DonorsChoose_KNN

October 7, 2019

1 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

```
<li>How to increase the consistency of project vetting across different volunteers to improve t
<li>How to focus volunteer time on the applications that need the most assistance</li>
</ul>
```

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.

1.1 About the DonorsChoose Data Set

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

Feature	Description
`project_id`	A unique identifier for the proposed project. **Example:** `p036502`

`project_title` | Title of the project. **Examples:**

Art Will Make You Happy!

First Grade Fun

`project_grade_category` | Grade level of students for which the project is targeted. One of the following enumerated values:

Grades PreK-2

Grades 3-5

Grades 6-8

Grades 9-12

`project_subject_categories` | One or more (comma-separated) subject categories for the project from the following enumerated list of values:

Applied Learning
Care & Hunger
Health & Sports
History & Civics
Literacy & Language
Math & Science
Music & The Arts
Special Needs
Warmth
Examples:
Music & The Arts
Literacy & Language, Math & Science

`school_state` | State where school is located (Two-letter U.S. postal code). **Example:** `WY`

`project_subject_subcategories` | One or more (comma-separated) subject subcategories for the project. **Examples:**

Literacy
Literature & Writing, Social Sciences

`project_resource_summary` | An explanation of the resources needed for the project. **Example:**

My students need hands on literacy materials to manage sensory needs!</code

`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.

1.1.1 Notes on the Essay Data

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

project_essay_1: "Introduce us to your classroom"

project_essay_2: "Tell us more about your students"

project_essay_3: "Describe how your students will use the materials you're requesting"

project_essay_3: "Close by sharing why your project will make a difference"

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

project_essay_1: "Describe your students: What makes your students special? Specific details about their background, your neighborhood, and your school are all helpful."

project_essay_2: "About your project: How will these materials make a difference in your students' learning and improve their school lives?"

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

```
In [1]: %matplotlib inline
        import warnings
        warnings.filterwarnings("ignore")

        import sqlite3
        import pandas as pd
        import numpy as np
        import nltk
        import string
        import 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.model_selection import train_test_split
        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 collections import Counter

# suppress warnings
warnings.filterwarnings("ignore")
```

1.2 1.1 Reading Data

In [7]:
```
project_data = pd.read_csv('../resources/train_data.csv')
resource_data = pd.read_csv('../resources/resources.csv')
project_data.head(3)
```

Out[7]:

	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
0	160221	p253737	c90749f5d961ff158d4b4d1e7dc665fc	Mrs.	IN	2016-12-05 13:43:57	Grades PreK-2	Literacy & Language	ESL, Literacy	Educational Support for English Learners at Home	My students are English learners that are work...
1	140945	p258326	897464ce9ddc600bced1151f324dd63a	Mr.	FL	2016-10-25 09:22:10	Grades 6-8	History & Civics, Health & Sports	Civics & Government, Team Sports	Wanted: Projector for Hungry Learners	Our students arrive to our school eager to lea...
2	21895	p182444	3465aaf82da834c0582ebd0ef8040ca0	Ms.	AZ	2016-08-31 12:03:56	Grades 6-8	Health & Sports	Health & Wellness, Team Sports	Soccer Equipment for AWESOME Middle School Stu...	

```
2  \r\n\"True champions aren't always the ones th...

                                    project_essay_2 project_essay_3  \
0  \"The limits of your language are the limits o...             NaN
1  The projector we need for our school is very c...             NaN
2  The students on the campus come to school know...             NaN

  project_essay_4                         project_resource_summary  \
0             NaN  My students need opportunities to practice beg...
1             NaN  My students need a projector to help with view...
2             NaN  My students need shine guards, athletic socks,...

   teacher_number_of_previously_posted_projects  project_is_approved
0                                             0                   0
1                                             7                   1
2                                             1                   0
```

```
In [8]: print("Number of data points in project data frame", project_data.shape)
        print('-'*50)
        print("The attributes of data :", project_data.columns.values)
```

```
Number of data points in project data frame (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 [9]: # 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.co

        #sort dataframe based on time pandas python: https://stackoverflow.com/a/49702492/4084
        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]
```

```
In [10]: print("Number of data points in our resource data frame", resource_data.shape)
         print(resource_data.columns.values)
         resource_data.head(2)
```

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

Out[10]:
```
         id                                          description  quantity  \
0  p233245  LC652 - Lakeshore Double-Space Mobile Drying Rack         1
1  p069063         Bouncy Bands for Desks (Blue support pipes)         3

    price
0  149.00
1   14.95
```

In [11]:
```
# https://stackoverflow.com/questions/22407798/how-to-reset-a-dataframes-indexes-for-
price_data = resource_data.groupby('id').agg({'price':'sum', 'quantity':'sum'}).reset_
price_data.head(2)
```

Out[11]:
```
         id   price  quantity
0  p000001  459.56         7
1  p000002  515.89        21
```

In [12]:
```
# join two dataframes in python:
project_data = pd.merge(project_data, price_data, on='id', how='left')
project_data.head(5)
```

Out[12]:
```
   Unnamed: 0       id                         teacher_id teacher_prefix  \
0        8393  p205479  2bf07ba08945e5d8b2a3f269b2b3cfe5           Mrs.
1       37728  p043609  3f60494c61921b3b43ab61bdde2904df            Ms.
2       74477  p189804  4a97f3a390bfe21b99cf5e2b81981c73           Mrs.
3      100660  p234804  cbc0e38f522143b86d372f8b43d4cff3           Mrs.
4       33679  p137682  06f6e62e17de34fcf81020c77549e1d5           Mrs.

  school_state                 Date project_grade_category  \
0           CA 2016-04-27 00:27:36          Grades PreK-2
1           UT 2016-04-27 00:31:25             Grades 3-5
2           CA 2016-04-27 00:46:53          Grades PreK-2
3           GA 2016-04-27 00:53:00          Grades PreK-2
4           WA 2016-04-27 01:05:25             Grades 3-5

  project_subject_categories           project_subject_subcategories  \
0            Math & Science  Applied Sciences, Health & Life Science
1             Special Needs                           Special Needs
2       Literacy & Language                                Literacy
3          Applied Learning                     Early Development
4       Literacy & Language                                Literacy

                                  project_title  \
0   Engineering STEAM into the Primary Classroom
1                         Sensory Tools for Focus
2  Mobile Learning with a Mobile Listening Center
3         Flexible Seating for Flexible Learning
4         Going Deep: The Art of Inner Thinking!

                                    project_essay_1  \
```

```
0  I have been fortunate enough to use the Fairy ...
1  Imagine being 8-9 years old. You're in your th...
2  Having a class of 24 students comes with diver...
3  I recently read an article about giving studen...
4  My students crave challenge, they eat obstacle...

                                      project_essay_2  \
0  My students come from a variety of backgrounds...
1  Most of my students have autism, anxiety, anot...
2  I have a class of twenty-four kindergarten stu...
3  I teach at a low-income (Title 1) school. Ever...
4  We are an urban, public k-5 elementary school...

                                      project_essay_3  \
0  Each month I try to do several science or STEM...
1  It is tough to do more than one thing at a tim...
2  By having a mobile listening and storage cente...
3  We need a classroom rug that we can use as a c...
4  With the new common core standards that have b...

                                      project_essay_4  \
0  It is challenging to develop high quality scie...
1  When my students are able to calm themselves d...
2  A mobile listening center will help keep equip...
3  Benjamin Franklin once said, \"Tell me and I f...
4  These remarkable gifts will provide students w...

                             project_resource_summary  \
0  My students need STEM kits to learn critical s...
1  My students need Boogie Boards for quiet senso...
2  My students need a mobile listening center to ...
3  My students need flexible seating in the class...
4  My students need copies of the New York Times ...

   teacher_number_of_previously_posted_projects  project_is_approved   price  \
0                                            53                    1  725.05
1                                             4                    1  213.03
2                                            10                    1  329.00
3                                             2                    1  481.04
4                                             2                    1   17.74

   quantity
0         4
1         8
2         1
3         9
4        14
```

```
In [13]: print("Number of data points in project data after merging price and quantity", projec
         print(project_data.columns.values)
```

```
Number of data points in project data after merging price and quantity (109248, 19)
['Unnamed: 0' 'id' 'teacher_id' 'teacher_prefix' 'school_state' 'Date'
 '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' 'price' 'quantity']
```

```
In [14]: project_data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 109248 entries, 0 to 109247
Data columns (total 19 columns):
Unnamed: 0                                      109248 non-null int64
id                                              109248 non-null object
teacher_id                                      109248 non-null object
teacher_prefix                                  109245 non-null object
school_state                                    109248 non-null object
Date                                            109248 non-null datetime64[ns]
project_grade_category                          109248 non-null object
project_subject_categories                      109248 non-null object
project_subject_subcategories                   109248 non-null object
project_title                                   109248 non-null object
project_essay_1                                 109248 non-null object
project_essay_2                                 109248 non-null object
project_essay_3                                 3758 non-null object
project_essay_4                                 3758 non-null object
project_resource_summary                        109248 non-null object
teacher_number_of_previously_posted_projects    109248 non-null int64
project_is_approved                             109248 non-null int64
price                                           109248 non-null float64
quantity                                        109248 non-null int64
dtypes: datetime64[ns](1), float64(1), int64(4), object(13)
memory usage: 16.7+ MB
```

1.3 1.1.1 Handling Null Values

```
In [15]: # from above matric I know that teacher_prefix has 3 null values we need to handle th
         # also most of values of project_essay_3 and project_essay_4 are null

         project_data["teacher_prefix"].fillna( value = 'Mrs.', inplace = True)
```

```
In [16]: ## 1.5 Combining 4 essay columns to get a single Essay column
```

```
        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)

        project_data.drop(['project_essay_1','project_essay_2','project_essay_3','project_essa
        # project_data['essay'].head()
```

```
In [17]: # it can be clearly seen that we have handled all null values in our data frame.
         project_data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 109248 entries, 0 to 109247
Data columns (total 16 columns):
Unnamed: 0                                      109248 non-null int64
id                                              109248 non-null object
teacher_id                                      109248 non-null object
teacher_prefix                                  109248 non-null object
school_state                                    109248 non-null object
Date                                            109248 non-null datetime64[ns]
project_grade_category                          109248 non-null object
project_subject_categories                      109248 non-null object
project_subject_subcategories                   109248 non-null object
project_title                                   109248 non-null object
project_resource_summary                        109248 non-null object
teacher_number_of_previously_posted_projects    109248 non-null int64
project_is_approved                             109248 non-null int64
price                                           109248 non-null float64
quantity                                        109248 non-null int64
essay                                           109248 non-null object
dtypes: datetime64[ns](1), float64(1), int64(4), object(10)
memory usage: 14.2+ MB
```

```
In [18]: df_approved = project_data[project_data.project_is_approved==1].tail(44000)
         df_rejected = project_data[project_data.project_is_approved==0]

         final_df = pd.concat([df_approved, df_rejected])
         print(final_df.shape)
```

```
(60542, 16)
```

1.4 1.2 preprocessing of `project_subject_categories`

```
In [19]: def preprocess_text(column_name):
             catogories = list(final_df[column_name].values)
             # remove special characters from list of strings python: https://stackoverflow.co
             # https://www.geeksforgeeks.org/removing-stop-words-nltk-python/
```

```
        # https://stackoverflow.com/questions/23669024/how-to-strip-a-specific-word-from-
        # https://stackoverflow.com/questions/8270092/remove-all-whitespace-in-a-string-i
        cat_list = []
        for i in catogories:
            temp = ""
            # consider we have text like this "Math & Science, Warmth, Care & Hunger"
            for j in i.split(','): # it will split it in three parts ["Math & Science", "
                if 'The' in j.split(): # this will split each of the catogory based on sp
                    j=j.replace('The','') # if we have the words "The" we are going to re
                j = j.replace(' ','') # we are placeing all the ' '(space) with ''(empty)
                temp+=j.strip()+" " #" abc ".strip() will return "abc", remove the traili
                temp = temp.replace('&','_') # we are replacing the & value into
            cat_list.append(temp.strip())
        return cat_list
```

```
In [20]: # preprocessing of `project_subject_categories`
         final_df['clean_categories'] = preprocess_text('project_subject_categories')
         final_df.drop(['project_subject_categories'], axis=1, inplace=True)
```

1.5 1.3 preprocessing of `project_subject_subcategories`

```
In [21]: # preprocessing of `project_subject_subcategories`
         final_df['clean_subcategories'] = preprocess_text('project_subject_subcategories')
         final_df.drop(['project_subject_subcategories'], axis=1, inplace=True)
```

1.6 1.4 Adding New Feature `No. of words in project_title`

```
In [22]: final_df['title_word_count'] = final_df['project_title'].apply(lambda x: len(x.split(
```

```
In [23]: final_df.head(2)
```

```
Out[23]:        Unnamed: 0       id                         teacher_id teacher_prefix  \
         57914       20585  p162378  d7f9112bc7cb9f651090a0afc0808f1d           Ms.
         57915       67525  p074880  a8731a23e04ca6fa1d528e5f8914d6a8          Mrs.

               school_state                Date project_grade_category  \
         57914           MA 2016-10-10 12:30:53          Grades PreK-2
         57915           FL 2016-10-10 12:32:36            Grades 9-12

                                                project_title  \
         57914  Providing Access to Technology to First Graders
         57915              This Little Piggy Goes to Bio Class

                                          project_resource_summary  \
         57914  My students need Kindle Fire tablets to provid...
         57915  My students need 24 pig anatomy kits and a box...

                teacher_number_of_previously_posted_projects  project_is_approved  \
```

```
57914                                                 0                    1
57915                                                 1                    1

       price  quantity                                                essay  \
57914  99.99         4  I spend each day with a group of phenomenal fi...
57915  45.85        25  My students are an amazing group of individual...

        clean_categories clean_subcategories  title_word_count
57914  Literacy_Language           Literacy                 7
57915       Math_Science  Health_LifeScience                 7
```

1.7 1.5 Preprocessing project grade category

```
In [24]: # replacing space with _.
         final_df['project_grade_category'] = final_df['project_grade_category'].apply(lambda x
         print('Post Preprocessing: ')
         final_df['project_grade_category'].value_counts()
```

```
Post Preprocessing:
```

```
Out[24]: Grades_PreK_2    24307
         Grades_3_5       20295
         Grades_6_8        9596
         Grades_9_12       6344
         Name: project_grade_category, dtype: int64
```

1.8 1.6 Preprocessing teacher_prefix

```
In [25]: # replacing '.' with ''
         final_df['teacher_prefix'] = final_df['teacher_prefix'].apply(lambda x: x.replace('.'
         print('Post Preprocessing: ')
         final_df['teacher_prefix'].value_counts()
```

```
Post Preprocessing:
```

```
Out[25]: Mrs        31061
         Ms         21895
         Mr          6136
         Teacher     1440
         Dr            10
         Name: teacher_prefix, dtype: int64
```

1.9 1.6 Adding New Feature `No. of words in Essay`

```
In [26]: final_df['essay_word_count'] = final_df['essay'].apply(lambda x: len(x.split()))

In [27]: final_df.head(2)
```

Out[27]:
```
       Unnamed: 0       id                         teacher_id teacher_prefix  \
57914       20585  p162378  d7f9112bc7cb9f651090a0afc0808f1d             Ms
57915       67525  p074880  a8731a23e04ca6fa1d528e5f8914d6a8            Mrs

      school_state                Date project_grade_category  \
57914           MA 2016-10-10 12:30:53          Grades_PreK_2
57915           FL 2016-10-10 12:32:36            Grades_9_12

                                        project_title  \
57914  Providing Access to Technology to First Graders
57915              This Little Piggy Goes to Bio Class

                                project_resource_summary  \
57914  My students need Kindle Fire tablets to provid...
57915  My students need 24 pig anatomy kits and a box...

       teacher_number_of_previously_posted_projects  project_is_approved  \
57914                                             0                   1
57915                                             1                   1

       price  quantity                                                essay  \
57914  99.99         4  I spend each day with a group of phenomenal fi...
57915  45.85        25  My students are an amazing group of individual...

        clean_categories clean_subcategories  title_word_count  \
57914  Literacy_Language            Literacy                 7
57915       Math_Science  Health_LifeScience                 7

       essay_word_count
57914               284
57915               222
```

1.10 1.7 Preprocessing of essay

In [28]:
```
# https://stackoverflow.com/a/47091490/4084039
import re
from tqdm import tqdm

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


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


def preprocess_sentences(column_name):
    preprocessed = []
    # tqdm is for printing the status bar
    for sentance in tqdm(final_df[column_name].values):
        sent = decontracted(sentance)
        sent = sent.replace('\\r', ' ')
        sent = sent.replace('\\"', ' ')
        sent = sent.replace('\\n', ' ')
        sent = re.sub('[^A-Za-z0-9]+', ' ', sent)
        # https://gist.github.com/sebleier/554280
        sent = ' '.join(e for e in sent.split() if e.lower() not in stopwords)
        preprocessed.append(sent.lower().strip())
    return preprocessed
```

In [29]:
```
final_df['clean_essay'] = preprocess_sentences('essay')
final_df.drop(['essay'], axis=1, inplace=True)
final_df.head(2)
```

```
100%|| 60542/60542 [00:32<00:00, 1874.09it/s]
```

Out[29]:

