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

Out[211]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1a52aee810>
```





Set 2 : Categorical, Numerical features + Project_title(TFIDF) + Preprocessed_essay (TFIDF with bi-grams with min_df=10 and max_features=5000)

In [134]:

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

X_tr = hstack((categories_one_hot_train, sub_categories_one_hot_train,
school_state_categories_one_hot_train,
               project_grade_categories_one_hot_train, teacher_prefix_categories_one_hot_train, pri
ce_train,
               quantity_train, prev_projects_train, title_word_count_train, essay_word_count_train,
text_tfidf_train,
               title_tfidf_train)).tocsr()
X_te = hstack((categories_one_hot_test, sub_categories_one_hot_test,
school_state_categories_one_hot_test,
               project_grade_categories_one_hot_test, teacher_prefix_categories_one_hot_test, price
_test,
               quantity_test, prev_projects_test, title_word_count_test, essay_word_count_test, tex
t_tfidf_test,
               title_tfidf_test)).tocsr()
X_cr = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
school_state_categories_one_hot_cv,
               project_grade_categories_one_hot_cv, teacher_prefix_categories_one_hot_cv, price_cv,
quantity_cv,
               prev_projects_cv, title_word_count_cv, essay_word_count_cv, text_tfidf_cv,
title_tfidf_cv)).tocsr()
```

In [135]:

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

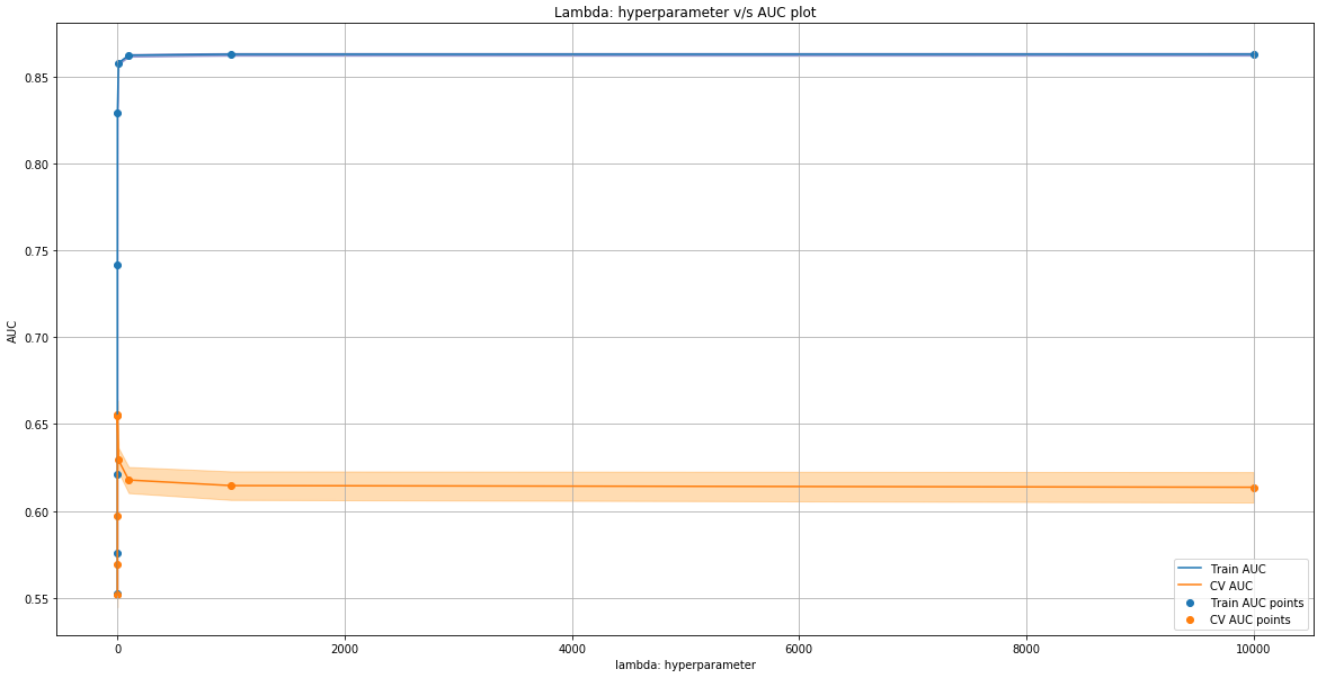
```
Final Data matrix
((49041, 6788), (49041,))
((24155, 6788), (24155,))
((36052, 6788), (36052,))
====================================================================================================
```

A) GridSearchCV (K Fold Cross Validation)

In [136]:

```
lr = LogisticRegression()

parameters = {'C':[10**-4, 10**-3, 10**-2, 10**-1, 10**0, 10**1, 10**2, 10**3, 10**4]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')

clf.fit(X_tr, y_train)

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

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

```
plt.plot(parameters['C'], train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],train_auc - train_auc_std,train_auc +
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```