	Unnamed: 0	id	teacher_id	teacher_prefix	\
57914	20585	p162378	d7f9112bc7cb9f651090a0afc0808f1d	Ms	

```
57915       67525  p074880  a8731a23e04ca6fa1d528e5f8914d6a8           Mrs

      school_state                Date project_grade_category  \
57914           MA 2016-10-10 12:30:53          Grades_PreK_2
57915           FL 2016-10-10 12:32:36            Grades_9_12

                                        project_title  \
57914  Providing Access to Technology to First Graders
57915              This Little Piggy Goes to Bio Class

                                project_resource_summary  \
57914  My students need Kindle Fire tablets to provid...
57915  My students need 24 pig anatomy kits and a box...

       teacher_number_of_previously_posted_projects  project_is_approved  \
57914                                             0                   1
57915                                             1                   1

       price  quantity   clean_categories clean_subcategories  \
57914  99.99         4  Literacy_Language            Literacy
57915  45.85        25       Math_Science  Health_LifeScience

       title_word_count  essay_word_count  \
57914                 7               284
57915                 7               222

                                           clean_essay
57914  spend day group phenomenal first graders toget...
57915  students amazing group individuals overcoming ...
```

1.11 1.8 Preprocessing of `project_title`

```
In [30]: # preprocessing of `project_title`
         final_df['clean_title'] = preprocess_sentences('project_title')
         final_df.drop(['project_title'], axis=1, inplace=True)
         final_df.head(2)
```

```
100%|| 60542/60542 [00:01<00:00, 38236.36it/s]
```

```
Out[30]:       Unnamed: 0       id                         teacher_id teacher_prefix  \
         57914       20585  p162378  d7f9112bc7cb9f651090a0afc0808f1d            Ms
         57915       67525  p074880  a8731a23e04ca6fa1d528e5f8914d6a8           Mrs

               school_state                Date project_grade_category  \
         57914           MA 2016-10-10 12:30:53          Grades_PreK_2
         57915           FL 2016-10-10 12:32:36            Grades_9_12
```

```
                                project_resource_summary  \
57914  My students need Kindle Fire tablets to provid...
57915  My students need 24 pig anatomy kits and a box...

       teacher_number_of_previously_posted_projects  project_is_approved  \
57914                                             0                    1
57915                                             1                    1

       price  quantity   clean_categories clean_subcategories  \
57914  99.99         4  Literacy_Language            Literacy
57915  45.85        25       Math_Science  Health_LifeScience

       title_word_count  essay_word_count  \
57914                 7               284
57915                 7               222

                                          clean_essay  \
57914  spend day group phenomenal first graders toget...
57915  students amazing group individuals overcoming ...

                                    clean_title
57914  providing access technology first graders
57915               little piggy goes bio class
```

2.1 Splitting data into Train, Cross validation and Test: Stratified Sampling

```
In [31]: # I have divided the data into train, cv and test set with ratio 60:20:20 .

         X_1, X_test, y_1, y_test = train_test_split(final_df, final_df['project_is_approved']
         X_train, X_cv, y_train, y_cv = train_test_split(X_1, y_1, test_size=0.2, random_state=

In [32]: X_train.drop(['project_is_approved'], axis=1, inplace=True)
         X_cv.drop(['project_is_approved'], axis=1, inplace=True)
         X_test.drop(['project_is_approved'], axis=1, inplace=True)
```

2.2 Make Data Model Ready: encoding numerical, categorical features

```
In [33]: X_train.columns

Out[33]: Index(['Unnamed: 0', 'id', 'teacher_id', 'teacher_prefix', 'school_state',
                'Date', 'project_grade_category', 'project_resource_summary',
                'teacher_number_of_previously_posted_projects', 'price', 'quantity',
                'clean_categories', 'clean_subcategories', 'title_word_count',
                'essay_word_count', 'clean_essay', 'clean_title'],
               dtype='object')
```

we are going to consider

```
- school_state : categorical data
- clean_categories : categorical data
- clean_subcategories : categorical data
- title_word_count: No. of words in project_title
_ essay_word_count: No. of words in essay.


- project_grade_category : categorical data
- teacher_prefix : categorical data

- clean_title : text data
- clean_essay : text data
- project_resource_summary: text data (optinal)

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

2.2.1 Vectorizing numerical features

- I am using one hot encoding technique to encode our categorical features.

A) Price

```
In [34]: # encoding price
         from sklearn.preprocessing import StandardScaler

         # standardizer.fit(X_train['price'].values)
         # this will rise an error Expected 2D array, got 1D array instead: # array=[105.22 21
         # 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.


         standardizer = StandardScaler(with_mean=False)
         standardizer.fit(X_train['price'].values.reshape(-1,1))
         print(f"Mean : {standardizer.mean_[0]}, Standard deviation : {np.sqrt(standardizer.va

         # Now standardize the data with above mean and variance.

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


         print('Post Standardization')
         print(price_train.shape, y_train.shape)
         print(price_cv.shape, y_cv.shape)
```

```
        print(price_test.shape, y_test.shape)
        print('*'*100)
```

```
Mean : 298.5071535126206, Standard deviation : 376.42382111593906

Post Standardization
(38746, 1) (38746,)
(9687, 1) (9687,)
(12109, 1) (12109,)
****************************************************************************************************
```

B) Quantity

```
In [35]: standardizer = StandardScaler(with_mean=False)
         standardizer.fit(X_train['quantity'].values.reshape(-1,1))
         print(f"Mean : {standardizer.mean_[0]}, Standard deviation : {np.sqrt(standardizer.va

         # Now standardize the data with above mean and variance.

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


         print('Post Standardization')
         print(quantity_train.shape, y_train.shape)
         print(quantity_cv.shape, y_cv.shape)
         print(quantity_test.shape, y_test.shape)
         print('*'*100)
```

```
Mean : 16.54139782171063, Standard deviation : 25.628978294366323

Post Standardization
(38746, 1) (38746,)
(9687, 1) (9687,)
(12109, 1) (12109,)
****************************************************************************************************
```

C) Number of projects previously posted by Teacher

```
In [36]: standardizer = StandardScaler(with_mean=False)
         standardizer.fit(X_train['teacher_number_of_previously_posted_projects'].values.reshap
         print(f"Mean : {standardizer.mean_[0]}, Standard deviation : {np.sqrt(standardizer.va

         # Now standardize the data with above mean and variance.

         prev_teacher_proj_train = standardizer.transform(X_train['teacher_number_of_previously
```

```
        prev_teacher_proj_cv = standardizer.transform(X_cv['teacher_number_of_previously_poste
        prev_teacher_proj_test = standardizer.transform(X_test['teacher_number_of_previously_p


        print('Post Standardization')
        print(prev_teacher_proj_train.shape, y_train.shape)
        print(prev_teacher_proj_cv.shape, y_cv.shape)
        print(prev_teacher_proj_test.shape, y_test.shape)
        print('*'*100)
```

```
Mean : 12.029370773757291, Standard deviation : 29.518216519463813

Post Standardization
(38746, 1) (38746,)
(9687, 1) (9687,)
(12109, 1) (12109,)
****************************************************************************************************
```

D) Title word Count

```
In [37]: standardizer = StandardScaler(with_mean=False)
         standardizer.fit(X_train['title_word_count'].values.reshape(-1,1))
         print(f"Mean : {standardizer.mean_[0]}, Standard deviation : {np.sqrt(standardizer.va

         # Now standardize the data with above mean and variance.

         title_word_count_train = standardizer.transform(X_train['title_word_count'].values.res
         title_word_count_cv = standardizer.transform(X_cv['title_word_count'].values.reshape(
         title_word_count_test = standardizer.transform(X_test['title_word_count'].values.resha


         print('Post Standardization')
         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)
```

```
Mean : 5.087209002219584, Standard deviation : 2.0904440065863996

Post Standardization
(38746, 1) (38746,)
(9687, 1) (9687,)
(12109, 1) (12109,)
****************************************************************************************************
```

E) Essay word Count

```
In [38]: standardizer = StandardScaler(with_mean=False)
         standardizer.fit(X_train['essay_word_count'].values.reshape(-1,1))
         print(f"Mean : {standardizer.mean_[0]}, Standard deviation : {np.sqrt(standardizer.va

         # Now standardize the data with above mean and variance.

         essay_word_count_train = standardizer.transform(X_train['essay_word_count'].values.re
         essay_word_count_cv = standardizer.transform(X_cv['essay_word_count'].values.reshape(
         essay_word_count_test = standardizer.transform(X_test['essay_word_count'].values.resh


         print('Post Standardization')
         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)
```

```
Mean : 251.49785784339028, Standard deviation : 62.24243896188054

Post Standardization
(38746, 1) (38746,)
(9687, 1) (9687,)
(12109, 1) (12109,)
****************************************************************************************************
```

2.2.2 Encoding categorical features

```
In [39]: from sklearn.feature_extraction.text import CountVectorizer
         from collections import Counter

         # we use count vectorizer to convert the values into one

         def get_categorical_vectorizer_for_training(df,column_name):
             my_counter = Counter()
             for word in df[column_name].values:
                 my_counter.update(word.split())
             cat_dict = dict(my_counter)
             sorted_cat_dict = dict(sorted(cat_dict.items(), key=lambda kv: kv[1]))
             vectorizer = CountVectorizer(vocabulary=list(sorted_cat_dict.keys()), lowercase=Fa
             return vectorizer.fit(df[column_name].values)
```

A) Encoding clean_categories

```
In [40]: vectorizer = get_categorical_vectorizer_for_training(X_train, 'clean_categories')

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

```
        print('Post Encoding: ')
        print(vectorizer.get_feature_names())

        print('*'*100)
        print('Encoded training sample: ')
        print(categories_one_hot_train[:5])
        print('*'*100)

        print("Shape of matrix after one hot encodig ",categories_one_hot_train.shape)
        print("Shape of matrix after one hot encodig ",categories_one_hot_cv.shape)
        print("Shape of matrix after one hot encodig ",categories_one_hot_test.shape)

        print('*'*100)
```

```
Post Encoding:
['Warmth', 'Care_Hunger', 'History_Civics', 'Health_Sports', 'Music_Arts', 'AppliedLearning',
****************************************************************************************************
Encoded training sample:
  (0, 6)        1
  (1, 7)        1
  (2, 8)        1
  (3, 7)        1
  (4, 7)        1
  (4, 8)        1
****************************************************************************************************
Shape of matrix after one hot encodig  (38746, 9)
Shape of matrix after one hot encodig  (9687, 9)
Shape of matrix after one hot encodig  (12109, 9)
****************************************************************************************************
```

B) Encoding clean_subcategories

```
In [41]: vectorizer = get_categorical_vectorizer_for_training(X_train, 'clean_subcategories')

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

        print('Post Encoding: ')
        print(vectorizer.get_feature_names())

        print('*'*100)
        print('Encoded training sample: ')
        print(sub_categories_one_hot_train[5:10])
        print('*'*100)
```

```
        print("Shape of matrix after one hot encodig ",sub_categories_one_hot_train.shape)
        print("Shape of matrix after one hot encodig ",sub_categories_one_hot_cv.shape)
        print("Shape of matrix after one hot encodig ",sub_categories_one_hot_test.shape)

        print('*'*100)
```

```
Post Encoding:
['Economics', 'CommunityService', 'NutritionEducation', 'Civics_Government', 'FinancialLiteracy
**************************************************************************************************
Encoded training sample:
  (0, 25)       1
  (0, 29)       1
  (1, 27)       1
  (2, 28)       1
  (2, 29)       1
  (3, 27)       1
  (3, 29)       1
  (4, 29)       1
**************************************************************************************************
Shape of matrix after one hot encodig  (38746, 30)
Shape of matrix after one hot encodig  (9687, 30)
Shape of matrix after one hot encodig  (12109, 30)
**************************************************************************************************
```

C) Encoding school_state

```
In [42]: vectorizer = get_categorical_vectorizer_for_training(X_train, 'school_state')

        school_state_one_hot_train = vectorizer.transform(X_train['school_state'].values)
        school_state_one_hot_cv = vectorizer.transform(X_cv['school_state'].values)
        school_state_one_hot_test = vectorizer.transform(X_test['school_state'].values)

        print('Post Encoding: ')
        print(vectorizer.get_feature_names())

        print('*'*100)
        print('Encoded training sample: ')
        print(school_state_one_hot_train[:5])
        print('*'*100)

        print("Shape of matrix after one hot encodig ",school_state_one_hot_train.shape)
        print("Shape of matrix after one hot encodig ",school_state_one_hot_cv.shape)
        print("Shape of matrix after one hot encodig ",school_state_one_hot_test.shape)

        print('*'*100)
```

```
Post Encoding:
['VT', 'WY', 'ND', 'MT', 'NE', 'DE', 'SD', 'RI', 'AK', 'NH', 'WV', 'ME', 'DC', 'HI', 'IA', 'NM
```

```
****************************************************************************************************
Encoded training sample:
  (0, 36)        1
  (1, 44)        1
  (2, 50)        1
  (3, 50)        1
  (4, 50)        1
****************************************************************************************************
Shape of matrix after one hot encodig  (38746, 51)
Shape of matrix after one hot encodig  (9687, 51)
Shape of matrix after one hot encodig  (12109, 51)
****************************************************************************************************
```

D) Encoding teacher_prefix

```
In [43]: vectorizer = get_categorical_vectorizer_for_training(X_train, 'teacher_prefix')

         teacher_prefix_one_hot_train = vectorizer.transform(X_train['teacher_prefix'].values)
         teacher_prefix_one_hot_cv = vectorizer.transform(X_cv['teacher_prefix'].values)
         teacher_prefix_one_hot_test = vectorizer.transform(X_test['teacher_prefix'].values)

         print('Post Encoding')
         print(vectorizer.get_feature_names())

         print('*'*100)
         print('Encoded training sample: ')
         print(teacher_prefix_one_hot_train[:5])
         print('*'*100)

         print("Shape of matrix after one hot encodig ",teacher_prefix_one_hot_train.shape)
         print("Shape of matrix after one hot encodig ",teacher_prefix_one_hot_cv.shape)
         print("Shape of matrix after one hot encodig ",teacher_prefix_one_hot_test.shape)

         print('*'*100)
```

```
Post Encoding
['Dr', 'Teacher', 'Mr', 'Ms', 'Mrs']
****************************************************************************************************
Encoded training sample:
  (0, 3)        1
  (1, 4)        1
  (2, 2)        1
  (3, 3)        1
  (4, 1)        1
****************************************************************************************************
Shape of matrix after one hot encodig  (38746, 5)
Shape of matrix after one hot encodig  (9687, 5)
```

```
Shape of matrix after one hot encodig  (12109, 5)
**************************************************************************************************
```

E) Encoding project_grade_category

```
In [44]: vectorizer = get_categorical_vectorizer_for_training(X_train, 'project_grade_category

         project_grade_category_one_hot_train = vectorizer.transform(X_train['project_grade_ca
         project_grade_category_one_hot_cv = vectorizer.transform(X_cv['project_grade_category
         project_grade_category_one_hot_test = vectorizer.transform(X_test['project_grade_cate

         print('Post Encoding')
         print(vectorizer.get_feature_names())

         print('*'*100)
         print('Encoded training sample: ')
         print(project_grade_category_one_hot_test[:5])
         print('*'*100)

         print("Shape of matrix after one hot encodig ",project_grade_category_one_hot_train.sh
         print("Shape of matrix after one hot encodig ",project_grade_category_one_hot_cv.shape
         print("Shape of matrix after one hot encodig ",project_grade_category_one_hot_test.sha

         print('*'*100)

         # final_df.head(2)
```

```
Post Encoding
['Grades_9_12', 'Grades_6_8', 'Grades_3_5', 'Grades_PreK_2']
**************************************************************************************************
Encoded training sample:
  (0, 1)        1
  (1, 0)        1
  (2, 1)        1
  (3, 3)        1
  (4, 0)        1
**************************************************************************************************
Shape of matrix after one hot encodig  (38746, 4)
Shape of matrix after one hot encodig  (9687, 4)
Shape of matrix after one hot encodig  (12109, 4)
**************************************************************************************************
```

2.2.3 Vectorizing Text features

A) Bag of Words (BOW)

Bag of Words - clean_essay

```
In [46]: # performing bow on essay field

         vectorizer = CountVectorizer(min_df=10)
         vectorizer.fit(X_train['clean_essay'])

         essay_bow_train = vectorizer.transform(X_train['clean_essay'])
         essay_bow_cv = vectorizer.transform(X_cv['clean_essay'])
         essay_bow_test = vectorizer.transform(X_test['clean_essay'])


         print('Post Vectorization')

         print("Shape of matrix after bow vectorization of essay on train data ",essay_bow_tra
         print("Shape of matrix after bow vectorization of essay on cv data",essay_bow_cv.shap
         print("Shape of matrix after bow vectorization of essay on test data",essay_bow_test.

         print('*'*100)
```

```
Post Vectorization
Shape of matrix after bow vectorization of essay on train data  (38746, 10968)
Shape of matrix after bow vectorization of essay on cv data (9687, 10968)
Shape of matrix after bow vectorization of essay on test data (12109, 10968)
****************************************************************************************
```

Bag of Words - clean_title

```
In [47]: vectorizer = CountVectorizer(min_df=10)
         vectorizer.fit(X_train['clean_title'])


         title_bow_train = vectorizer.transform(X_train['clean_title'])
         title_bow_cv = vectorizer.transform(X_cv['clean_title'])
         title_bow_test = vectorizer.transform(X_test['clean_title'])


         print('Post Vectorization: ')

         print("Shape of matrix after bow vectorization of title on train data ",title_bow_tra
         print("Shape of matrix after bow vectorization of title on cv data",title_bow_cv.shap
         print("Shape of matrix after bow vectorization of title on test data",title_bow_test.

         print('*'*100)
```

```
Post Vectorization:
Shape of matrix after bow vectorization of title on train data  (38746, 1718)
Shape of matrix after bow vectorization of title on cv data (9687, 1718)
Shape of matrix after bow vectorization of title on test data (12109, 1718)
```

****

B) TFIDF Vectorizer

TFIDF - clean_essay

```
In [48]: vectorizer = TfidfVectorizer(min_df=10)
         vectorizer.fit(X_train['clean_title'])


         title_tfidf_train = vectorizer.transform(X_train['clean_title'])
         title_tfidf_cv = vectorizer.transform(X_cv['clean_title'])
         title_tfidf_test = vectorizer.transform(X_test['clean_title'])

         print('Post Vectorization')

         print("Shape of matrix after tfidf vectorization of title on train data ",title_tfidf_
         print("Shape of matrix after tfidf vectorization of title on cv data",title_tfidf_cv.s
         print("Shape of matrix after tfidf vectorization of title on test data",title_tfidf_te
         print('*'*100)
```

```
Post Vectorization
Shape of matrix after tfidf vectorization of title on train data  (38746, 1718)
Shape of matrix after tfidf vectorization of title on cv data (9687, 1718)
Shape of matrix after tfidf vectorization of title on test data (12109, 1718)
**********
```

TFIDF - clean_title

```
In [49]: vectorizer = TfidfVectorizer(min_df=10)
         vectorizer.fit(X_train['clean_essay'])


         essay_tfidf_train = vectorizer.transform(X_train['clean_essay'])
         essay_tfidf_cv = vectorizer.transform(X_cv['clean_essay'])
         essay_tfidf_test = vectorizer.transform(X_test['clean_essay'])

         print('Post Vectorization: ')

         print("Shape of matrix after tfidf vectorization of essay on train data ",essay_tfidf_
         print("Shape of matrix after tfidf vectorization of essay on cv data",essay_tfidf_cv.s
         print("Shape of matrix after tfidf vectorization of essay on test data",essay_tfidf_te
         print('*'*100)
```

```
Post Vectorization:
Shape of matrix after tfidf vectorization of essay on train data  (38746, 10968)
Shape of matrix after tfidf vectorization of essay on cv data (9687, 10968)
```

```
Shape of matrix after tfidf vectorization of essay on test data (12109, 10968)
**********************************************************************************************
```

C) Avg W2V

```
In [50]: # https://stackoverflow.com/questions/37793118/load-pretrained-glove-vectors-in-pytho

         import numpy as np
         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 [52]: glove_model = loadGloveModel('../resources/glove.42B.300d.txt')

2054it [00:00, 10257.90it/s]

Loading Glove Model


1917495it [02:44, 11645.27it/s]

Done. 1917495  words loaded!




In [62]: from gensim.models import Word2Vec
         from gensim.models import KeyedVectors

         def perform_avg_w2v(list_sent, w2v_model, w2v_words):
             # average Word2Vec
             # compute average word2vec for each review.
             avg_w2v = []; # the avg-w2v for each sentence/review is stored in this list
             for sent in tqdm(list_sent): # for each review/sentence
                 sent_vec = np.zeros(300) # as word vectors are of zero length 50, you might n
                 cnt_words =0; # num of words with a valid vector in the sentence/review
                 for word in sent.split(): # for each word in a review/sentence
                     if word in w2v_words:
                         vec = w2v_model[word]
```

```
                    sent_vec += vec
                    cnt_words += 1
            if cnt_words != 0:
                sent_vec /= cnt_words
            avg_w2v.append(sent_vec)
        avg_w2v = np.array(avg_w2v)
        return avg_w2v
```

Avg W2V - clean_essay

```
In [63]: train_essays_words = []
         for i in X_train['clean_essay'] :
             train_essays_words.extend(i.split(' '))

         # Find the total number of words in the Train data of Essays.
         print("all the words in the X_train clean_essay", len(train_essays_words))

         # Find the unique words in this set of words
         train_essays_words = set(train_essays_words)
         print("the unique words in the X_train clean_essay", len(train_essays_words))


         common_words = set(glove_model.keys()).intersection(train_essays_words)
         print("The number of words that are present in both glove vectors and our X_train clea
               .format(len(common_words), np.round((float(len(common_words))/len(train_essays_w
```

```
all the words in the X_train clean_essay 5275914
the unique words in the X_train clean_essay 37447
The number of words that are present in both glove vectors and our X_train clean_essay are 3468
```

```
In [64]: corpus_train_essay_words = {}
         words_glove = set(glove_model.keys())
         for i in train_essays_words:
             if i in words_glove:
                 corpus_train_essay_words[i] = glove_model[i]
         print("word2vec length of our X_train clean_essay", len(corpus_train_essay_words))
```

```
word2vec length of our X_train clean_essay 34687
```

```
In [65]: # storing variables into pickle files python: http://www.jessicayung.com/how-to-use-p
         import pickle
         with open('glove_vectors_w2v_clean_essay', 'wb') as f:
             pickle.dump(corpus_train_essay_words, f)
```

```
In [66]: # loading stored vectors from pickle file
         with open('glove_vectors_w2v_clean_essay', 'rb') as f:
             model = pickle.load(f)
             glove_words_essay = set(model.keys())
```

```
In [67]: essay_avg_w2v_train = perform_avg_w2v(X_train['clean_essay'], glove_model, glove_words
         essay_avg_w2v_cv = perform_avg_w2v(X_cv['clean_essay'], glove_model, glove_words_essa
         essay_avg_w2v_test = perform_avg_w2v(X_test['clean_essay'], glove_model, glove_words_

         print('Post Vectorization: ')

         print("Shape of matrix after avg w2v vectorization of essay on train data ",essay_avg
         print("Shape of matrix after avg w2v vectorization of essay on cv data",essay_avg_w2v
         print("Shape of matrix after avg w2v vectorization of essay on test data",essay_avg_w
         print('*'*100)
```

```
100%|| 38746/38746 [00:08<00:00, 4313.27it/s]
100%|| 9687/9687 [00:02<00:00, 4023.72it/s]
100%|| 12109/12109 [00:03<00:00, 4025.90it/s]

Post Vectorization:
Shape of matrix after avg w2v vectorization of essay on train data  (38746, 300)
Shape of matrix after avg w2v vectorization of essay on cv data (9687, 300)
Shape of matrix after avg w2v vectorization of essay on test data (12109, 300)
****************************************************************************************
```

Avg W2V - clean_title

```
In [68]: train_title_words = []
         for i in X_train['clean_title'] :
             train_title_words.extend(i.split(' '))

         # Find the total number of words in the Train data of Essays.
         print("all the words in the X_train clean_title", len(train_title_words))

         # Find the unique words in this set of words
         train_title_words = set(train_title_words)
         print("the unique words in the X_train clean_title", len(train_title_words))


         common_words = set(glove_model.keys()).intersection(train_title_words)
         print("The number of words that are present in both glove vectors and our X_train clea
               .format(len(common_words), np.round((float(len(common_words))/len(train_title_w
```

```
all the words in the X_train clean_title 142143
the unique words in the X_train clean_title 10451
The number of words that are present in both glove vectors and our X_train clean_essay are 1005
```

```
In [69]: corpus_train_title_words = {}
         words_glove = set(glove_model.keys())
```

```
        for i in train_title_words:
            if i in words_glove:
                corpus_train_title_words[i] = glove_model[i]
        print("word2vec length of our X_train clean_title", len(corpus_train_title_words))
```

```
word2vec length of our X_train clean_title 10055
```

```
In [70]: # storing variables into pickle files python: http://www.jessicayung.com/how-to-use-p
         import pickle
         with open('glove_vectors_w2v_clean_title', 'wb') as f:
             pickle.dump(corpus_train_title_words, f)
```

```
In [71]: # loading stored vectors from pickle file
         with open('glove_vectors_w2v_clean_title', 'rb') as f:
             model = pickle.load(f)
             glove_words_title = set(model.keys())
```

```
In [72]: title_avg_w2v_train = perform_avg_w2v(X_train['clean_title'], glove_model, glove_words
         title_avg_w2v_cv = perform_avg_w2v(X_cv['clean_title'], glove_model, glove_words_titl
         title_avg_w2v_test = perform_avg_w2v(X_test['clean_title'], glove_model, glove_words_


         print('Post Vectorization: ')

         print("Shape of matrix after avg w2v vectorization of title on train data ",title_avg
         print("Shape of matrix after avg w2v vectorization of title on cv data",title_avg_w2v
         print("Shape of matrix after avg w2v vectorization of title on test data",title_avg_w
         print('*'*100)
```

```
100%|| 38746/38746 [00:00<00:00, 75067.60it/s]
100%|| 9687/9687 [00:00<00:00, 75887.75it/s]
100%|| 12109/12109 [00:00<00:00, 72865.04it/s]


Post Vectorization:
Shape of matrix after avg w2v vectorization of title on train data  (38746, 300)
Shape of matrix after avg w2v vectorization of title on cv data (9687, 300)
Shape of matrix after avg w2v vectorization of title on test data (12109, 300)
**********
```

C) TF-IDF W2V

```
In [74]: #https://colab.research.google.com/drive/1jOxJr8OXlDZkOKNf14nvPZxArc9bo7zm#scrollTo=C

         def perform_tfidf_w2v(preprocessed_text, glove_words, dictionary, tfidf_words, model)
             tfidf_w2v = [];
             for sentence in tqdm(preprocessed_text):
```

```
            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
            for word in sentence.split(): # for each word in a review/sentence
                if (word in glove_words) and (word in tfidf_words):
#                   if word in tfidf_words:
                        vec = model[word] # getting the vector for each word
#                         vec = tfidf_model[word]
                        # here we are multiplying idf value(dictionary[word]) and the tf valu
                        tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.split()))
                        vector += (vec * tf_idf) # calculating tfidf weighted w2v
                        tf_idf_weight += tf_idf
            if tf_idf_weight != 0:
                vector /= tf_idf_weight
            tfidf_w2v.append(vector)

        tfidf_w2v = np.array(tfidf_w2v)
        return tfidf_w2v
```

Tf-Idf W2V - clean_essay

In [75]:
```
# performing tfidf_w2v on essay field

tfidf_model = TfidfVectorizer()
tfidf_model.fit(X_train['clean_essay'])

dictionary = dict(zip(tfidf_model.get_feature_names(), list(tfidf_model.idf_)))
tfidf_words = set(tfidf_model.get_feature_names())
```

In [76]:
```
essay_tfidf_w2v_train = perform_tfidf_w2v(X_train['clean_essay'], glove_words_essay, d
essay_tfidf_w2v_cv = perform_tfidf_w2v(X_cv['clean_essay'], glove_words_essay, dictio
essay_tfidf_w2v_test = perform_tfidf_w2v(X_test['clean_essay'], glove_words_essay, di

print('Post Vectorization: ')

print("Shape of matrix after tfidf w2v vectorization of essay on train data ",essay_t
print("Shape of matrix after tfidf w2v vectorization of essay on cv data",essay_tfidf
print("Shape of matrix after tfidf w2v vectorization of essay on test data",essay_tfi
print('*'*100)
```

```
100%|| 38746/38746 [01:15<00:00, 510.94it/s]
100%|| 9687/9687 [00:17<00:00, 545.82it/s]
100%|| 12109/12109 [00:21<00:00, 572.98it/s]

Post Vectorization:
Shape of matrix after tfidf w2v vectorization of essay on train data  (38746, 300)
Shape of matrix after tfidf w2v vectorization of essay on cv data (9687, 300)
Shape of matrix after tfidf w2v vectorization of essay on test data (12109, 300)
****************************************************************************************
```

Tf-Idf W2V - clean_title

```
In [77]: # performing tfidf_w2v on title field

         tfidf_model = TfidfVectorizer()
         tfidf_model.fit(X_train['clean_title'])

         dictionary = dict(zip(tfidf_model.get_feature_names(), list(tfidf_model.idf_)))
         tfidf_words = set(tfidf_model.get_feature_names())

In [78]: title_tfidf_w2v_train = perform_tfidf_w2v(X_train['clean_title'], glove_words_title, d
         title_tfidf_w2v_cv = perform_tfidf_w2v(X_cv['clean_title'], glove_words_title, dictio
         title_tfidf_w2v_test = perform_tfidf_w2v(X_test['clean_title'], glove_words_title, di


         print('Post Vectorization: ')

         print("Shape of matrix after tfidf w2v vectorization of title on train data ",title_ti
         print("Shape of matrix after tfidf w2v vectorization of title on cv data",title_tfidf_
         print("Shape of matrix after tfidf w2v vectorization of title on test data",title_tfid
         print('*'*100)

100%|| 38746/38746 [00:01<00:00, 35054.42it/s]
100%|| 9687/9687 [00:00<00:00, 33854.54it/s]
100%|| 12109/12109 [00:00<00:00, 32445.79it/s]


Post Vectorization:
Shape of matrix after tfidf w2v vectorization of title on train data  (38746, 300)
Shape of matrix after tfidf w2v vectorization of title on cv data (9687, 300)
Shape of matrix after tfidf w2v vectorization of title on test data (12109, 300)
****************************************************************************************
```

2 Assignment 3: Apply KNN

[Task-1] Apply KNN(brute force version) on these feature sets

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

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

Set 3: categorical, numerical features + project_title(AVG W2V)+ preprocessed_essay (AVG W2V)

Set 4: categorical, numerical features + project_title(TFIDF W2V)+ preprocessed_essay (TFIDF W2V)

Hyper paramter tuning to find best K

Find the best hyper parameter which results in 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 write your own for loops to do this task

```
</ul>
</li>
<br>
<li>
<strong>Representation of results</strong>
    <ul>
<li>You need to plot the performance of model both on train data and cross validation data for
<img src='../resources/train_cv_auc.JPG' width=300px></li>
<li>Once you find the best hyper parameter, you need to train your model-M using the best hyper
<img src='../resources/train_test_auc.JPG' width=300px></li>
<li>Along with plotting ROC curve, you need to print the <a href='https://www.appliedaicourse.c
<img src='../resources/confusion_matrix.png' width=300px></li>
    </ul>
</li>
<li><strong> [Task-2] </strong>
    <ul>
        <li>Select top 2000 features from feature <font color='red'>Set 2</font> using <a href=
```

and then apply KNN on top of these features

```
    <li>
            <pre>
            from sklearn.datasets import load_digits
            from sklearn.feature_selection import SelectKBest, chi2
            X, y = load_digits(return_X_y=True)
            X.shape
            X_new = SelectKBest(chi2, k=20).fit_transform(X, y)
            X_new.shape
            ========
            output:
            (1797, 64)
            (1797, 20)
            </pre>
        </li>
        <li>Repeat the steps 2 and 3 on the data matrix after feature selection</li>
    </ul>
</li>
<br>
<li><strong>Conclusion</strong>
    <ul>
<li>You need to summarize the results at the end of the notebook, summarize it in the table for
    <img src='../resources/summary.JPG' width=400px>
</li>
    </ul>
```

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-leakag, 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 Merging all the above features

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

3. K Nearest Neighbor

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

```
In [79]: import matplotlib.pyplot as plt
         # from sklearn.cross_validation import train_test_split
         from sklearn.neighbors import KNeighborsClassifier
         from sklearn.metrics import accuracy_score
         from sklearn.model_selection import cross_val_score
         from collections import Counter
         from sklearn.metrics import accuracy_score
         # from sklearn import cross_validation
         from scipy.sparse import hstack

         from sklearn.neighbors import NearestNeighbors
         from sklearn.metrics import roc_curve, auc, roc_auc_score

         # creating odd list of K for KNN
         myList = list(range(0,16))
         k_values = [1, 5, 10, 15, 21, 31, 41, 51]


         def batch_predict(clf, data, is_predict_prob=True):
             # roc_auc_score(y_true, y_score) the 2nd parameter should be probability estimate
             # not the predicted outputs
             y_data_pred = []
             tr_loop = data.shape[0] - data.shape[0]%3000
             # consider you X_tr shape is 49041, then your cr_loop will be 49041 - 49041%1000 =
             for i in range(0, tr_loop, 1000):
                 if is_predict_prob:
                     y_data_pred.extend(clf.predict_proba(data[i:i+1000])[:,1])
                 else:
                     y_data_pred.extend(clf.predict(data[i:i+1000]))
                 # we will be predicting for the last data points
             if data[tr_loop:].shape[0] != 0:
                 if is_predict_prob:
                     y_data_pred.extend(clf.predict_proba(data[tr_loop:])[:,1])
```

```
        else:
            y_data_pred.extend(clf.predict(data[tr_loop:]))
    return y_data_pred



def find_best_k_using_auc(X_tr, y_tr, X_cv, y_cv):
    '''
     This func will accept train and cv data and return the best k
    '''
    train_auc = []
    cv_auc = []
    X_tr = X_tr
    X_cv = X_cv
    shape_tr = X_tr.shape[0]
    shape_cv = X_cv.shape[0]

    for k in tqdm(k_values):
        # instantiate learning model (k = 30)
        knn = KNeighborsClassifier(n_neighbors=k, algorithm='brute')
        knn.fit(X_tr, y_tr)

        y_train_pred =  batch_predict(knn, X_tr, True )
        y_cv_pred =  batch_predict(knn, X_cv, True )

        train_auc.append(roc_auc_score(y_tr, y_train_pred))
        cv_auc.append(roc_auc_score(y_cv, y_cv_pred))

    # determining best k
    optimal_k = k_values[cv_auc.index(max(cv_auc))]
    print('\nThe optimal number of neighbors is %d.' % optimal_k)
    return optimal_k, train_auc, cv_auc


def plot_k_vs_roc(train_auc, cv_auc):
    '''
    This func will plot K-values versus CV AUC
    '''
    plt.plot(k_values,train_auc, label='Train AUC')
    plt.scatter(k_values, train_auc, label='Train AUC')
    plt.plot(k_values,cv_auc, label='CV AUC')
    plt.scatter(k_values, cv_auc, label='CV AUC')
    plt.xlabel("K: hyperparameter")
    plt.ylabel("AUC")
    plt.title("ERROR PLOTS")
    plt.legend()
    plt.show()
```