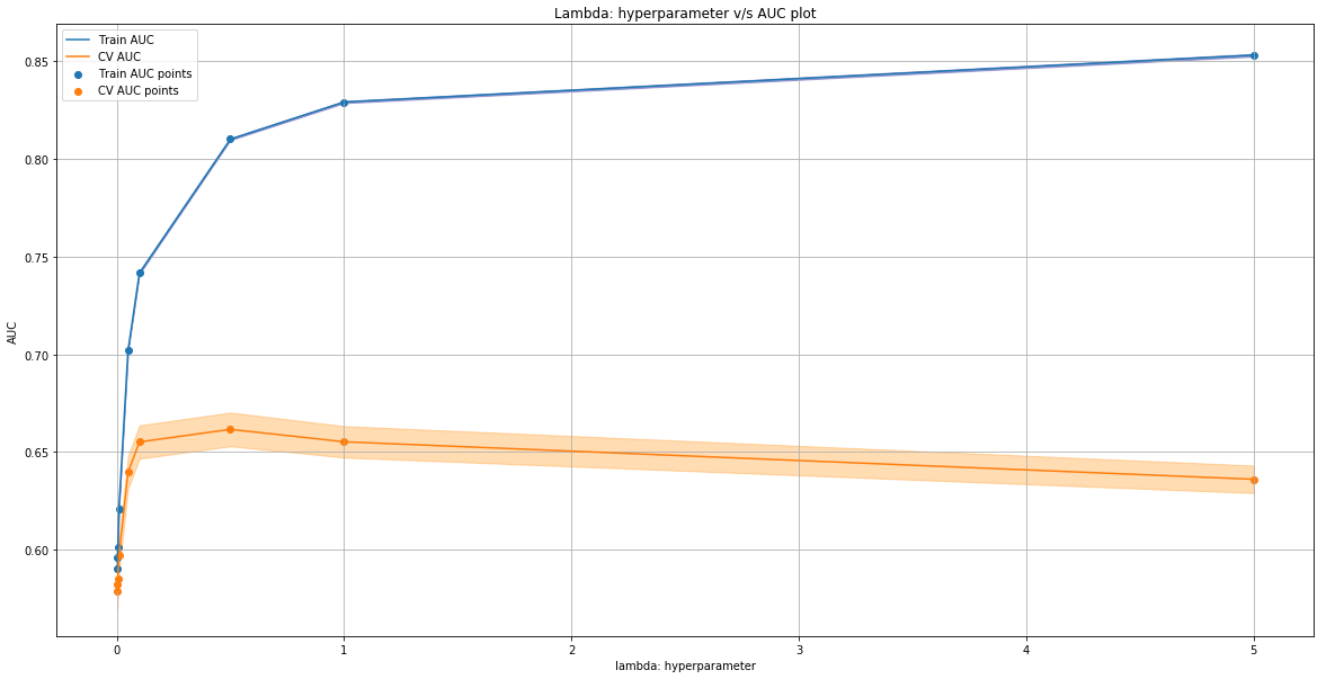
Inference

I was not able to deteremine an appropriate value for my parameter. So, I have re-run the GridSearchCV on a smaller set of parameter values.

In [138]:

```
lr = LogisticRegression()

parameters = {'C':[5, 1, 0.5, 0.1, 0.05, 0.01, 0.005, 0.004, 0.003]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')

clf.fit(X_tr, y_train)

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

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

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

```
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```



Inference

1) 0.1 is chosen as the best hyperparameter value.

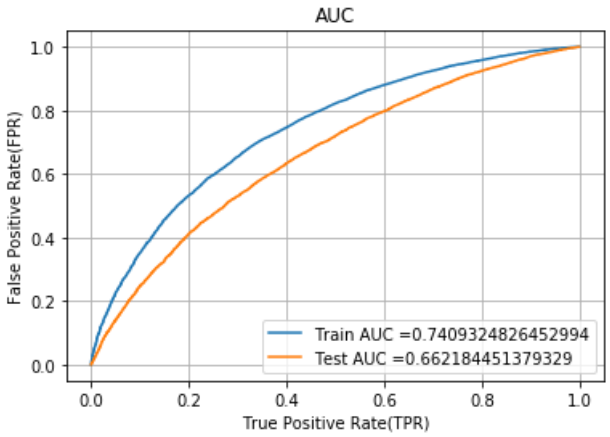
2) The AUC values for the parameters/points before and after 0.5 seems to be lower. While for 0.5 there seems to be a major difference between the Train and the Test model. So, 0.1 is considered.

B) Train the model using the best hyper parameter value

In [140]:

```
model = LogisticRegression(C = 0.1)

model.fit(X_tr, y_train)

# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive
class
# not the predicted outputs

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

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

plt.plot(train_fpr, train_tpr, label="Train AUC ="+str(auc(train_fpr, train_tpr)))
```

```
plt.plot(test_fpr, test_tpr, label="Test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("True Positive Rate(TPR)")
plt.ylabel("False Positive Rate(FPR)")
plt.title("AUC")
plt.grid()
plt.show()
```



C) Confusion Matrix

Train Data

In [141]:

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

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

Train confusion matrix
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.815)
[[ 3713  3713]
 [ 7429 34186]]
```

In [142]:

```
conf_matr_df_train_2 = pd.DataFrame(confusion_matrix(y_train, predict(y_train_pred, tr_thresholds,
train_fpr, train_fpr)), range(2),range(2))
```

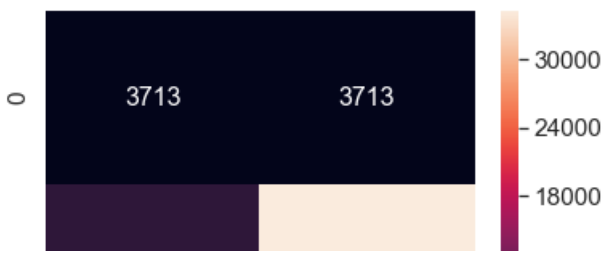
```
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.815)
```

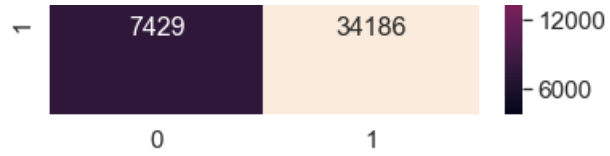
In [210]:

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

Out[210]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa42d1350>
```





Test Data

In [143]:

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

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

Test confusion matrix
('the maximum value of tpr*(1-fpr)', 0.24999999161092995, 'for threshold', 0.836)
[[ 2944  2515]
 [ 9523 21070]]
```

In [144]:

```
conf_matr_df_test_2 = pd.DataFrame(confusion_matrix(y_test, predict(y_test_pred, tr_thresholds, tes
t_fpr, test_fpr)), range(2),range(2))
```

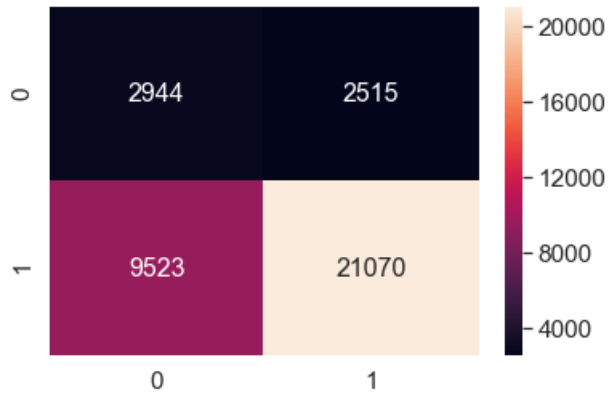
```
('the maximum value of tpr*(1-fpr)', 0.24999999161092995, 'for threshold', 0.836)
```

In [209]:

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

Out[209]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa4ffcd50>
```



Set 3 : Categorical, Numerical features + Project_title(AVG W2V) + Preprocessed_essay (AVG W2V)

In [145]:

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

X_tr = hstack((categories_one_hot_train, sub_categories_one_hot_train,
school_state_categories_one_hot_train,
               project_grade_categories_one_hot_train, teacher_prefix_categories_one_hot_train, pri
ce_train,
               quantity_train, prev_projects_train, title_word_count_train, essay_word_count_train,
```

```
                avg_w2v_vectors_train, avg_w2v_vectors_titles_train)).tocsr()
X_te = hstack((categories_one_hot_test, sub_categories_one_hot_test,
school_state_categories_one_hot_test,
                project_grade_categories_one_hot_test, teacher_prefix_categories_one_hot_test, price
_test,
                quantity_test, prev_projects_test, title_word_count_test, essay_word_count_test, avg
_w2v_vectors_test,
                avg_w2v_vectors_titles_test)).tocsr()
X_cr = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
school_state_categories_one_hot_cv,
                project_grade_categories_one_hot_cv, teacher_prefix_categories_one_hot_cv, price_cv,
quantity_cv,
                prev_projects_cv, title_word_count_cv, essay_word_count_cv, avg_w2v_vectors_cv,
                avg_w2v_vectors_titles_cv)).tocsr()
```

In [146]:

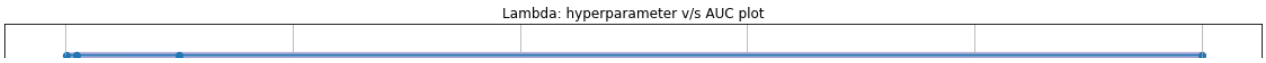
```
print("Final Data matrix")
print(X_tr.shape, y_train.shape)
print(X_cr.shape, y_cv.shape)
print(X_te.shape, y_test.shape)
print("="*100)
```

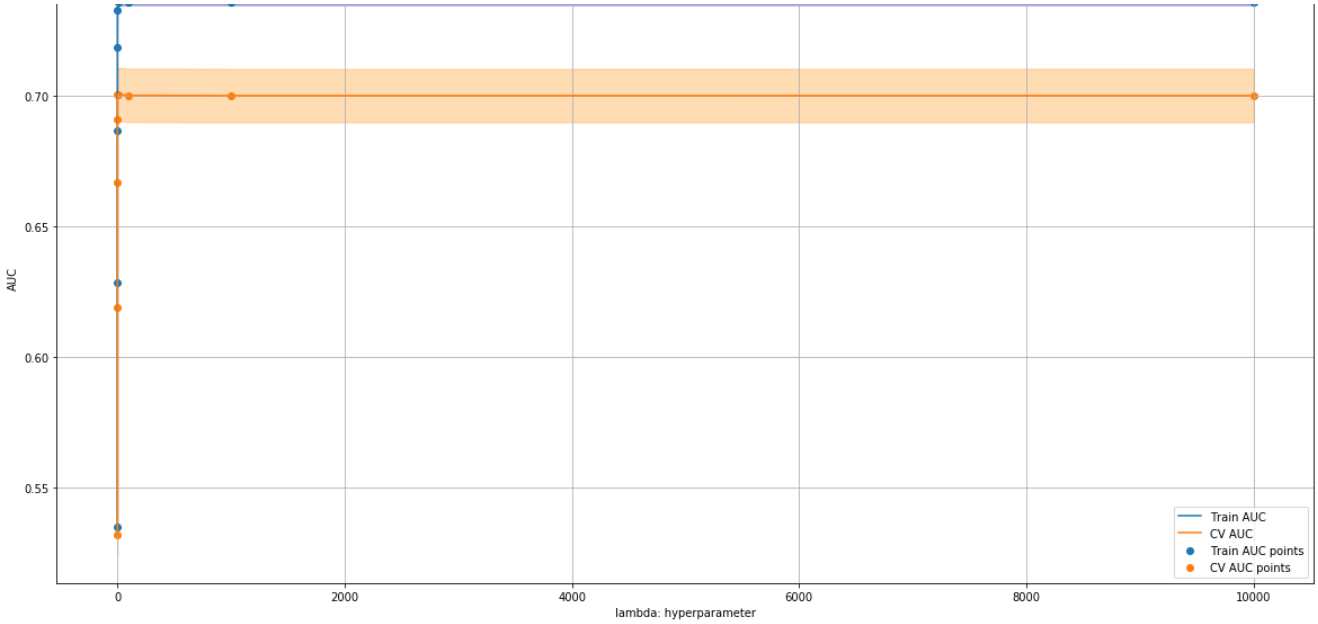
```
Final Data matrix
((49041, 705), (49041,))
((24155, 705), (24155,))
((36052, 705), (36052,))
====================================================================================================
```

A) GridSearchCV (K Fold Cross Validation)

In [147]:

```
lr = LogisticRegression()

parameters = {'C':[10**-4, 10**-3, 10**-2, 10**-1, 10**0, 10**1, 10**2, 10**3, 10**4]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')

clf.fit(X_tr, y_train)

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

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

plt.plot(parameters['C'], train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],train_auc - train_auc_std,train_auc +
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```





Inference

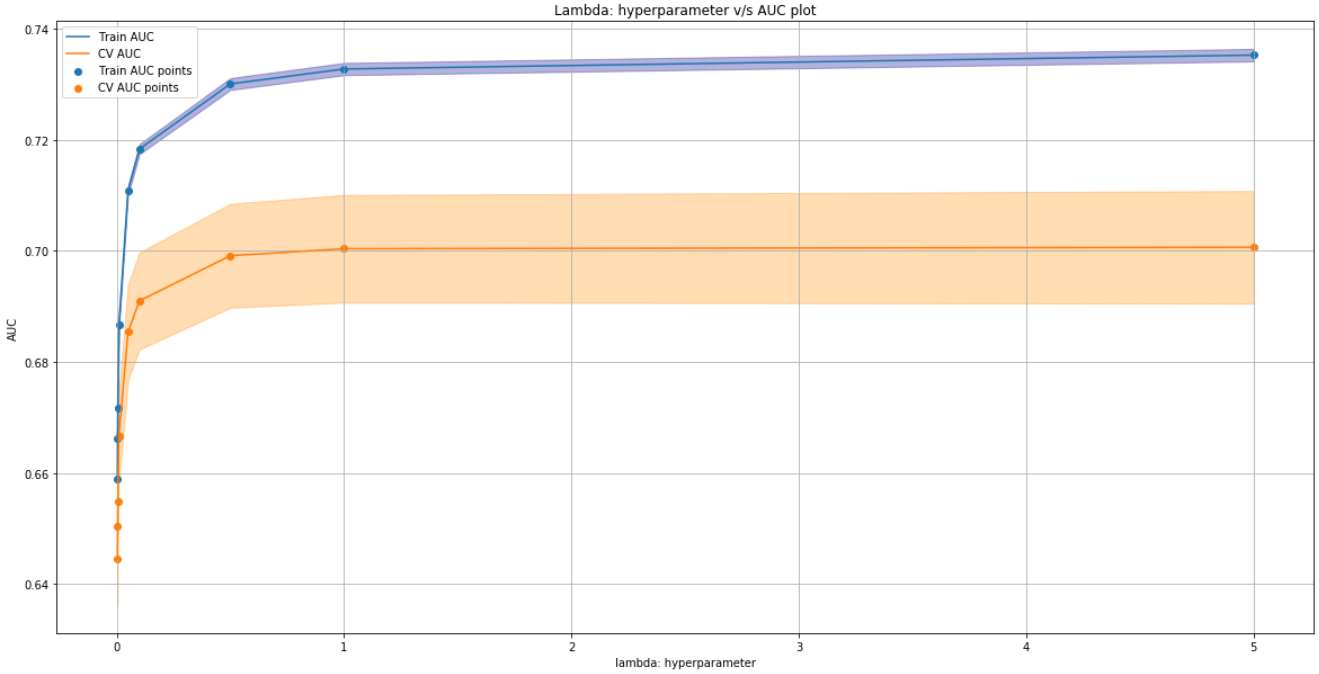
1. We observe that points/parameters ranging 100 and above seem to be futile as the AUC is almost constant after a certain point.