In [80]:
```
import itertools

def plot_confusion_matrix(cm, classes,
                          normalize=False,
                          title='Confusion matrix',
                          cmap=plt.cm.Blues):
    """
    This function prints and plots the confusion matrix.
    Normalization can be applied by setting `normalize=True`.
    """
    if normalize:
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
        print("Normalized confusion matrix")
    else:
        print('Confusion matrix, without normalization')

    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=45)
    plt.yticks(tick_marks, classes)

    fmt = '.2f' if normalize else 'd'

    thresh = (cm.max() / 2) + 100
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, format(cm[i, j], fmt),
                 horizontalalignment="center",
                 color="white" if cm[i, j] > thresh else "black")

    plt.ylabel('True label')
    plt.xlabel('Predicted label')
    plt.tight_layout()
```

In [81]:
```
def predict(proba, threshold, fpr, tpr):
    t = threshold[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.r
    predictions = []
    for i in proba:
        if i>=t:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

```
# (confusion_matrix(y_train, predict(y_train_pred, thresh1, fpr_train, tpr_train)))


def compute_confusion_matrix(y_actual, y_pred, threshold, fpr, tpr):
    '''
     This func will compute and plot confusion matrix on test data
    '''

    class_names = [0, 1]
    cnf_matrix = confusion_matrix(y_actual, predict(y_pred, threshold, fpr, tpr))
    np.set_printoptions(precision=2)

    # Plot non-normalized confusion matrix
    plt.figure()
    plot_confusion_matrix(cnf_matrix,classes=class_names,
                          title='Confusion matrix, without normalization')

    # Plot normalized confusion matrix
    plt.figure()
    plot_confusion_matrix(cnf_matrix, classes=class_names, normalize=True,
                          title='Normalized confusion matrix')
    plt.show()
    print('*'*70)
```

3.0.1 Set1: categorical, numerical features + project_title(BOW) + preprocessed_essay (BOW)

2.4.1 Applying KNN brute force on BOW, SET 1

In [82]:
```
# Please write all the code with proper documentation

X_train_set1 = hstack((categories_one_hot_train, sub_categories_one_hot_train,
           school_state_one_hot_train, teacher_prefix_one_hot_train,
           project_grade_category_one_hot_train, price_train, quantity_train,
           prev_teacher_proj_train, title_word_count_train, essay_word_count_train,
           essay_bow_train, title_bow_train)).tocsr()

X_cv_set1 = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
           school_state_one_hot_cv, teacher_prefix_one_hot_cv,
           project_grade_category_one_hot_cv, price_cv, quantity_cv,
           prev_teacher_proj_cv, title_word_count_cv, essay_word_count_cv,
           essay_bow_cv, title_bow_cv)).tocsr()

X_test_set1 = hstack((categories_one_hot_test, sub_categories_one_hot_test,
           school_state_one_hot_test, teacher_prefix_one_hot_test,
           project_grade_category_one_hot_test, price_test, quantity_test,
           prev_teacher_proj_test, title_word_count_test, essay_word_count_test,
           essay_bow_test, title_bow_test)).tocsr()
```

```
In [83]: print("Final Data matrix for set1")
         print(X_train_set1.shape, y_train.shape)
         print(X_cv_set1.shape, y_cv.shape)
         print(X_test_set1.shape, y_test.shape)
         print("="*100)
```

```
Final Data matrix for set1
(38746, 12790) (38746,)
(9687, 12790) (9687,)
(12109, 12790) (12109,)
====================================================================================================
```

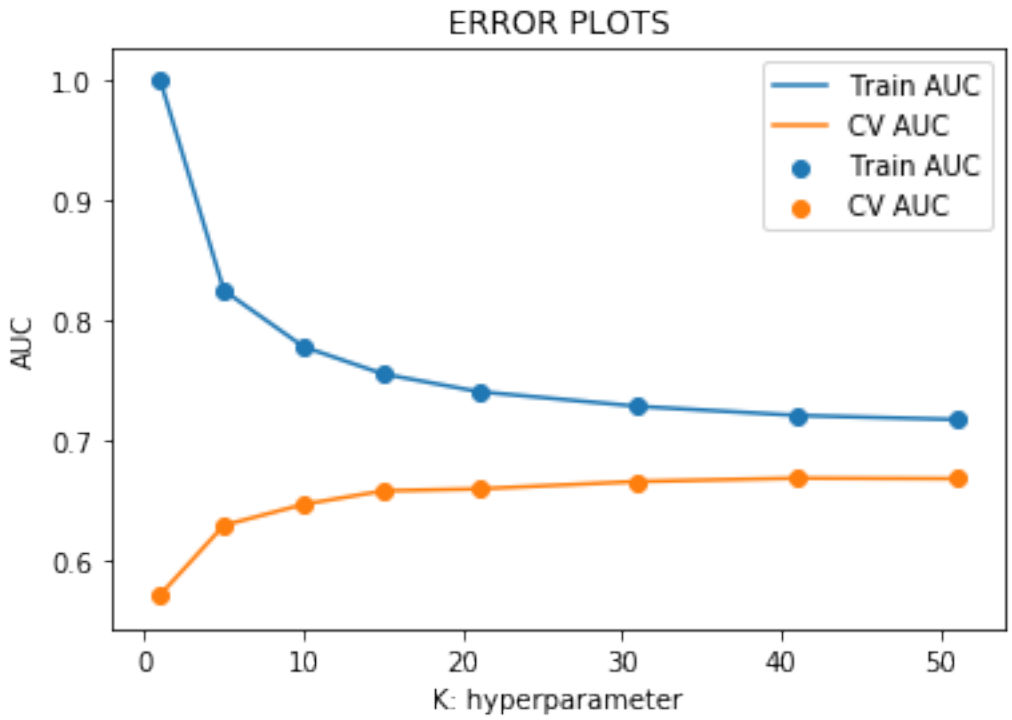
3.1 A) Find the best hyper parameter which results in the maximum AUC value

```
In [84]: best_k_set1, train_auc, cv_auc = find_best_k_using_auc(X_train_set1, y_train, X_cv_set
```

```
100%|| 8/8 [18:30<00:00, 138.38s/it]
```

```
The optimal number of neighbors is 41.
```

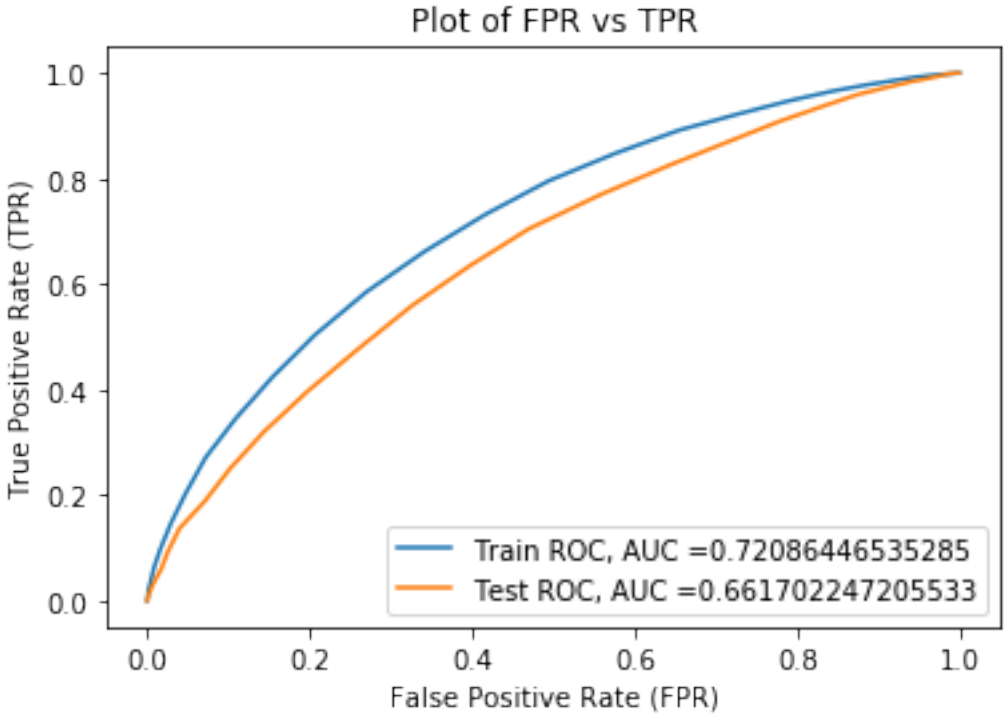
```
In [85]: # plot showing performance of model both on train data and cross validation data for
         plot_k_vs_roc(train_auc, cv_auc)
```



3.2 B) Train model with best hyper-parameter value

In [86]:
```
knn = KNeighborsClassifier(best_k_set1)
knn.fit(X_train_set1,y_train)

# print(X_test_set1)
y_train_pred = batch_predict( knn, X_train_set1)
y_test_pred = batch_predict( knn, X_test_set1)


fpr_train, tpr_train, thresh1 = roc_curve(y_train, y_train_pred)
fpr_test, tpr_test, thresh = roc_curve(y_test, y_test_pred)



test_auc_set1 = roc_auc_score(y_test, y_test_pred)
```

In [87]:
```
plt.plot(fpr_train,tpr_train, label='Train ROC, AUC ='+str(auc(fpr_train, tpr_train)))
plt.plot(fpr_test,tpr_test, label='Test ROC, AUC ='+str(auc(fpr_test, tpr_test)))
plt.xlabel('False Positive Rate (FPR)')
plt.ylabel("True Positive Rate (TPR)")
plt.title('Plot of FPR vs TPR')
plt.legend()
plt.show()
```

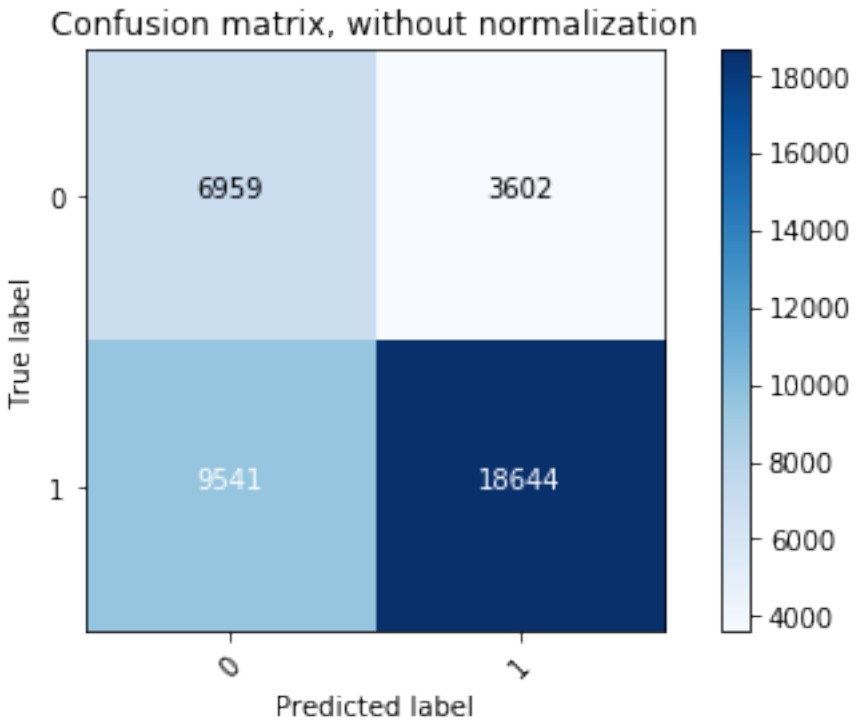


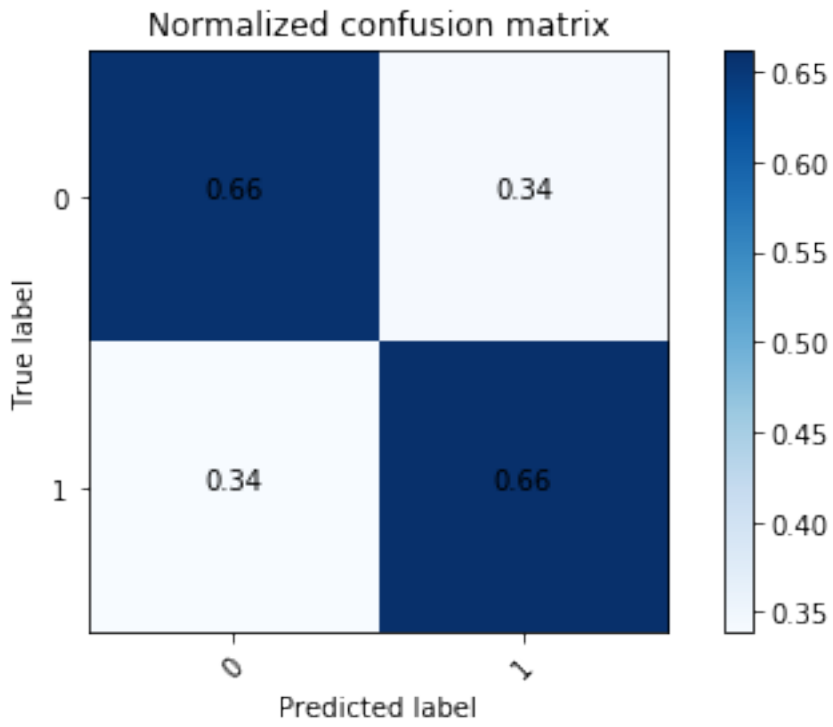
3.3 D) Confusion Matrix

3.3.1 Train Set

```
In [88]: # computa and plot confusion matrix for train data
         print("="*100)
         print("Train confusion matrix")

         compute_confusion_matrix(y_train, y_train_pred, thresh1, fpr_train, tpr_train)
```

```
====================================================================================================
Train confusion matrix
the maximum value of tpr*(1-fpr) 0.4358758918280356 for threshold 0.659
Confusion matrix, without normalization
Normalized confusion matrix
```



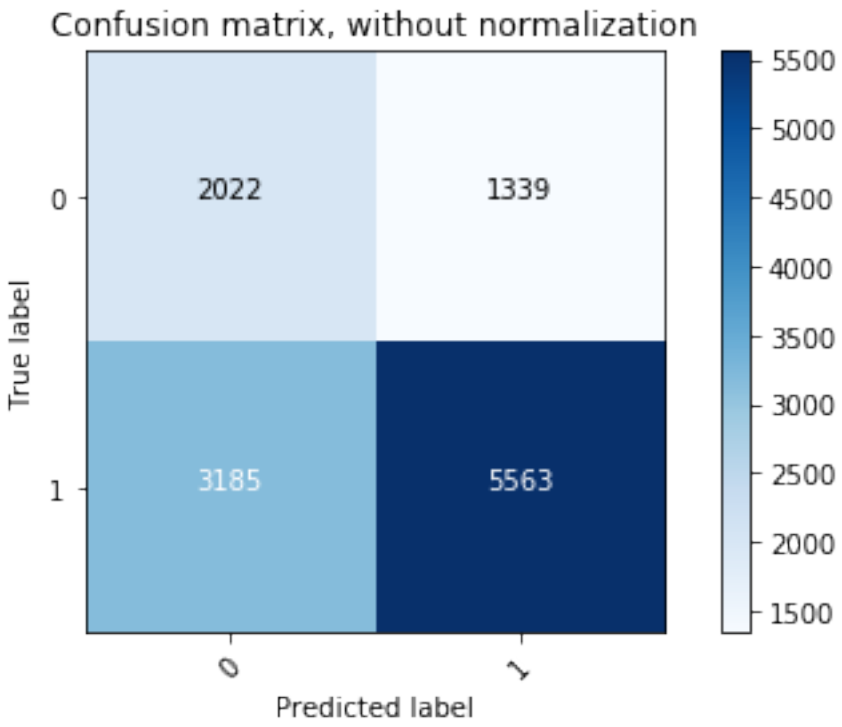


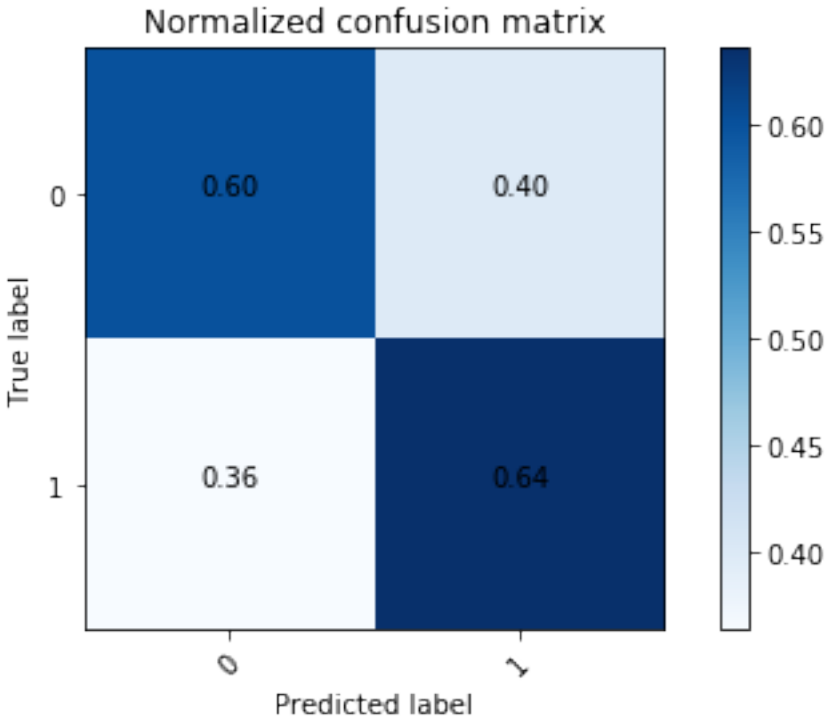
****

3.3.2 Test Set

```
In [89]: print("="*100)
         print("Test confusion matrix")
         # computa and plot confusion matrix for test data

         compute_confusion_matrix(y_test, y_test_pred, thresh, fpr_test, tpr_test)
```

```
====================================================================================================
Test confusion matrix
the maximum value of tpr*(1-fpr) 0.3825717736205135 for threshold 0.659
Confusion matrix, without normalization
Normalized confusion matrix
```


Confusion matrix, without normalization
2022
1339
3185
5563
0
1
True label
0
1
Predicted label
5500
5000
4500
4000
3500
3000
2500
2000
1500


Normalized confusion matrix
0.60
0.40
0.36
0.64
0
1
True label
0
1
Predicted label
0.60
0.55
0.50
0.45
0.40

****

Observations

- We get k=41 as best value of k.
- Our model's AUC is quite better than that of a random model.

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

3.4.1 2.4.2 Applying KNN brute force on TFIDF, SET 2

In [90]:
```
# Please write all the code with proper documentation

        X_train_set2 = hstack((categories_one_hot_train, sub_categories_one_hot_train,
                   school_state_one_hot_train, teacher_prefix_one_hot_train,
                   project_grade_category_one_hot_train, price_train, quantity_train,
                   prev_teacher_proj_train, title_word_count_train, essay_word_count_train,
                   essay_tfidf_train, title_tfidf_train)).tocsr()

        X_cv_set2 = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
                   school_state_one_hot_cv, teacher_prefix_one_hot_cv,
                   project_grade_category_one_hot_cv, price_cv, quantity_cv,
                   prev_teacher_proj_cv, title_word_count_cv, essay_word_count_cv,
                   essay_tfidf_cv, title_tfidf_cv)).tocsr()

        X_test_set2 = hstack((categories_one_hot_test, sub_categories_one_hot_test,
                   school_state_one_hot_test, teacher_prefix_one_hot_test,
                   project_grade_category_one_hot_test, price_test, quantity_test,
                   prev_teacher_proj_test, title_word_count_test, essay_word_count_test,
                   essay_tfidf_test, title_tfidf_test)).tocsr()
```

In [91]:
```
print("Final Data matrix for set2")
print(X_train_set2.shape, y_train.shape)
print(X_cv_set2.shape, y_cv.shape)
print(X_test_set2.shape, y_test.shape)
print("="*100)
```

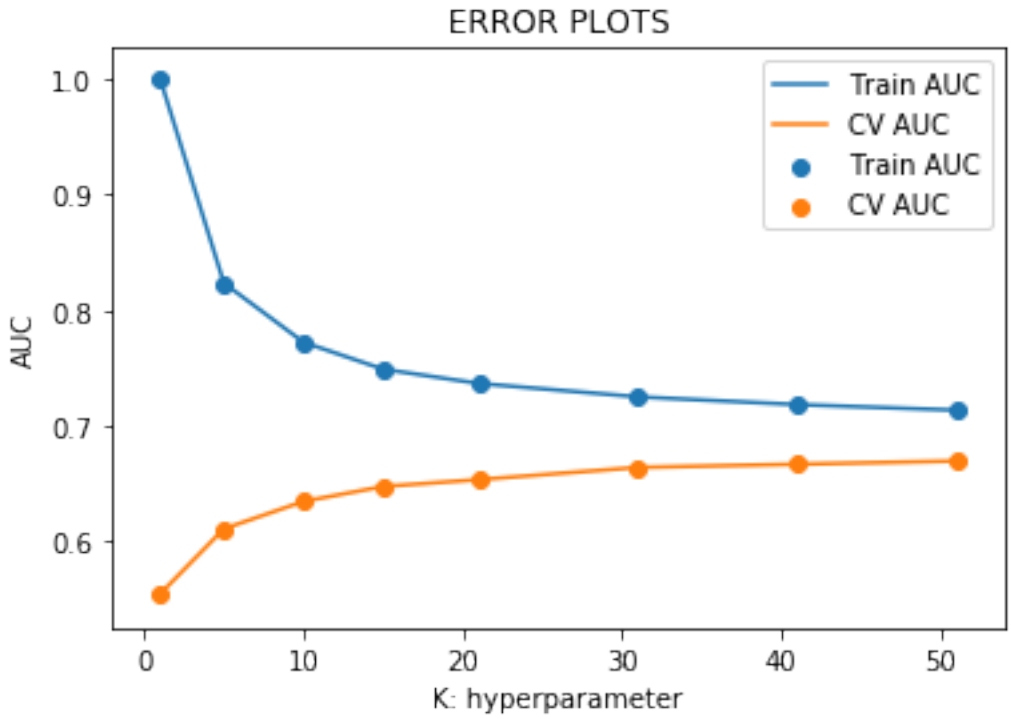
```
Final Data matrix for set2
(38746, 12790) (38746,)
(9687, 12790) (9687,)
(12109, 12790) (12109,)
====================================================================================================
```

3.5 A) Find the best hyper parameter which results in the maximum AUC value

In [92]:
```
best_k_set2, train_auc, cv_auc = find_best_k_using_auc(X_train_set2, y_train, X_cv_set
```

```
100%|| 8/8 [18:42<00:00, 140.86s/it]

The optimal number of neighbors is 51.
```

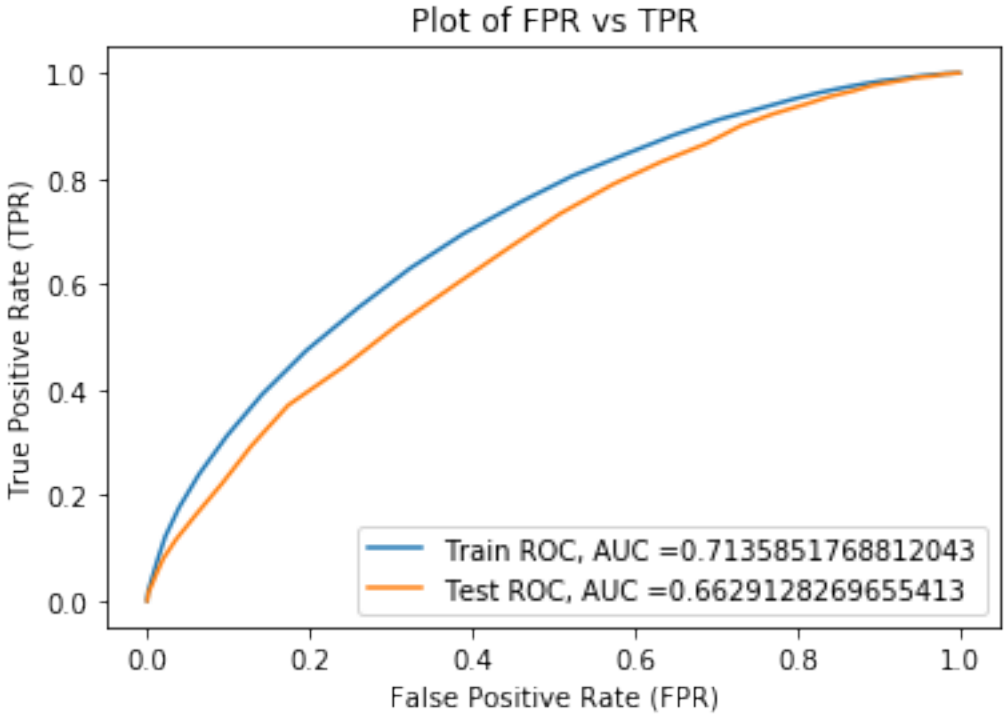
```
In [93]: # plot showing performance of model both on train data and cross validation data for
         plot_k_vs_roc(train_auc, cv_auc)
```



3.6 B) Train model with best hyper-parameter value

```
In [94]: knn = KNeighborsClassifier(best_k_set2)
         knn.fit(X_train_set2,y_train)

         # print(X_test_set1)
         y_train_pred = batch_predict( knn, X_train_set2)
         y_test_pred = batch_predict( knn, X_test_set2)


         fpr_train, tpr_train, thresh1 = roc_curve(y_train, y_train_pred)
         fpr_test, tpr_test, thresh = roc_curve(y_test, y_test_pred)
         test_auc_set2 = roc_auc_score(y_test, y_test_pred)
```

```
In [95]: plt.plot(fpr_train,tpr_train, label='Train ROC, AUC ='+str(auc(fpr_train, tpr_train)))
         plt.plot(fpr_test,tpr_test, label='Test ROC, AUC ='+str(auc(fpr_test, tpr_test)))
         plt.xlabel('False Positive Rate (FPR)')
         plt.ylabel("True Positive Rate (TPR)")
         plt.title('Plot of FPR vs TPR')
         plt.legend()
         plt.show()
```

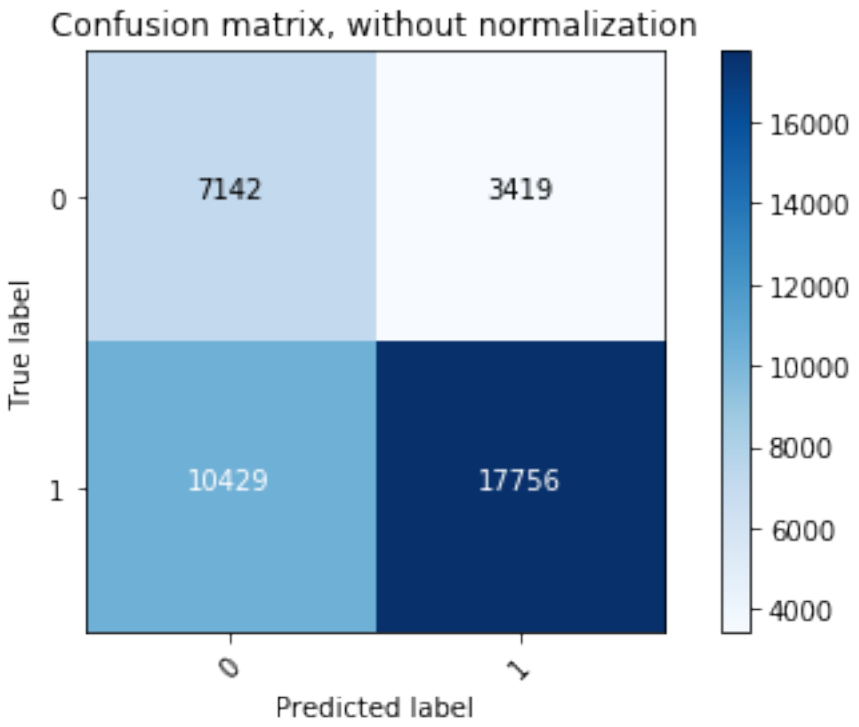


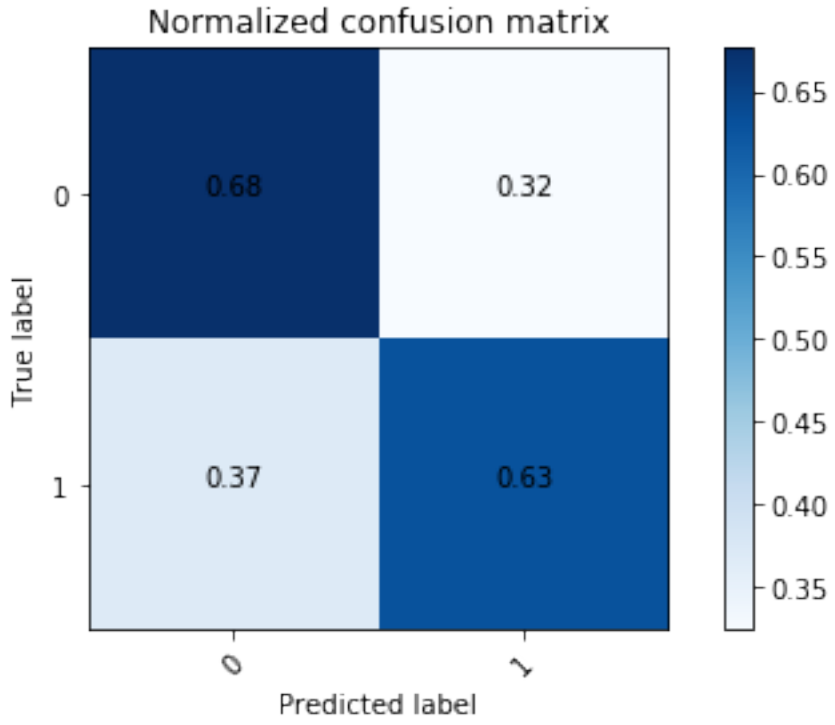
3.7 D) Confusion Matrix

3.7.1 Train Set

```
In [96]: # computa and plot confusion matrix for train data
         print("="*100)
         print("Train confusion matrix")
         compute_confusion_matrix(y_train, y_train_pred, thresh1, fpr_train, tpr_train)
```

```
====================================================================================================
Train confusion matrix
the maximum value of tpr*(1-fpr) 0.42603168559242494 for threshold 0.745
Confusion matrix, without normalization
Normalized confusion matrix
```


Confusion matrix, without normalization
7142
3419
10429
17756
0
1
True label
0
1
Predicted label
16000
14000
12000
10000
8000
6000
4000

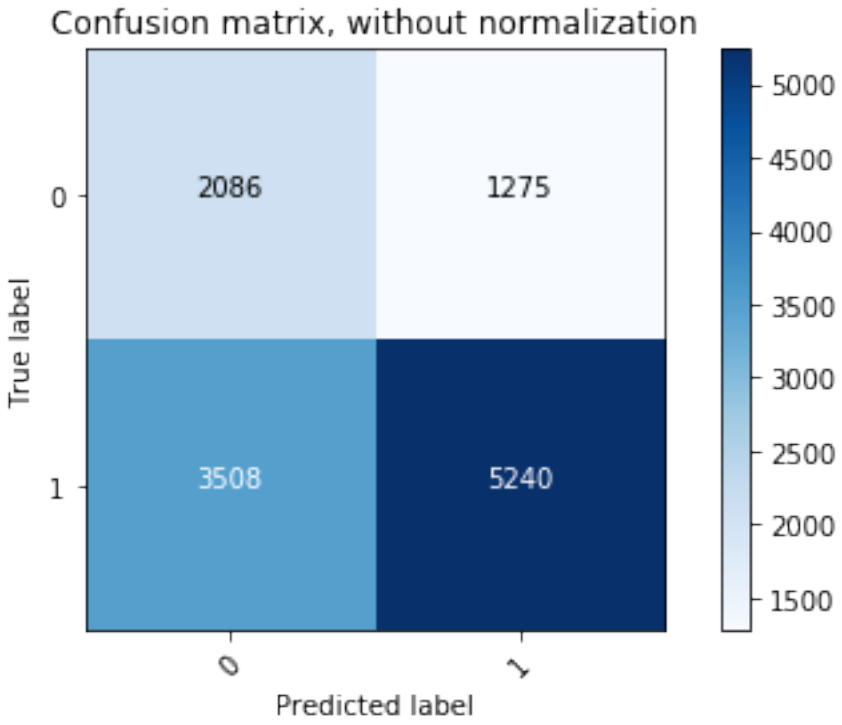

Normalized confusion matrix
0.68
0.32
0.37
0.63
0
1
True label
0
1
Predicted label
0.65
0.60
0.55
0.50
0.45
0.40
0.35

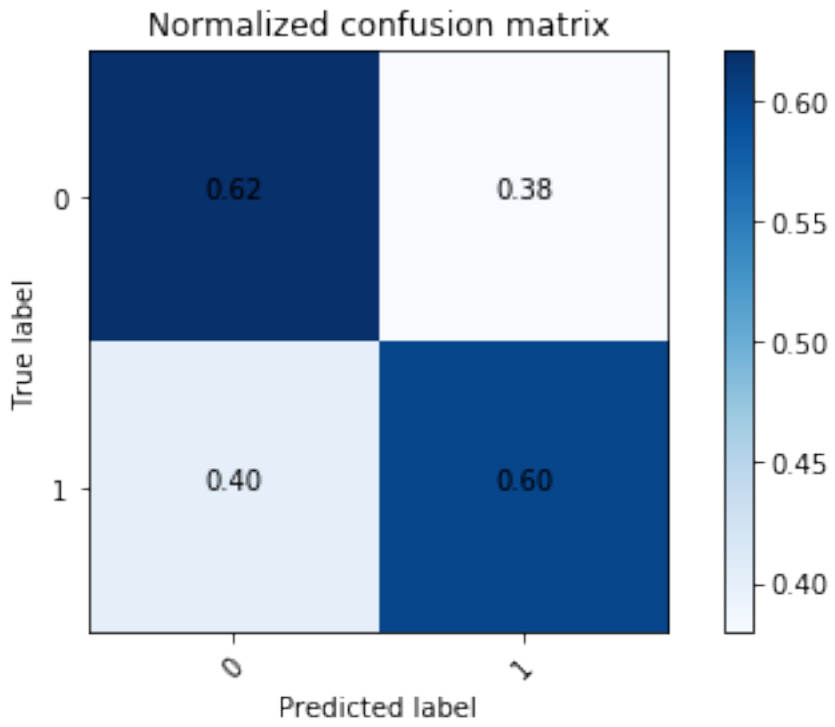
****

3.7.2 Test Set

```
In [97]: print("="*100)
         print("Test confusion matrix")
         compute_confusion_matrix(y_test, y_test_pred, thresh, fpr_test, tpr_test)
```