2. Also very low values ranging between 10^-4 and 10^-3 do not have a very appreciatable AUC score.

3. Lets consider the points in between for a better understanding and to obtain a better model.

In [148]:

```
lr = LogisticRegression()

parameters = {'C':[5, 1, 0.5, 0.1, 0.05, 0.01, 0.005, 0.004, 0.003]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')

clf.fit(X_tr, y_train)

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

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

plt.plot(parameters['C'], train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],train_auc - train_auc_std,train_auc +
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```



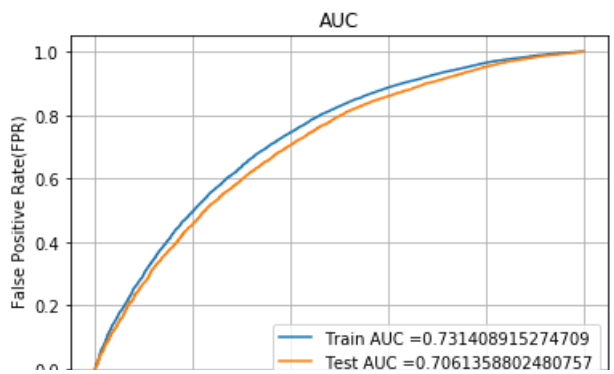
Inference

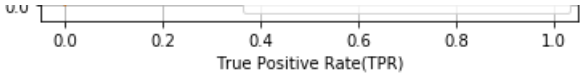
1.0 is chosen as the best hyper parameter value.

B) Train the model using the best hyper parameter value

In [149]:

```
model = LogisticRegression(C = 1.0)

model.fit(X_tr, y_train)

# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive
class
# not the predicted outputs

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

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

plt.plot(train_fpr, train_tpr, label="Train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="Test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("True Positive Rate(TPR)")
plt.ylabel("False Positive Rate(FPR)")
plt.title("AUC")
plt.grid()
plt.show()
```





C) Confusion Matrix

Train Data

In [150]:

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

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

Train confusion matrix
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.784)
[[ 3713  3713]
 [ 7167 34448]]
```

In [151]:

```
conf_matr_df_train_3 = pd.DataFrame(confusion_matrix(y_train, predict(y_train_pred, tr_thresholds,
train_fpr, train_fpr)), range(2),range(2))
```

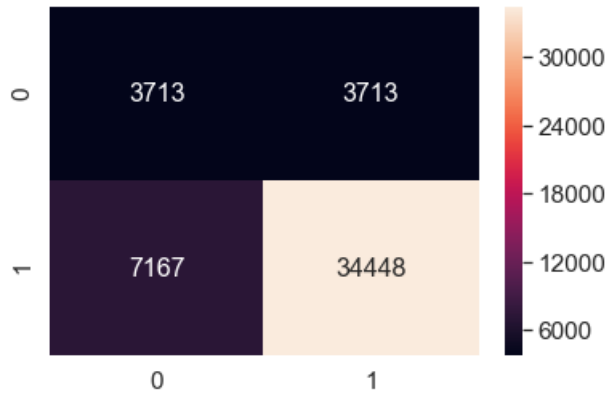
```
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.784)
```

In [208]:

```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_train_3, annot=True,annot_kws={"size": 16}, fmt='g')
```

Out[208]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa4c7abd0>
```



Test Data

In [152]:

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

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

Test confusion matrix
('the maximum value of tpr*(1-fpr)', 0.24999999161092998, 'for threshold', 0.831)
```

```
[[ 3324  2135]
 [ 9246 21347]]
```

In [153]:

```
conf_matr_df_test_3 = pd.DataFrame(confusion_matrix(y_test, predict(y_test_pred, tr_thresholds, tes
t_fpr, test_fpr)), range(2),range(2))
```

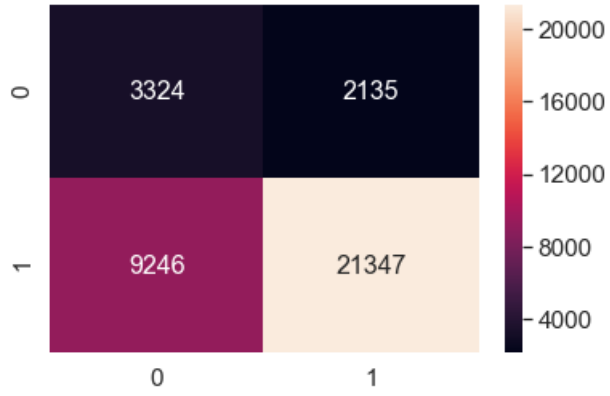
```
('the maximum value of tpr*(1-fpr)', 0.24999999161092998, 'for threshold', 0.831)
```

In [207]:

```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_test_3, annot=True,annot_kws={"size": 16}, fmt='g')
```

Out[207]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa57bdd90>
```



Set 4 : Categorical, Numerical features + Project_title(TFIDF W2V) + Preprocessed_essay (TFIDF W2V)

In [154]:

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

X_tr = hstack((categories_one_hot_train, sub_categories_one_hot_train,
school_state_categories_one_hot_train,
               project_grade_categories_one_hot_train, teacher_prefix_categories_one_hot_train, pri
ce_train,
               quantity_train, prev_projects_train, title_word_count_train, essay_word_count_train,

               tfidf_w2v_vectors_train, tfidf_w2v_vectors_titles_train)).tocsr()
X_te = hstack((categories_one_hot_test, sub_categories_one_hot_test,
school_state_categories_one_hot_test,
               project_grade_categories_one_hot_test, teacher_prefix_categories_one_hot_test, price
_test,
               quantity_test, prev_projects_test, title_word_count_test, essay_word_count_test,
               tfidf_w2v_vectors_test, tfidf_w2v_vectors_titles_test)).tocsr()
X_cr = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
school_state_categories_one_hot_cv,
               project_grade_categories_one_hot_cv, teacher_prefix_categories_one_hot_cv, price_cv,

               quantity_cv, prev_projects_cv, title_word_count_cv, essay_word_count_cv,
tfidf_w2v_vectors_cv,
               tfidf_w2v_vectors_titles_cv)).tocsr()
```