```
====================================================================================================
Test confusion matrix
the maximum value of tpr*(1-fpr) 0.3717648320041052 for threshold 0.745
Confusion matrix, without normalization
Normalized confusion matrix
```





****

Observations

- We get k=51 as best value of k.
- Our model's AUC is very close to that of a random model.

3.8 Set 3: categorical, numerical features + project_title(AVG W2V)+ preprocessed_essay (AVG W2V)

3.8.1 2.4.3 Applying KNN brute force on AVG W2V, SET 3

In [98]:
```
# Please write all the code with proper documentation

X_train_set3 = hstack((categories_one_hot_train, sub_categories_one_hot_train,
           school_state_one_hot_train, teacher_prefix_one_hot_train,
           project_grade_category_one_hot_train, price_train, quantity_train,
           prev_teacher_proj_train, title_word_count_train, essay_word_count_train,
           essay_avg_w2v_train, title_avg_w2v_train)).tocsr()

X_cv_set3 = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
           school_state_one_hot_cv, teacher_prefix_one_hot_cv,
           project_grade_category_one_hot_cv, price_cv, quantity_cv,
```

```
                    prev_teacher_proj_cv, title_word_count_cv, essay_word_count_cv,
                    essay_avg_w2v_cv, title_avg_w2v_cv)).tocsr()

        X_test_set3 = hstack((categories_one_hot_test, sub_categories_one_hot_test,
                    school_state_one_hot_test, teacher_prefix_one_hot_test,
                    project_grade_category_one_hot_test, price_test, quantity_test,
                    prev_teacher_proj_test, title_word_count_test, essay_word_count_test,
                    essay_avg_w2v_test, title_avg_w2v_test)).tocsr()
```

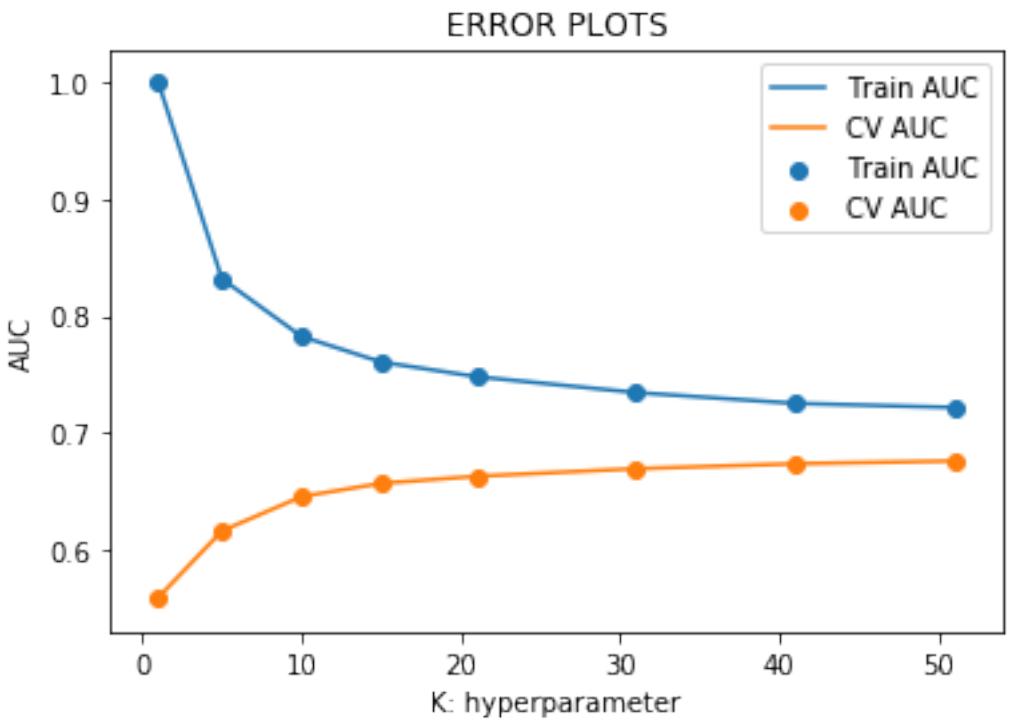
```
In [99]: print("Final Data matrix for set3")
         print(X_train_set3.shape, y_train.shape)
         print(X_cv_set3.shape, y_cv.shape)
         print(X_test_set3.shape, y_test.shape)
         print("="*100)
```

```
Final Data matrix for set3
(38746, 704) (38746,)
(9687, 704) (9687,)
(12109, 704) (12109,)
====================================================================================================
```

3.9 A) Find the best hyper parameter which results in the maximum AUC value

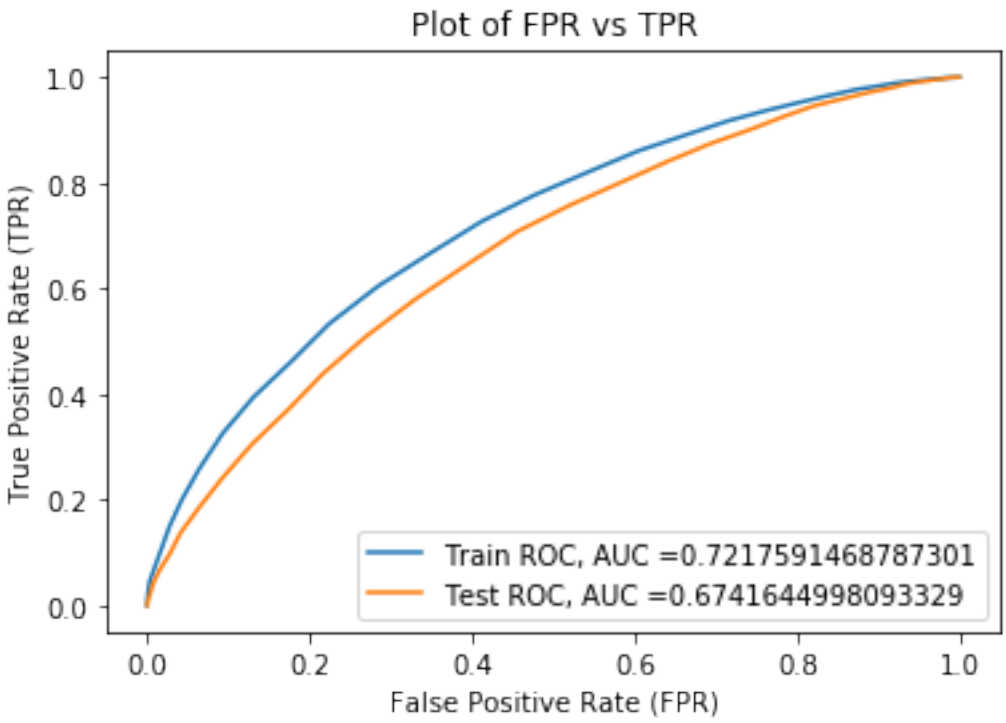
```
In [100]: best_k_set3, train_auc, cv_auc = find_best_k_using_auc(X_train_set3, y_train, X_cv_s

          # plot showing performance of model both on train data and cross validation data for
          plot_k_vs_roc(train_auc, cv_auc)
```

```
100%|| 8/8 [3:47:18<00:00, 1686.96s/it]


The optimal number of neighbors is 51.
```



3.10 B) Train model with best hyper-parameter value

```
In [101]: knn = KNeighborsClassifier(best_k_set3)
          knn.fit(X_train_set3,y_train)

          # print(X_test_set1)
          y_train_pred = batch_predict( knn, X_train_set3)
          y_test_pred = batch_predict( knn, X_test_set3)


          fpr_train, tpr_train, thresh1 = roc_curve(y_train, y_train_pred)
          fpr_test, tpr_test, thresh = roc_curve(y_test, y_test_pred)

          test_auc_set3 = roc_auc_score(y_test, y_test_pred)

In [102]: plt.plot(fpr_train,tpr_train, label='Train ROC, AUC ='+str(auc(fpr_train, tpr_train)))
          plt.plot(fpr_test,tpr_test, label='Test ROC, AUC ='+str(auc(fpr_test, tpr_test)))
          plt.xlabel('False Positive Rate (FPR)')
          plt.ylabel("True Positive Rate (TPR)")
          plt.title('Plot of FPR vs TPR')
          plt.legend()
          plt.show()
```

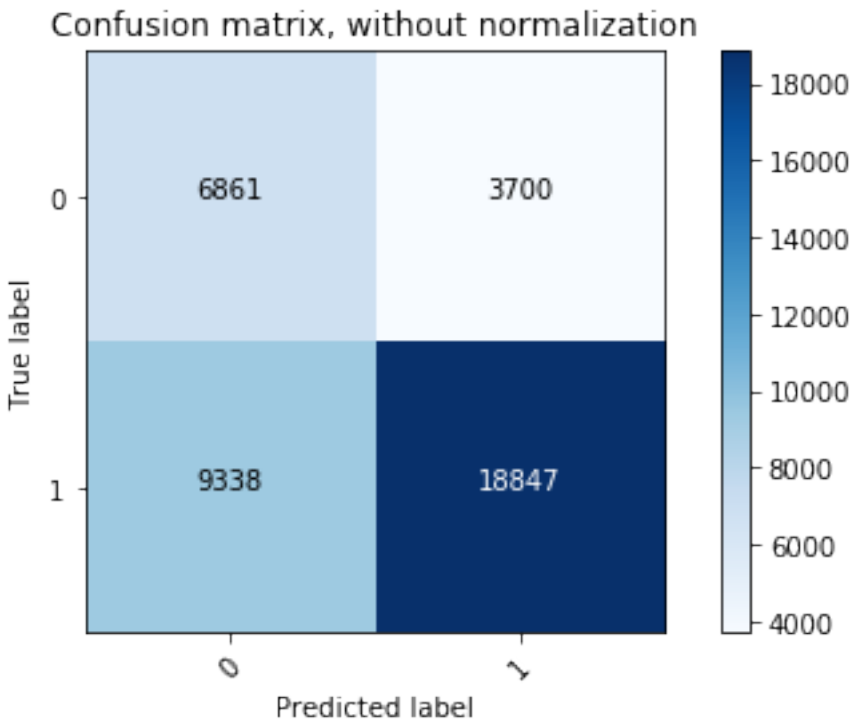


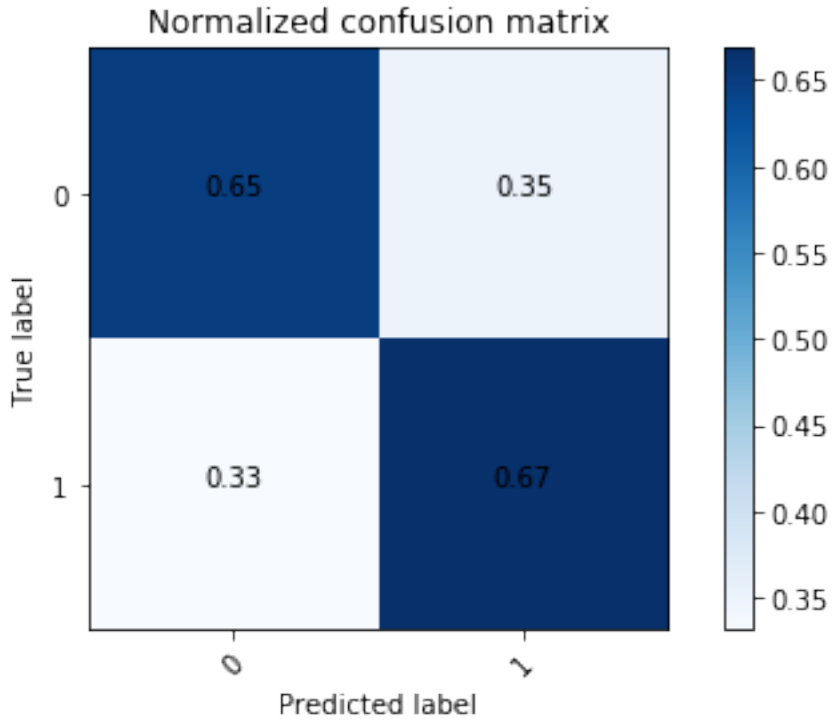
3.11 D) Confusion Matrix

3.11.1 Train Set

```
In [103]: # computa and plot confusion matrix for train data
          print("="*100)
          print("Train confusion matrix")
          compute_confusion_matrix(y_train, y_train_pred, thresh1, fpr_train, tpr_train)
```

```
====================================================================================================
Train confusion matrix
the maximum value of tpr*(1-fpr) 0.43441675591645057 for threshold 0.725
Confusion matrix, without normalization
Normalized confusion matrix
```


Confusion matrix, without normalization
6861
3700
9338
18847
0
1
True label
0
1
Predicted label
18000
16000
14000
12000
10000
8000
6000
4000

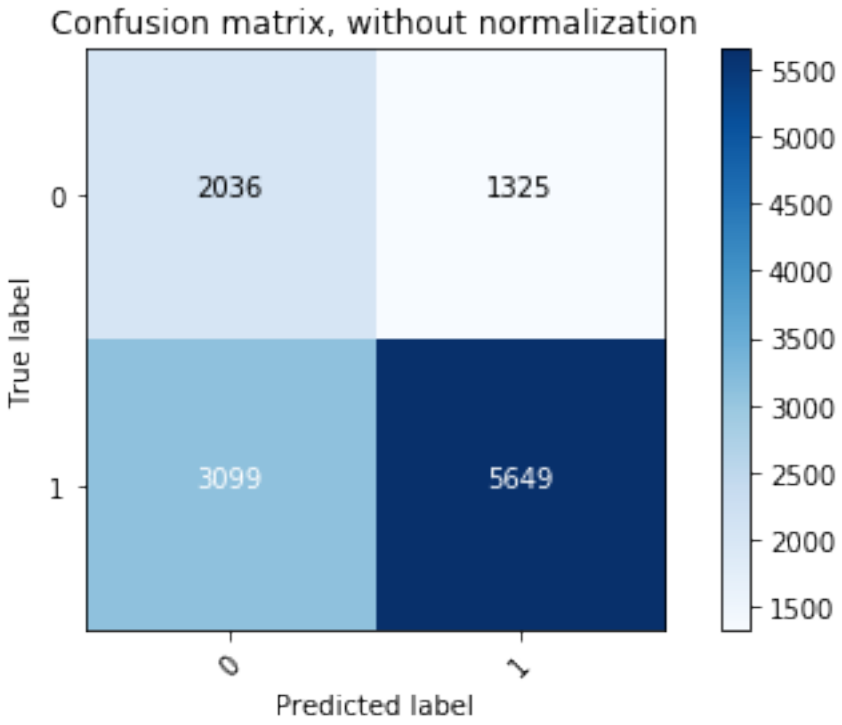

Normalized confusion matrix
0.65
0.35
0.33
0.67
0
1
True label
0
1
Predicted label
0.65
0.60
0.55
0.50
0.45
0.40
0.35

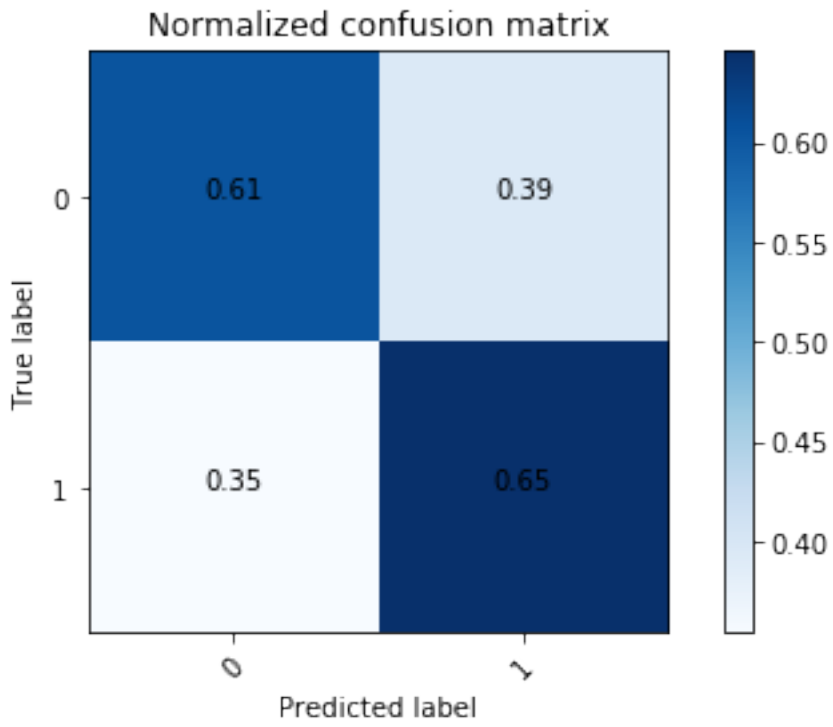
****

3.11.2 Test Set

```
In [104]: print("="*100)
          print("Test confusion matrix")
          compute_confusion_matrix(y_test, y_test_pred, thresh, fpr_test, tpr_test)
```

```
====================================================================================================
Test confusion matrix
the maximum value of tpr*(1-fpr) 0.3911758739907329 for threshold 0.725
Confusion matrix, without normalization
Normalized confusion matrix
```





****

Observations

- We get k=51 as best value of k.

3.12 Set 4: categorical, numerical features + project_title(TFIDF W2V)+ preprocessed_essay (TFIDF W2V)

3.12.1 2.4.4 Applying KNN brute force on TFIDF W2V, SET 4

In [105]:
```
# Please write all the code with proper documentation

essay_tfidf_w2v_train


X_train_set4 = hstack((categories_one_hot_train, sub_categories_one_hot_train,
            school_state_one_hot_train, teacher_prefix_one_hot_train,
            project_grade_category_one_hot_train, price_train, quantity_train,
            prev_teacher_proj_train, title_word_count_train, essay_word_count_train,
            essay_tfidf_w2v_train, title_tfidf_w2v_train)).tocsr()

X_cv_set4 = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
```

```
                    school_state_one_hot_cv, teacher_prefix_one_hot_cv,
                    project_grade_category_one_hot_cv, price_cv, quantity_cv,
                    prev_teacher_proj_cv, title_word_count_cv, essay_word_count_cv,
                    essay_tfidf_w2v_cv, title_tfidf_w2v_cv)).tocsr()

        X_test_set4 = hstack((categories_one_hot_test, sub_categories_one_hot_test,
                    school_state_one_hot_test, teacher_prefix_one_hot_test,
                    project_grade_category_one_hot_test, price_test, quantity_test,
                    prev_teacher_proj_test, title_word_count_test, essay_word_count_test,
                    essay_tfidf_w2v_test, title_tfidf_w2v_test)).tocsr()
```

In [106]:
```
print("Final Data matrix for set4")
print(X_train_set4.shape, y_train.shape)
print(X_cv_set4.shape, y_cv.shape)
print(X_test_set4.shape, y_test.shape)
print("="*100)
```

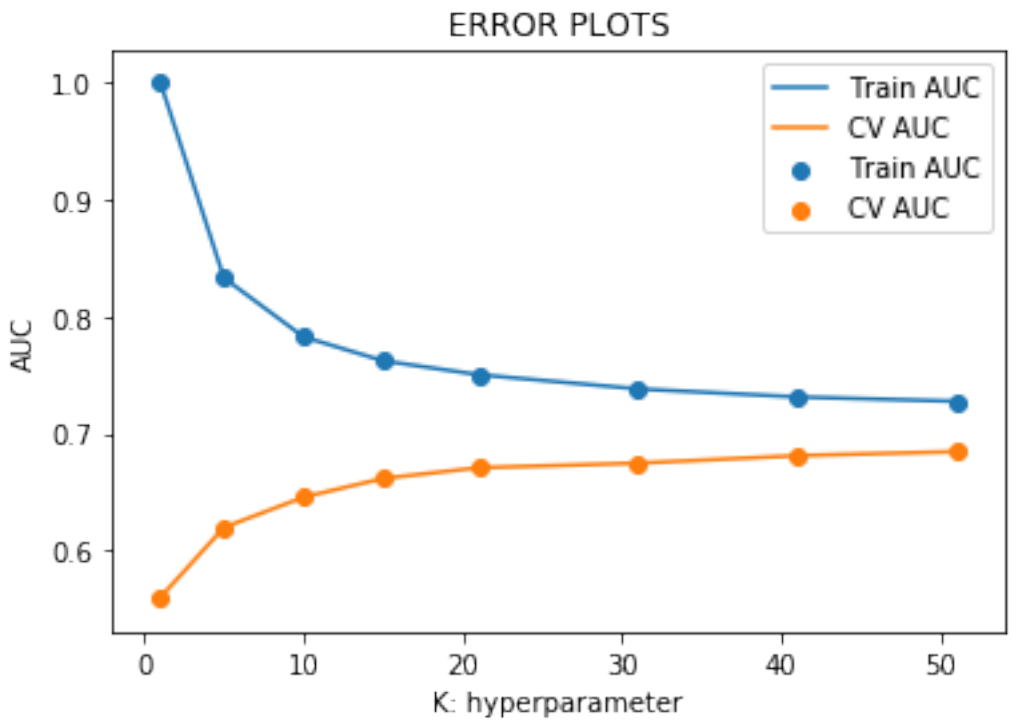
```
Final Data matrix for set4
(38746, 704) (38746,)
(9687, 704) (9687,)
(12109, 704) (12109,)
====================================================================================================
```

3.13 A) Find the best hyper parameter which results in the maximum AUC value

In [107]:
```
best_k_set4, train_auc, cv_auc = find_best_k_using_auc(X_train_set4, y_train, X_cv_se

# plot showing performance of model both on train data and cross validation data for
plot_k_vs_roc(train_auc, cv_auc)
```

```
100%|| 8/8 [4:20:29<00:00, 2001.25s/it]
```

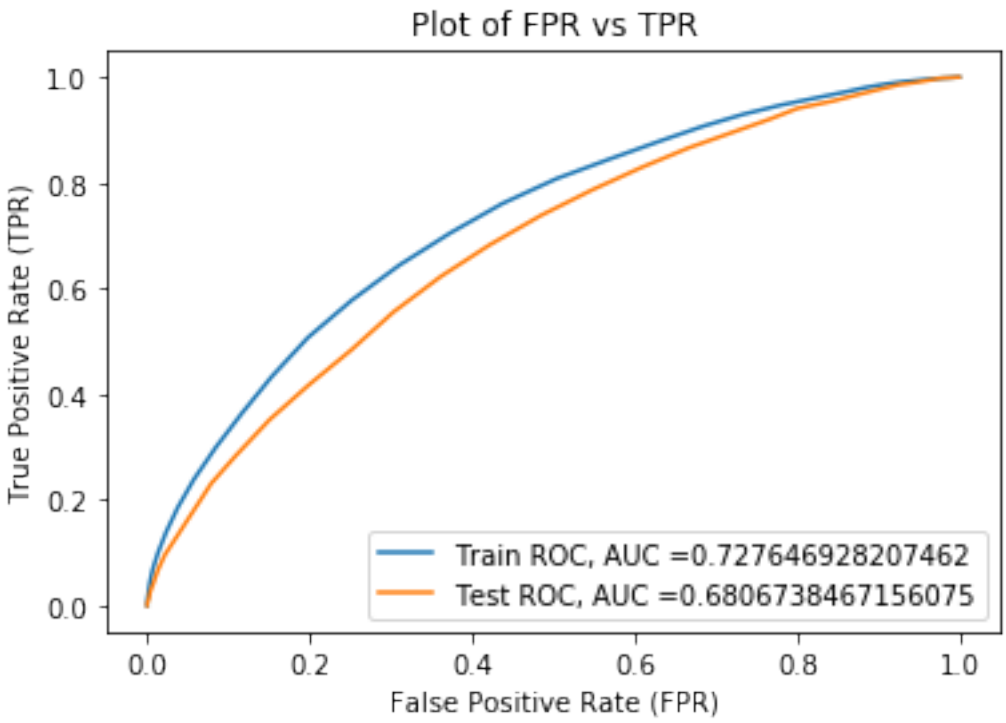
```
The optimal number of neighbors is 51.
```



3.14 B) Train model with best hyper-parameter value

In [108]:
```
knn = KNeighborsClassifier(best_k_set4)
knn.fit(X_train_set4,y_train)

# print(X_test_set1)
y_train_pred = batch_predict( knn, X_train_set4)
y_test_pred = batch_predict( knn, X_test_set4)


fpr_train, tpr_train, thresh1 = roc_curve(y_train, y_train_pred)
fpr_test, tpr_test, thresh = roc_curve(y_test, y_test_pred)
test_auc_set4 = roc_auc_score(y_test, y_test_pred)
```

In [109]:
```
plt.plot(fpr_train,tpr_train, label='Train ROC, AUC ='+str(auc(fpr_train, tpr_train)))
plt.plot(fpr_test,tpr_test, label='Test ROC, AUC ='+str(auc(fpr_test, tpr_test)))
plt.xlabel('False Positive Rate (FPR)')
plt.ylabel("True Positive Rate (TPR)")
plt.title('Plot of FPR vs TPR')
plt.legend()
plt.show()
```

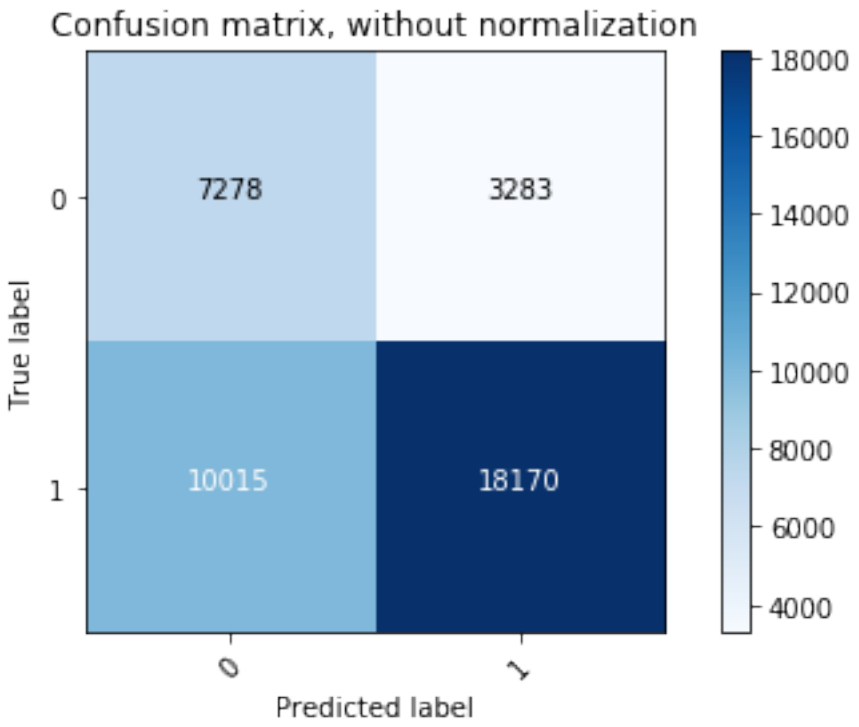


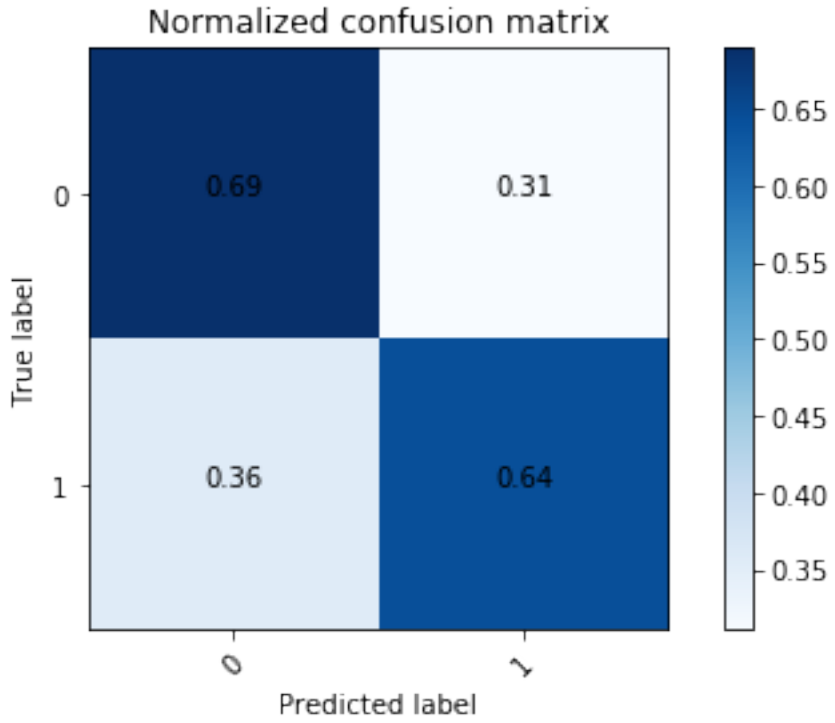
3.15 D) Confusion Matrix

3.15.1 Train Set

```
In [110]: # computa and plot confusion matrix for train data
          print("="*100)
          print("Train confusion matrix")
          compute_confusion_matrix(y_train, y_train_pred, thresh1, fpr_train, tpr_train)
```

```
====================================================================================================
Train confusion matrix
the maximum value of tpr*(1-fpr) 0.44426683794831107 for threshold 0.725
Confusion matrix, without normalization
Normalized confusion matrix
```


Confusion matrix, without normalization
7278
3283
10015
18170
0
1
True label
0
1
Predicted label
18000
16000
14000
12000
10000
8000
6000
4000

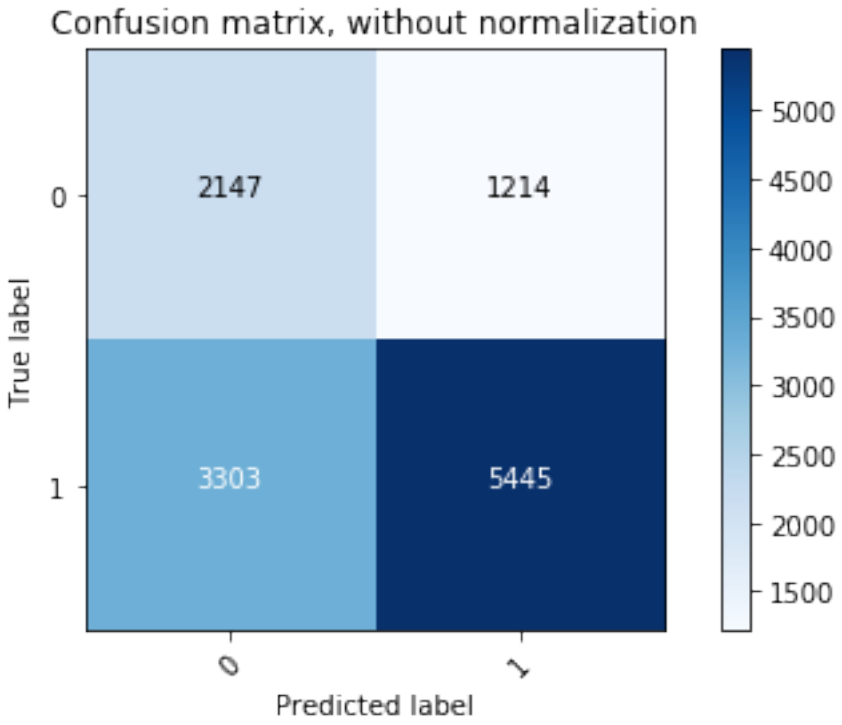

Normalized confusion matrix
0.69
0.31
0.36
0.64
0
1
True label
0
1
Predicted label
0.65
0.60
0.55
0.50
0.45
0.40
0.35

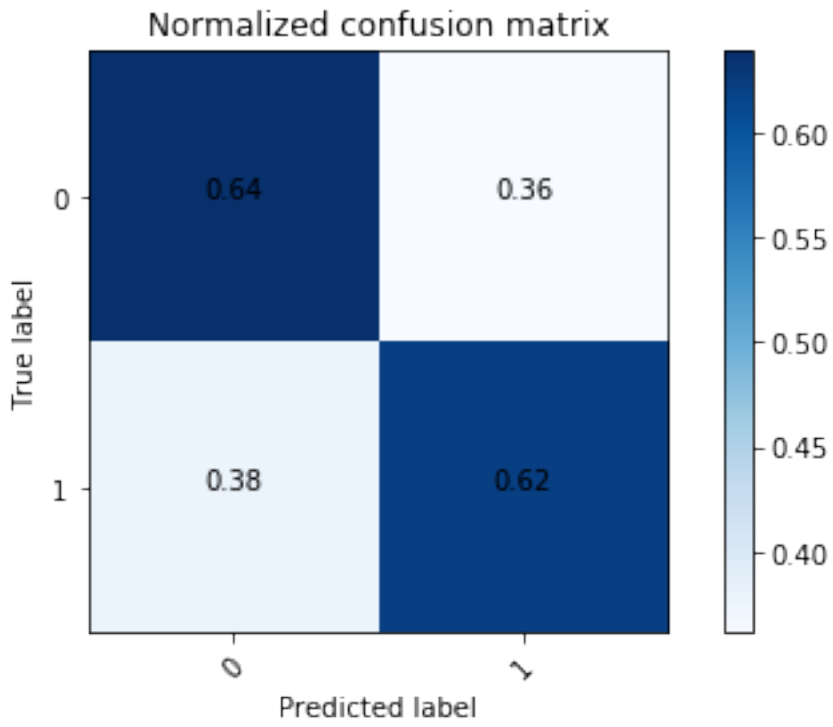
****

3.15.2 Test Set

```
In [111]: print("="*100)
          print("Test confusion matrix")
          compute_confusion_matrix(y_test, y_test_pred, thresh, fpr_test, tpr_test)
```

```
====================================================================================================
Test confusion matrix
the maximum value of tpr*(1-fpr) 0.39760573658388465 for threshold 0.725
Confusion matrix, without normalization
Normalized confusion matrix
```





****

Observations

- We get k=51 as best value of k.
- Our model's AUC is very close to that of a random model.

2.5 Feature selection with `SelectKBest`

```
In [112]: from sklearn.datasets import load_digits
          from sklearn.feature_selection import SelectKBest, chi2

          X_train_set2 = hstack((categories_one_hot_train, sub_categories_one_hot_train,
                     school_state_one_hot_train, teacher_prefix_one_hot_train,
                     project_grade_category_one_hot_train, price_train, quantity_train,
                     prev_teacher_proj_train, title_word_count_train, essay_word_count_train,
                     essay_tfidf_train, title_tfidf_train)).tocsr()

          X_cv_set2 = hstack((categories_one_hot_cv, sub_categories_one_hot_cv,
                     school_state_one_hot_cv, teacher_prefix_one_hot_cv,
                     project_grade_category_one_hot_cv, price_cv, quantity_cv,
                     prev_teacher_proj_cv, title_word_count_cv, essay_word_count_cv,
                     essay_tfidf_cv, title_tfidf_cv)).tocsr()
```