In [155]:

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

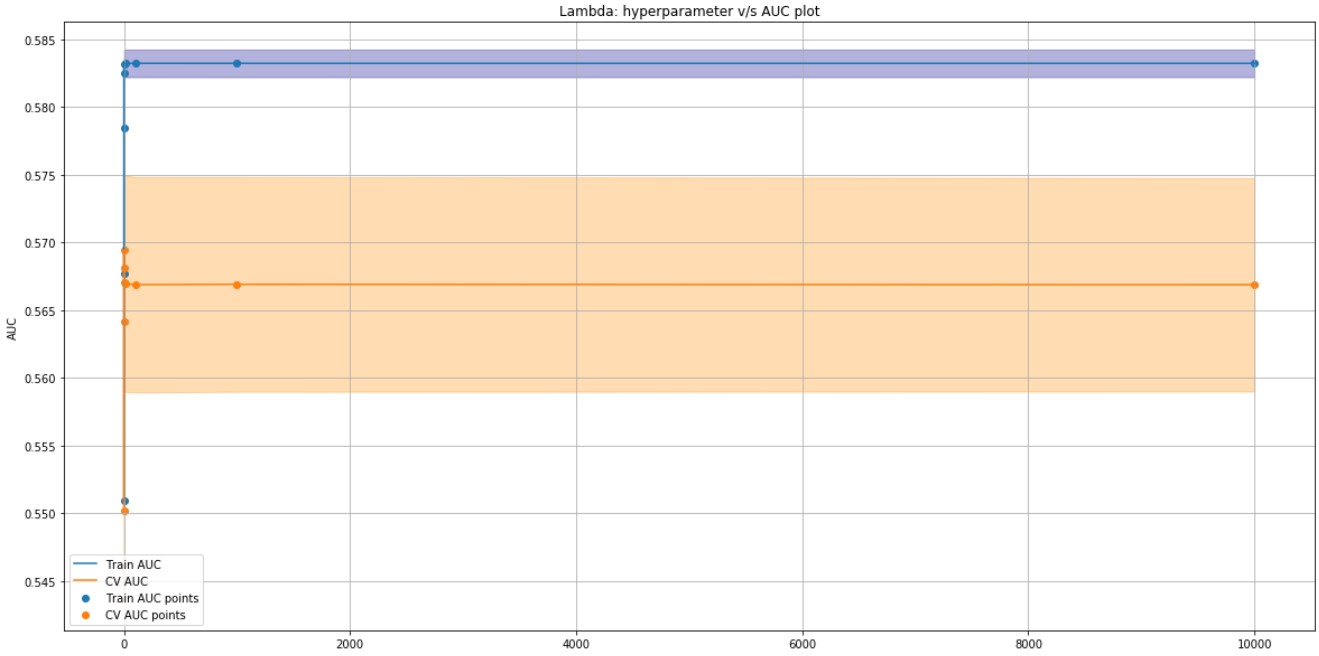
```
print("="*100)
```

```
Final Data matrix
((49041, 705), (49041,))
((24155, 705), (24155,))
((36052, 705), (36052,))
====================================================================================================
```

A) GridSearchCV (K Fold Cross Validation)

In [156]:

```
lr = LogisticRegression()

parameters = {'C':[10**-4, 10**-3, 10**-2, 10**-1, 10**0, 10**1, 10**2, 10**3, 10**4]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')

clf.fit(X_tr, y_train)

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

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

plt.plot(parameters['C'], train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],train_auc - train_auc_std,train_auc +
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```



Inference

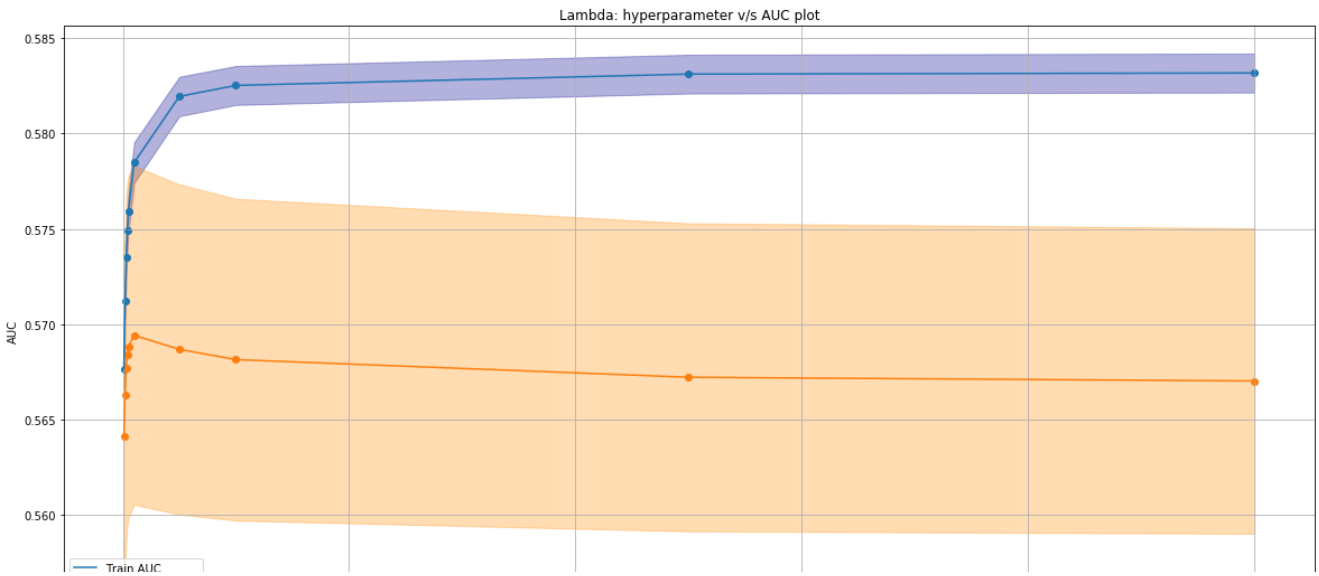
1. We observe that points/parameters ranging 100 and above seem to be futile as the AUC is almost constant after a certain point.

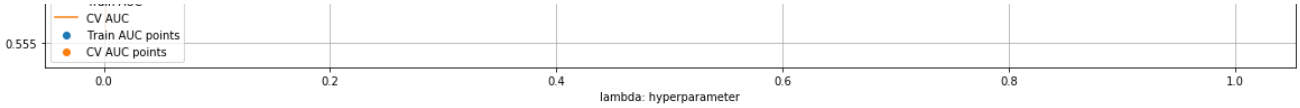
2. Also very low values ranging between 10^-4 and 10^-3 do not have a very appreciatable AUC score.

3. Lets consider the points in between for a better understanding and to obtain a better model.

In [158]:

```
lr = LogisticRegression()

parameters = {'C':[1, 0.5, 0.1, 0.05, 0.01, 0.005, 0.004, 0.003, 0.002, 0.001]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')

clf.fit(X_tr, y_train)

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

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

plt.plot(parameters['C'], train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],train_auc - train_auc_std,train_auc +
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```





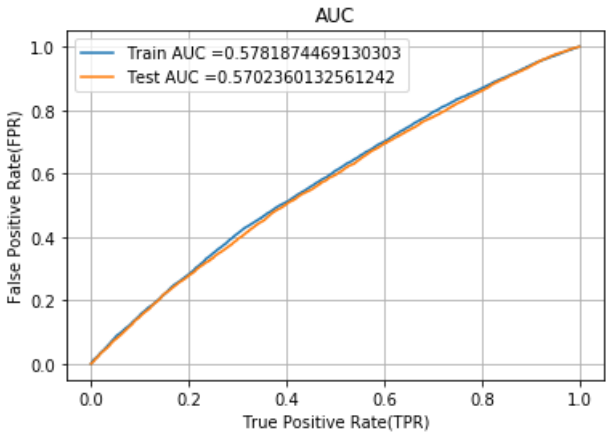
Inference

0.01 is chosen as the best hyper parameter value.

B) Train the model using the best hyper parameter value

In [159]:

```
model = LogisticRegression(C = 0.01)

model.fit(X_tr, y_train)

# roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimates of the positive
class
# not the predicted outputs

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

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

plt.plot(train_fpr, train_tpr, label="Train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="Test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("True Positive Rate(TPR)")
plt.ylabel("False Positive Rate(FPR)")
plt.title("AUC")
plt.grid()
plt.show()
```



C) Confusion Matrix

Train Data

In [160]:

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

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

Train confusion matrix
```

```
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.843)
[[ 3713  3713]
 [16302 25313]]
```

In [161]:

```
conf_matr_df_train_4 = pd.DataFrame(confusion_matrix(y_train, predict(y_train_pred, tr_thresholds,
train_fpr, train_fpr)), range(2),range(2))
```

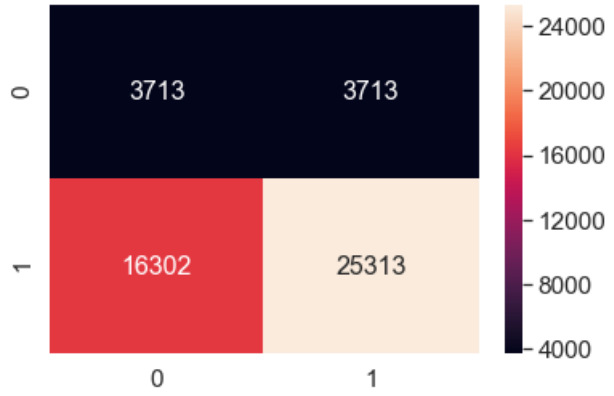
```
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.843)
```

In [206]:

```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_train_4, annot=True,annot_kws={"size": 16}, fmt='g')
```

Out[206]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa5625a50>
```



Test Data

In [162]:

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

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

Test confusion matrix
('the maximum value of tpr*(1-fpr)', 0.24999999161092995, 'for threshold', 0.848)
[[ 3050  2409]
 [14009 16584]]
```

In [163]:

```
conf_matr_df_test_4 = pd.DataFrame(confusion_matrix(y_test, predict(y_test_pred, tr_thresholds, tes
t_fpr, test_fpr)), range(2),range(2))
```

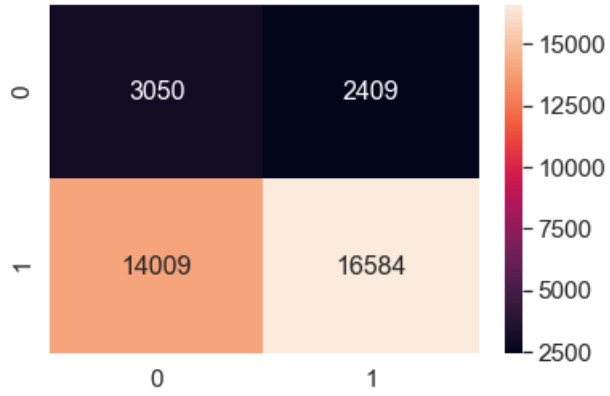
```
('the maximum value of tpr*(1-fpr)', 0.24999999161092995, 'for threshold', 0.848)
```

In [205]:

```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_test_4, annot=True,annot_kws={"size": 16}, fmt='g')
```

Out[205]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa4206d90>
```



Set 5 : Categorical features, Numerical features & Essay Sentiments

In [194]:

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

X_tr = hstack((categories_one_hot_train, sub_categories_one_hot_train,
school_state_categories_one_hot_train,
               project_grade_categories_one_hot_train, teacher_prefix_categories_one_hot_train, pri
ce_train,
               quantity_train, prev_projects_train, title_word_count_train, essay_word_count_train,

               essay_sent_pos_train, essay_sent_neg_train, essay_sent_neu_train,
essay_sent_comp_train)).tocsr()
X_te = hstack((categories_one_hot_test, sub_categories_one_hot_test,
school_state_categories_one_hot_test,
               project_grade_categories_one_hot_test, teacher_prefix_categories_one_hot_test, price
_test,
               quantity_test, prev_projects_test, title_word_count_test, essay_word_count_test, ess
ay_sent_pos_test,
               essay_sent_neg_test, essay_sent_neu_test, essay_sent_comp_test)).tocsr()
X_cr = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
school_state_categories_one_hot_cv,
               project_grade_categories_one_hot_cv, teacher_prefix_categories_one_hot_cv, price_cv,
quantity_cv,
               prev_projects_cv, title_word_count_cv, essay_word_count_cv, essay_sent_pos_cv, essay
_sent_neg_cv,
               essay_sent_neu_cv, essay_sent_comp_cv)).tocsr()
```

In [195]:

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

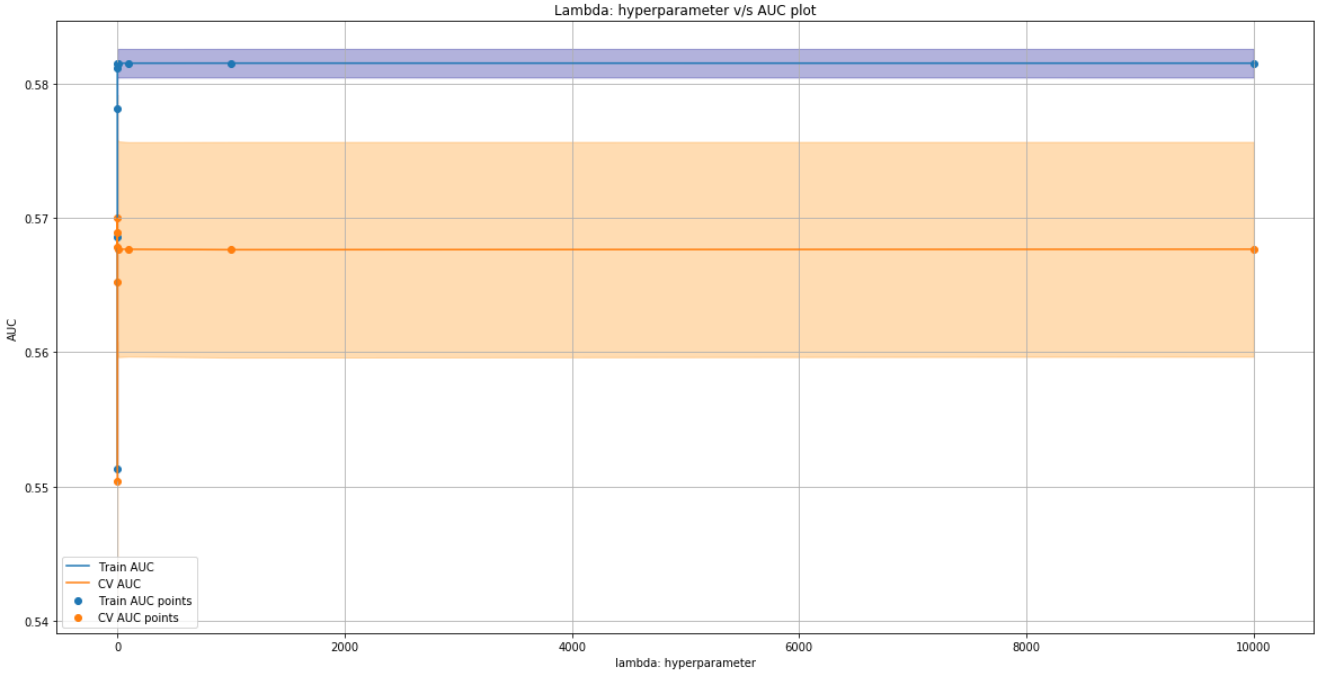
```
Final Data matrix
((49041, 109), (49041,))
((24155, 109), (24155,))
((36052, 109), (36052,))
====================================================================================================
```

A) GridSearchCV (K Fold Cross Validation)

In [196]:

```
lr = LogisticRegression()

parameters = {'C':[10**-4, 10**-3, 10**-2, 10**-1, 10**0, 10**1, 10**2, 10**3, 10**4]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')
```

```
clf.fit(X_tr, y_train)

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

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

plt.plot(parameters['C'], train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],train_auc - train_auc_std,train_auc +
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```



Inference

1. We observe that points/parameters ranging 100 and above seem to be futile as the AUC is almost constant after a certain point.

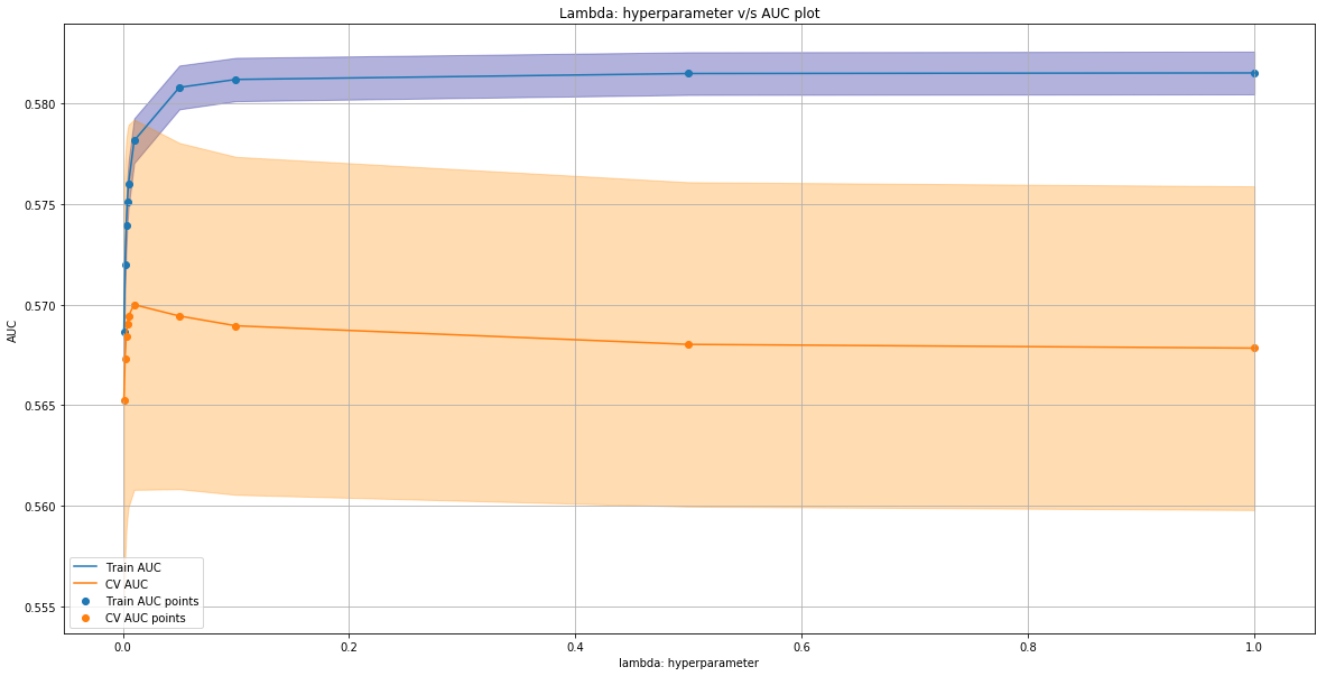
2. Also very low values ranging between 10^-4 and 10^-3 do not have a very appreciatable AUC score.

3. Lets consider the points in between for a better understanding and to obtain a better model.

In [197]:

```
lr = LogisticRegression()
```

```
parameters = {'C':[1, 0.5, 0.1, 0.05, 0.01, 0.005, 0.004, 0.003, 0.002, 0.001]}

clf = GridSearchCV(lr, parameters, cv= 10, scoring='roc_auc')

clf.fit(X_tr, y_train)

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

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

plt.plot(parameters['C'], train_auc, label='Train AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],train_auc - train_auc_std,train_auc +
train_auc_std,alpha=0.3,color='darkblue')

plt.plot(parameters['C'], cv_auc, label='CV AUC')
# this code is copied from here: https://stackoverflow.com/a/48803361/4084039
plt.gca().fill_between(parameters['C'],cv_auc - cv_auc_std,cv_auc + cv_auc_std,alpha=0.3,color='dar
korange')

plt.scatter(parameters['C'], train_auc, label='Train AUC points')
plt.scatter(parameters['C'], cv_auc, label='CV AUC points')


plt.legend()
plt.xlabel("lambda: hyperparameter")
plt.ylabel("AUC")
plt.title("Lambda: hyperparameter v/s AUC plot")
plt.grid()
plt.show()
```



Inference

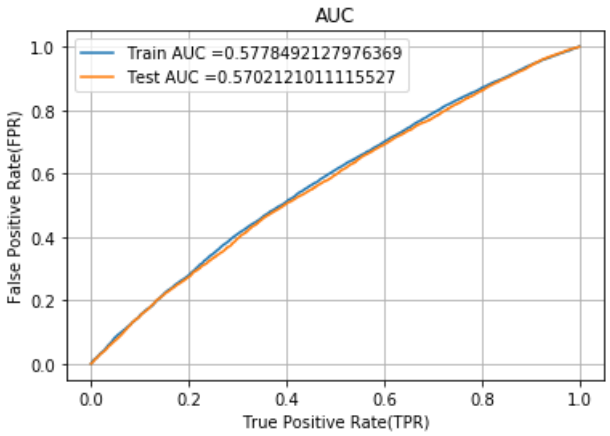
0.01 is chosen as the best hyper parameter value.

B) Train the model using the best hyper parameter value

In [198]:

```
model = LogisticRegression(C = 0.01)

model.fit(X_tr, y_train)
```

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

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

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

plt.plot(train_fpr, train_tpr, label="Train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="Test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("True Positive Rate(TPR)")
plt.ylabel("False Positive Rate(FPR)")
plt.title("AUC")
plt.grid()
plt.show()
```



C) Confusion Matrix

Train Data

In [199]:

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

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

Train confusion matrix
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.843)
[[ 3713  3713]
 [16201 25414]]
```

In [200]:

```
conf_matr_df_train_5 = pd.DataFrame(confusion_matrix(y_train, predict(y_train_pred, tr_thresholds,
train_fpr, train_fpr)), range(2),range(2))
```

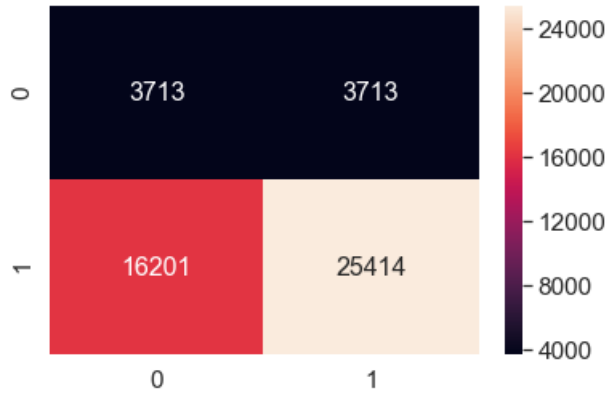
```
('the maximum value of tpr*(1-fpr)', 0.25, 'for threshold', 0.843)
```

In [204]:

```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_train_5, annot=True,annot_kws={"size": 16}, fmt='g')
```

Out[204]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa4f57250>
```



Test Data

In [201]:

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

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

Test confusion matrix
('the maximum value of tpr*(1-fpr)', 0.24999999161092998, 'for threshold', 0.85)
[[ 3155  2304]
 [14519 16074]]
```

In [202]:

```
conf_matr_df_test_5 = pd.DataFrame(confusion_matrix(y_test, predict(y_test_pred, tr_thresholds, tes
t_fpr, test_fpr)), range(2),range(2))
```

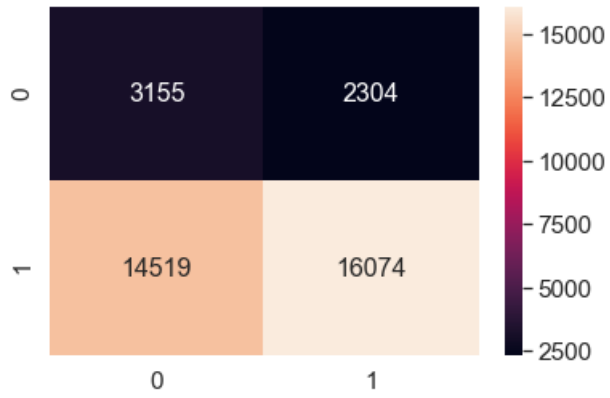
```
('the maximum value of tpr*(1-fpr)', 0.24999999161092998, 'for threshold', 0.85)
```

In [203]:

```
sns.set(font_scale=1.4)#for label size
sns.heatmap(conf_matr_df_test_5, annot=True,annot_kws={"size": 16}, fmt='g')
```

Out[203]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa55e8a10>
```



4. Conclusion

In [213]:

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

from prettytable import PrettyTable

#If you get a ModuleNotFoundError error , install prettytable using: pip3 install prettytable

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

x.add_row(["BOW", "Logistic Regression", 0.005, 0.67])
x.add_row(["TFIDF", "Logistic Regression", 0.1, 0.66])
x.add_row(["AVG W2V", "Logistic Regression", 1.0, 0.7])
x.add_row(["TFIDF W2V", "Logistic Regression", 0.01, 0.57])
x.add_row(["WITHOUT TEXT", "Logistic Regression", 0.01, 0.57])


print(x)
```

```
+--------------+---------------------+-----------------------+------+
|  Vectorizer  |        Model        | Alpha:Hyper Parameter | AUC  |
+--------------+---------------------+-----------------------+------+
|     BOW      | Logistic Regression |         0.005         | 0.67 |
|    TFIDF     | Logistic Regression |          0.1          | 0.66 |
|   AVG W2V    | Logistic Regression |          1.0          | 0.7  |
|  TFIDF W2V   | Logistic Regression |          0.01         | 0.57 |
| WITHOUT TEXT | Logistic Regression |          0.01         | 0.57 |
+--------------+---------------------+-----------------------+------+
```

Summary :

It is clearly visible that Text data contained in the Essays and Essay Titles indeed play a major role in predicting the outcome of the project. Hence, it cannot be neglected as most of the models containing them proved to have a better AUC score.