```
X_test_set2 = hstack((categories_one_hot_test, sub_categories_one_hot_test,
            school_state_one_hot_test, teacher_prefix_one_hot_test,
            project_grade_category_one_hot_test, price_test, quantity_test,
            prev_teacher_proj_test, title_word_count_test, essay_word_count_test,
            essay_tfidf_test, title_tfidf_test)).tocsr()



best_feat_vect = SelectKBest(chi2, k=2000).fit(X_train_set2, y_train)

X_train_top2000 =  best_feat_vect.transform(X_train_set2)

X_cv_top2000 = best_feat_vect.transform(X_cv_set2)

X_test_top2000 = best_feat_vect.transform(X_test_set2)
```

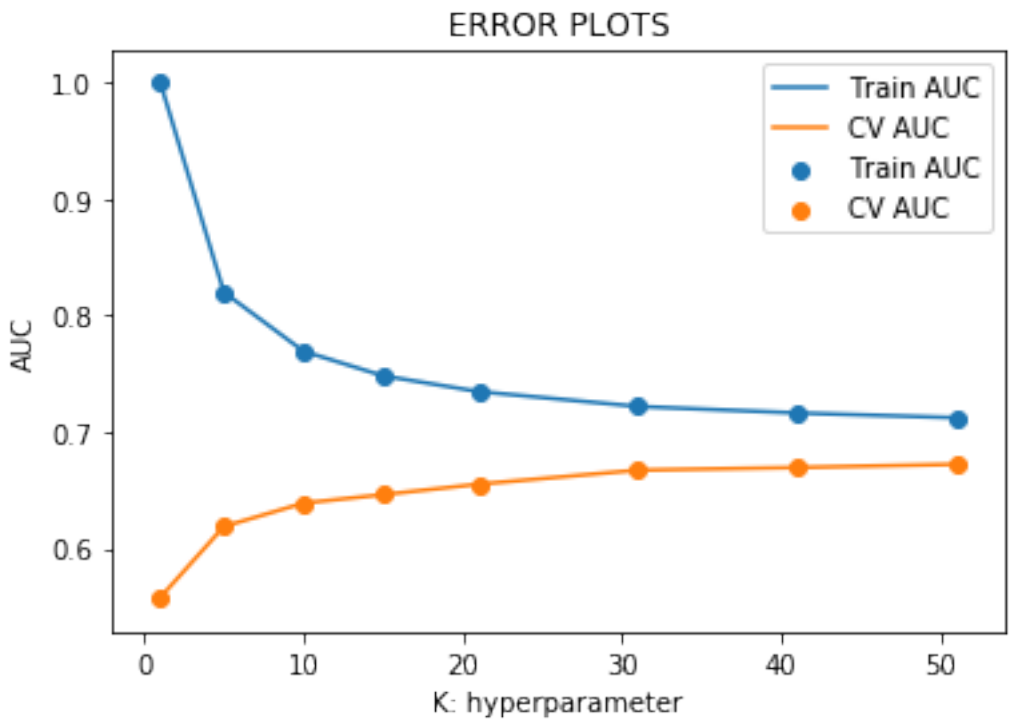
In [113]:
```
print("Final Data matrix for set5")
print(X_train_top2000.shape, y_train.shape)
print(X_cv_top2000.shape, y_cv.shape)
print(X_test_top2000.shape, y_test.shape)
print("="*100)
```

```
Final Data matrix for set5
(38746, 2000) (38746,)
(9687, 2000) (9687,)
(12109, 2000) (12109,)
====================================================================================================
```

3.16 A) Find the best hyper parameter which results in the maximum AUC value

In [114]:
```
best_k_set_top2000, train_auc, cv_auc = find_best_k_using_auc(X_train_top2000, y_tra

# plot showing performance of model both on train data and cross validation data for
plot_k_vs_roc(train_auc, cv_auc)
```

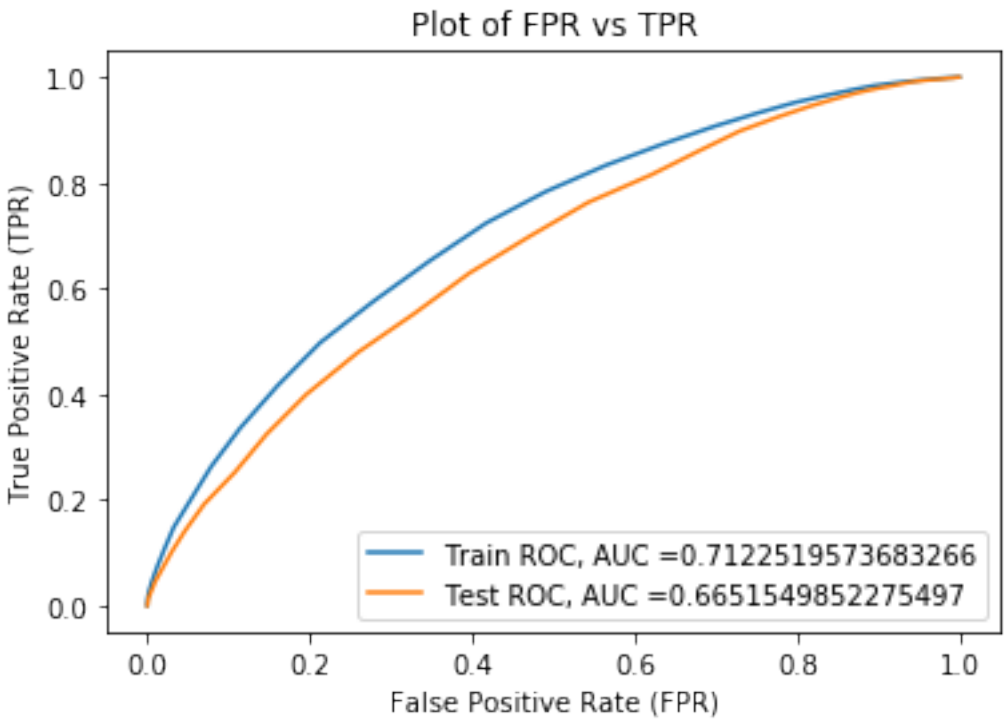
```
100%|| 8/8 [13:55<00:00, 104.13s/it]


The optimal number of neighbors is 51.
```



3.17 B) Train model with best hyper-parameter value

In [115]:
```
knn = KNeighborsClassifier(best_k_set_top2000)
knn.fit(X_train_top2000,y_train)

# print(X_test_set1)
y_train_pred = batch_predict( knn, X_train_top2000)
y_test_pred = batch_predict( knn, X_test_top2000)


fpr_train, tpr_train, thresh1 = roc_curve(y_train, y_train_pred)
fpr_test, tpr_test, thresh = roc_curve(y_test, y_test_pred)
test_auc_top2000 = roc_auc_score(y_test, y_test_pred)
```

In [116]:
```
plt.plot(fpr_train,tpr_train, label='Train ROC, AUC ='+str(auc(fpr_train, tpr_train)))
plt.plot(fpr_test,tpr_test, label='Test ROC, AUC ='+str(auc(fpr_test, tpr_test)))
plt.xlabel('False Positive Rate (FPR)')
plt.ylabel("True Positive Rate (TPR)")
plt.title('Plot of FPR vs TPR')
plt.legend()
plt.show()
```

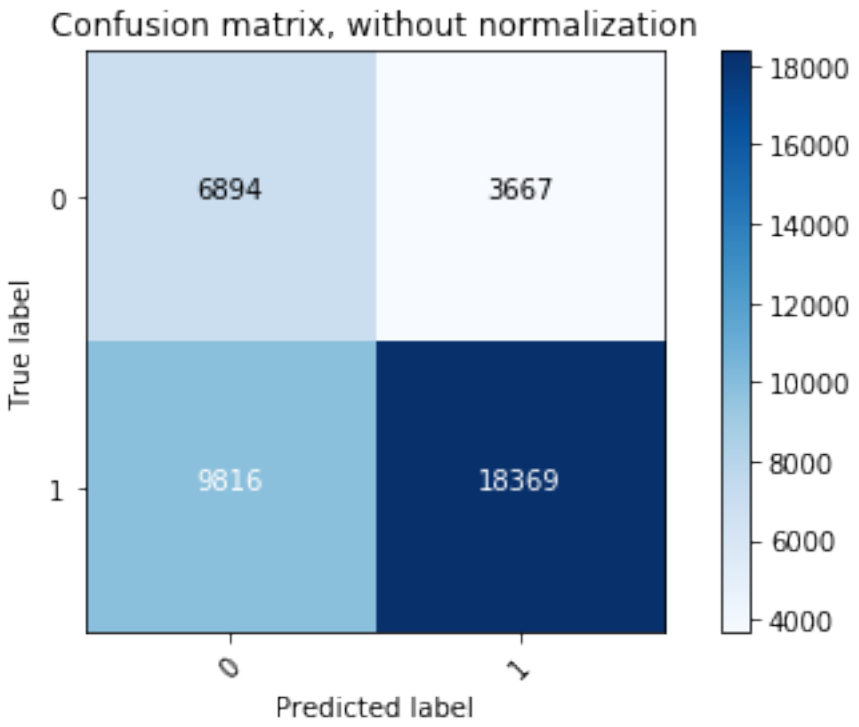


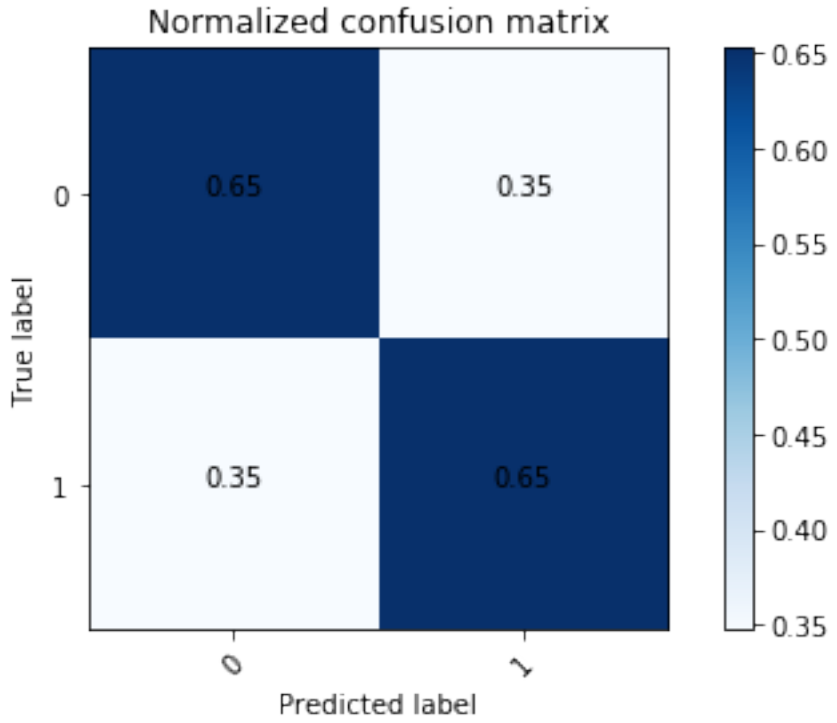
3.18 D) Confusion Matrix

3.18.1 Train Set

In [117]:
```
# computa and plot confusion matrix for train data

print("="*100)
print("Train confusion matrix")
compute_confusion_matrix(y_train, y_train_pred, thresh1, fpr_train, tpr_train)
```

```
====================================================================================================
Train confusion matrix
the maximum value of tpr*(1-fpr) 0.4254354854453352 for threshold 0.725
Confusion matrix, without normalization
Normalized confusion matrix
```


Confusion matrix, without normalization
6894
3667
9816
18369
0
1
True label
0
1
Predicted label
18000
16000
14000
12000
10000
8000
6000
4000

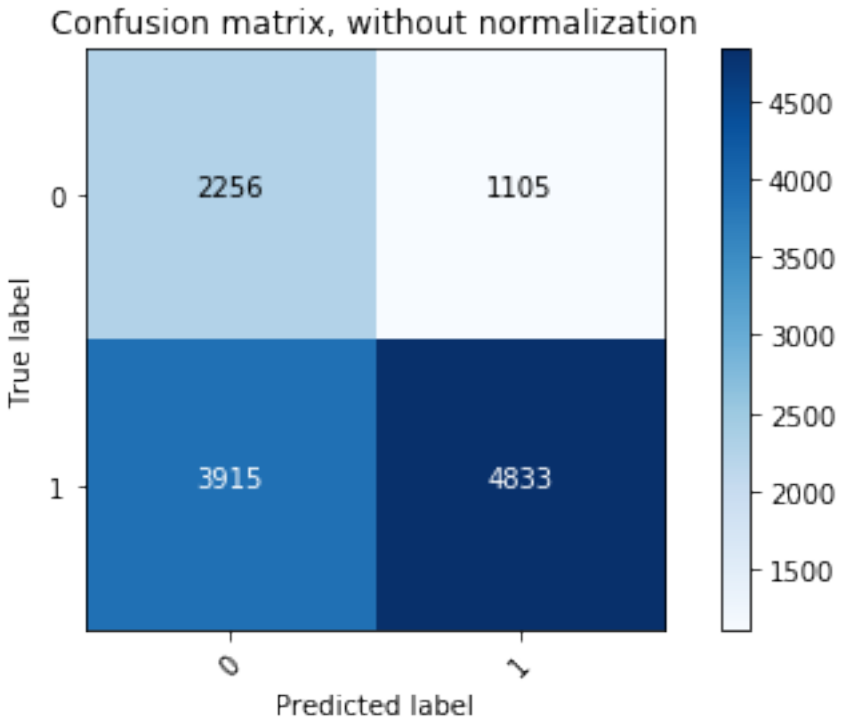

Normalized confusion matrix
0.65
0.35
0.35
0.65
0
1
True label
0
1
Predicted label
0.65
0.60
0.55
0.50
0.45
0.40
0.35

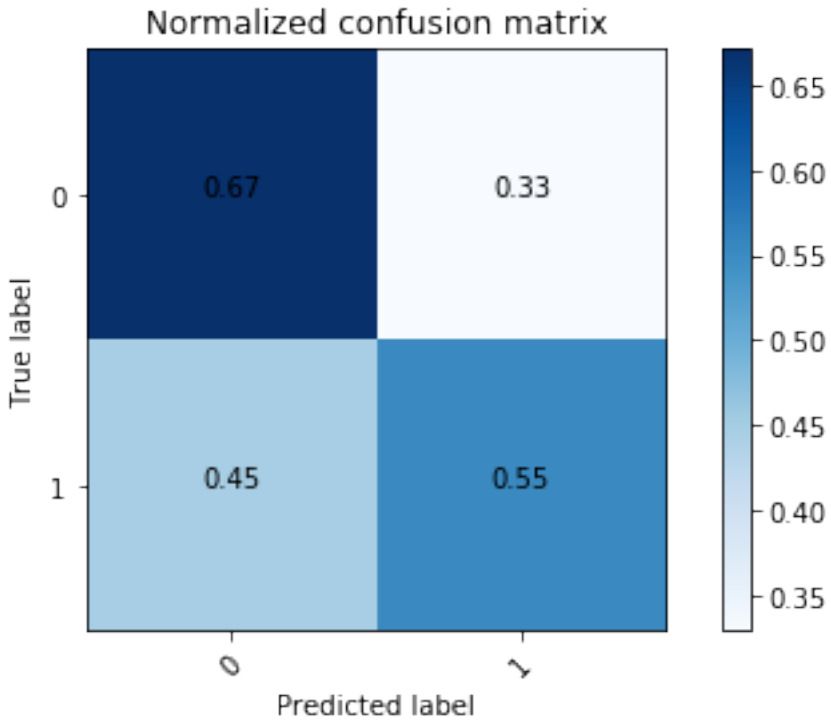
****

3.18.2 Test Set

```
In [118]: print("="*100)
          print("Test confusion matrix")
          compute_confusion_matrix(y_test, y_test_pred, thresh, fpr_test, tpr_test)
```

```
====================================================================================================
Test confusion matrix
the maximum value of tpr*(1-fpr) 0.3795881699044705 for threshold 0.745
Confusion matrix, without normalization
Normalized confusion matrix
```





****

Observations

- We get k=51 as best k value
- After selecting Top 2000 features from TFIDF, our test AUC is almost same to that of TFIDF without feature selection.

3. Conclusions

```
In [120]: from prettytable import PrettyTable

          x = PrettyTable()

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

          x.add_row(["BOW", 'Brute', best_k_set1, test_auc_set1])
          x.add_row(["TFIDF", 'Brute', best_k_set2, test_auc_set2])
          x.add_row(["W2V", 'Brute', best_k_set3, test_auc_set3])
          x.add_row(["TFIDFW2V", 'Brute', best_k_set4, test_auc_set4])
          x.add_row(["TFIDF(2000 features)", 'Brute', best_k_set_top2000, test_auc_top2000])

          print(x)
```

```
+----------------------+-------+----------------+--------------------+
|      Vectorizer      | Model | Hyper Parameter |        AUC         |
+----------------------+-------+----------------+--------------------+
|         BOW          | Brute |        41       | 0.661702247205533  |
|        TFIDF         | Brute |        51       | 0.6629128269655413 |
|         W2V          | Brute |        51       | 0.6741644998093329 |
|       TFIDFW2V       | Brute |        51       | 0.6806738467156075 |
| TFIDF(2000 features) | Brute |        51       | 0.6651549852275497 |
+----------------------+-------+----------------+--------------------+
```

Observations

- Based on above table, we can see that TFIDF Word To Vector has slight higher test AUC than others (This may be because we have taken only 64K points due to RAM limit)
- After selecting Top 2000 features from TFIDF, our test AUC is almost same to that of TFIDF without feature selection..
- Test AUC of almost all the models is very close to that of random model.

In [ ]: