Decision_Tree_Assignment

May 10, 2020

Decision Tree

0.1 Loading Data

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

import pandas as pd
import numpy as np
import nltk
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.metrics import confusion_matrix
from sklearn import metrics
from sklearn.metrics import roc_curve, auc

import re

import pickle
from tqdm import tqdm
import os

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

[2]:
```
data = pd.read_csv('preprocessed_data.csv')
```

[3]:
```
y=data['project_is_approved']
X=data.drop(['project_is_approved'],axis=1)
X.head()
```

[3]:
```
  school_state teacher_prefix project_grade_category  \
0           ca            mrs          grades_prek_2
1           ut             ms             grades_3_5
2           ca            mrs          grades_prek_2
3           ga            mrs          grades_prek_2
4           wa            mrs             grades_3_5

   teacher_number_of_previously_posted_projects   clean_categories  \
0                                            53       math_science
1                                             4       specialneeds
2                                            10  literacy_language
3                                             2    appliedlearning
4                                             2  literacy_language

                 clean_subcategories  \
0  appliedsciences health_lifescience
1                        specialneeds
2                            literacy
3                    earlydevelopment
4                            literacy

                                                 essay   price
0  i fortunate enough use fairy tale stem kits cl…  725.05
1  imagine 8 9 years old you third grade classroo…  213.03
2  having class 24 students comes diverse learner…  329.00
3  i recently read article giving students choice…  481.04
4  my students crave challenge eat obstacles brea…   17.74
```

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

[4]:
```
# train test split
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3,␣
 ↪stratify=y)

print("shape of train and test after split")
print(X_train.shape,y_train.shape)
print(X_test.shape,y_test.shape)
```

```
shape of train and test after split
(76473, 8) (76473,)
(32775, 8) (32775,)
```

Make Data Model Ready: encoding essay

0.2 encoding essay TFIDF

[5]:
```
#TFIDF ON Preproccesed Essay

vectorizer_essaytfidf = TfidfVectorizer(min_df=10)
vectorizer_essaytfidf.fit(X_train['essay'].values) # fit has to happen only on␣
↪train data

# we use the fitted TfidfVectorizer to convert the text to vector
X_train_essay_tfidf = vectorizer_essaytfidf.transform(X_train['essay'].values)
X_test_essay_tfidf = vectorizer_essaytfidf.transform(X_test['essay'].values)

print("After Tfidf vectorization of Essay")
print(X_train_essay_tfidf.shape, y_train.shape)  #shapes of Train ,Test after␣
↪encoding
print(X_test_essay_tfidf.shape, y_test.shape)
```

```
After Tfidf vectorization of Essay
(76473, 14476) (76473,)
(32775, 14476) (32775,)
```

0.3 Using Pretrained Models: TFIDF weighted W2V

[6]:
```
with open('glove_vectors', 'rb') as f:
    model = pickle.load(f)
    glove_words =  set(model.keys())
```

[7]:
```
tfidf_model = TfidfVectorizer()
tfidf_model.fit(X_train['essay'].values)
# we are converting a dictionary with word as a key, and the idf as a value
dictionary = dict(zip(tfidf_model.get_feature_names(), list(tfidf_model.idf_)))
tfidf_words = set(tfidf_model.get_feature_names())
```

[8]:
```
# average Word2Vec
# compute average word2vec for each review.
def tfidf_weighted_w2v(preprocessed_essay):
    tfidf_w2v_vectors = []; # the avg-w2v for each sentence/review is stored in␣
↪this list
    for sentence in tqdm(preprocessed_essay): # for each review/sentence
        vector = np.zeros(300) # as word vectors are of zero length
        tf_idf_weight =0; # num of words with a valid vector in the sentence/
↪review
        for word in sentence.split(): # for each word in a review/sentence
            if (word in glove_words) and (word in tfidf_words):
                vec = model[word] # getting the vector for each word
                # here we are multiplying idf value(dictionary[word]) and the␣
↪tf value((sentence.count(word)/len(sentence.split())))
```

```
                tf_idf = dictionary[word]*(sentence.count(word)/len(sentence.
↪split())) # getting the tfidf value for each word
                vector += (vec * tf_idf) # calculating tfidf weighted w2v
                tf_idf_weight += tf_idf
        if tf_idf_weight != 0:
            vector /= tf_idf_weight
        tfidf_w2v_vectors.append(vector)
    print(len(tfidf_w2v_vectors))
    print(len(tfidf_w2v_vectors[0]))
    return tfidf_w2v_vectors
```

[9]:
```
X_train_tfidf_weighted_w2v=tfidf_weighted_w2v(X_train['essay'].values)
X_test_tfidf_weighted_w2v=tfidf_weighted_w2v(X_test['essay'].values)
```

```
100%|
| 76473/76473 [03:10<00:00, 400.38it/s]
  1%|
| 253/32775 [00:00<01:05, 493.15it/s]

76473
300

100%|
| 32775/32775 [01:14<00:00, 441.06it/s]

32775
300
```

Make Data Model Ready: encoding numerical, categorical features

encoding categorical features: School State

[10]:
```
vectorizer_state= CountVectorizer(binary=True)

X_train_state = vectorizer_state.fit_transform(X_train['school_state'].values)
X_test_state = vectorizer_state.fit_transform(X_test['school_state'].values)

print("Shape of matrix after one hot encoding ")
print(X_train_state.shape,y_train.shape)
print(X_test_state.shape,y_test.shape)
```

```
Shape of matrix after one hot encoding
(76473, 51) (76473,)
(32775, 51) (32775,)
```

encoding categorical features: Teacher Prefix

[11]:
```
vectorizer_prefix= CountVectorizer(binary=True)
```

```
X_train_prefix = vectorizer_prefix.fit_transform(X_train['teacher_prefix'].
 ↪values)
X_test_prefix = vectorizer_prefix.fit_transform(X_test['teacher_prefix'].values)

print("Shape of matrix after one hot encoding ")
print(X_train_prefix.shape,y_train.shape)
print(X_test_prefix.shape,y_test.shape)
```

```
Shape of matrix after one hot encoding
(76473, 5) (76473,)
(32775, 5) (32775,)
```

encoding categorical features: Project Grade Category

[12]:
```
vectorizer_grade= CountVectorizer(binary=True)

X_train_grade = vectorizer_grade.
 ↪fit_transform(X_train['project_grade_category'].values)
X_test_grade= vectorizer_grade.fit_transform(X_test['project_grade_category'].
 ↪values)

print("Shape of matrix after one hot encoding ")
print(X_train_grade.shape,y_train.shape)
print(X_test_grade.shape,y_test.shape)
```

```
Shape of matrix after one hot encoding
(76473, 4) (76473,)
(32775, 4) (32775,)
```

encoding categorical features: Clean Categories

[13]:
```
vectorizer_categories= CountVectorizer(binary=True)

X_train_categories = vectorizer_categories.
 ↪fit_transform(X_train['clean_categories'].values)
X_test_categories= vectorizer_categories.
 ↪fit_transform(X_test['clean_categories'].values)

print("Shape of matrix after one hot encoding ")
print(X_train_categories.shape,y_train.shape)
print(X_test_categories.shape,y_test.shape)
```

```
Shape of matrix after one hot encoding
(76473, 9) (76473,)
(32775, 9) (32775,)
```

encoding categorical features: Clean SubCategories

[14]:
```
vectorizer_subcategories= CountVectorizer(binary=True)

X_train_subcategories = vectorizer_subcategories.
 ↪fit_transform(X_train['clean_subcategories'].values)
X_test_subcategories = vectorizer_subcategories.
 ↪fit_transform(X_test['clean_subcategories'].values)

print("Shape of matrix after one hot encoding ")
print(X_train_subcategories.shape,y_train.shape)
print(X_test_subcategories.shape,y_test.shape)
```

```
Shape of matrix after one hot encoding
(76473, 30) (76473,)
(32775, 30) (32775,)
```

encoding Numerical features: teacher_number_of_previously_posted_projects

[15]:
```
from sklearn.preprocessing import Normalizer
normalizer = Normalizer()

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

X_train_prev_proj=(normalizer.
 ↪transform(X_train['teacher_number_of_previously_posted_projects'].values.
 ↪reshape(1,-1))).reshape(-1,1)
X_test_prev_proj=(normalizer.
 ↪transform(X_test['teacher_number_of_previously_posted_projects'].values.
 ↪reshape(1,-1))).reshape(-1,1)

print("shape of matrix")
print(X_train_prev_proj.shape, y_train.shape)
print(X_test_prev_proj.shape, y_test.shape)
```

```
shape of matrix
(76473, 1) (76473,)
(32775, 1) (32775,)
```

encoding Numerical features: Price

[16]:
```
normalizer = Normalizer()
normalizer.fit(X_train['price'].values.reshape(1,-1))

X_train_price= (normalizer.transform(X_train['price'].values.reshape(1,-1))).
 ↪reshape(-1,1)
X_test_price=(normalizer.transform(X_test['price'].values.reshape(1,-1))).
 ↪reshape(-1,1)
```

```
print("Shape of price matrix")
print(X_train_price.shape, y_train.shape)
print(X_test_price.shape, y_test.shape)
```

```
Shape of price matrix
(76473, 1) (76473,)
(32775, 1) (32775,)
```

0.4 Concatinating all the features (essay-TFIDF)

[17]:
```
#concatinating all features- essay(tfidf)+Categorical+ Numerical Features using␣
 ↪hstack

from scipy.sparse import hstack

X_train_tfidf=hstack((X_train_essay_tfidf,X_train_state,X_train_prefix,X_train_grade,X_train_c
 ↪tocsr()
X_test_tfidf=hstack((X_test_essay_tfidf,X_test_state,X_test_prefix,X_test_grade,X_test_categor
 ↪tocsr()

print("Final Data matrix")
print(X_train_tfidf.shape, y_train.shape)
print(X_test_tfidf.shape, y_test.shape)
```

```
Final Data matrix
(76473, 14577) (76473,)
(32775, 14577) (32775,)
```

0.5 Concatinating all the features (essay-TFIDF_Weighted_W2V)

[18]:
```
#concatinating all features- essay(tfidf_weighted_w2v)+Categorical+ Numerical␣
 ↪Features using hstack

X_train_tfidfw2v=hstack((X_train_tfidf_weighted_w2v,X_train_state,X_train_prefix,X_train_grade
X_test_tfidfw2v=hstack((X_test_tfidf_weighted_w2v,X_test_state,X_test_prefix,X_test_grade,X_te

print("Final Data matrix")
print(X_train_tfidfw2v.shape, y_train.shape)
print(X_test_tfidfw2v.shape, y_test.shape)
```

```
Final Data matrix
(76473, 401) (76473,)
(32775, 401) (32775,)
```

Appling Decision Tree on different kind of featurization

1 Applying Decision Tree Set 1 Essay-TFIDF

1.1 Hyper Parameter Tuning

[19]:
```
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import roc_auc_score

dtclf=DecisionTreeClassifier(class_weight='balanced')

parameters={'max_depth':[1, 5, 10, 50],'min_samples_split':[5, 10, 100, 500]}
clf=GridSearchCV(dtclf,parameters,cv=3,scoring='roc_auc',return_train_score='True')
clf.fit(X_train_tfidf,y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_max_depth','param_min_samples_split'])

train_auc= results['mean_train_score']
cv_auc = results['mean_test_score']
max_depth= results['param_max_depth']
min_samples_split= results['param_min_samples_split']

results.head()
```

[19]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	param_max_depth	param_min_samples_split	params	split0_test_score	split1_test_score	split2_test_score	mean_test_score	std_test_score
0	1.098887	0.124138	0.086103	0.000493	1	5	{'max_depth': 1, 'min_samples_split': 5}	0.543328	0.541953	0.550895	0.545392	0.003931
1	0.990684	0.080930	0.086104	0.000470	1	10	{'max_depth': 1, 'min_samples_split': 10}	0.543328				
2	0.930178	0.002351	0.086793	0.001629	1	100	{'max_depth': 1, 'min_samples_split': 100}	0.543328				
3	1.022265	0.068000	0.107381	0.005778	1	500	{'max_depth': 1, 'min_samples_split': 500}	0.543328				
4	4.323438	0.162184	0.087765	0.000815	5	5	{'max_depth': 5, 'min_samples_split': 5}	0.627402				

```
1           0.541953           0.550895         0.545392        0.003931
2           0.541953           0.550895         0.545392        0.003931
3           0.541953           0.550895         0.545392        0.003931
4           0.625535           0.626332         0.626423        0.000765

   rank_test_score  split0_train_score  split1_train_score  \
0               13            0.543324            0.551316
1               13            0.543324            0.551316
2               13            0.543324            0.551316
3               13            0.543324            0.551316
4                6            0.647106            0.653015

   split2_train_score  mean_train_score  std_train_score
0            0.546895          0.547178         0.003269
1            0.546895          0.547178         0.003269
2            0.546895          0.547178         0.003269
3            0.546895          0.547178         0.003269
4            0.639338          0.646486         0.005601
```

[20]:
```
clf.best_params_
```

[20]:
```
{'max_depth': 10, 'min_samples_split': 500}
```

[21]:
```
best_maxdepth=clf.best_params_['max_depth']
best_minsamplessplit=clf.best_params_['min_samples_split']
print(best_maxdepth,best_minsamplessplit)
```

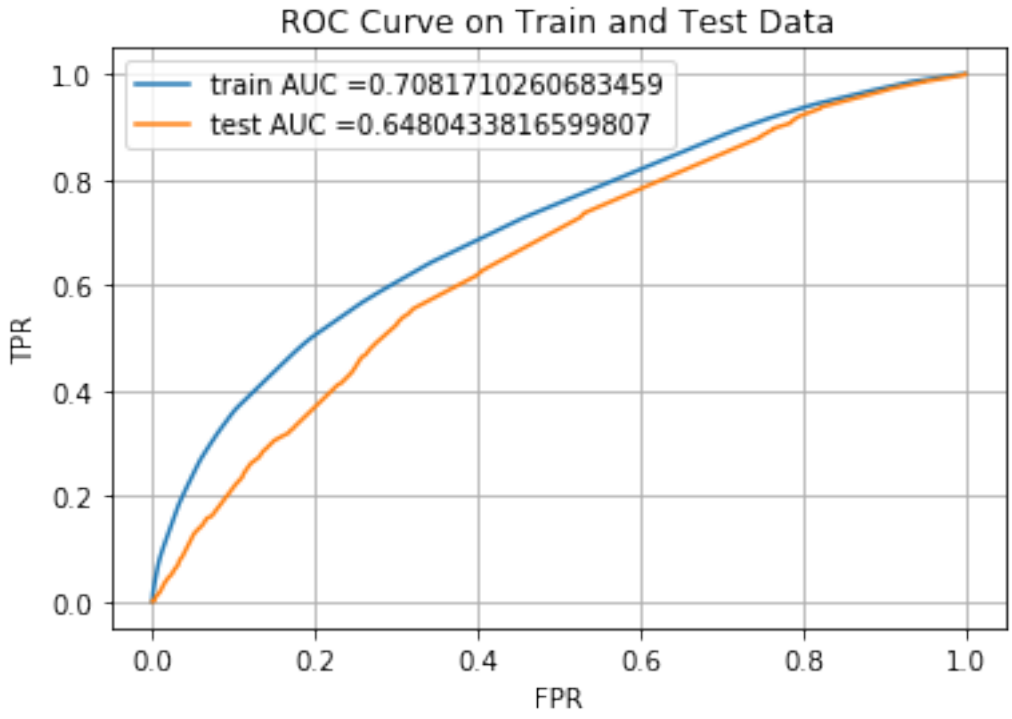
```
10 500
```

1.2 Representation of Results

[22]:
```
# https://plot.ly/python/3d-axes/
trace1 = go.Scatter3d(x=min_samples_split,y=max_depth,z=train_auc, name =␣
 ↪'train')
trace2 = go.Scatter3d(x=min_samples_split,y=max_depth,z=cv_auc, name = 'Cross␣
 ↪validation')
data = [trace1, trace2]

layout = go.Layout(scene = dict(
        xaxis = dict(title='min_samples_split'),
        yaxis = dict(title='max_depth'),
        zaxis = dict(title='AUC'),))

fig = go.Figure(data=data, layout=layout)
offline.iplot(fig, filename='3d-scatter-colorscale')
```

1.3 Testing Performance of the Model with Best Hyper Parameters

[23]:
```
from sklearn.metrics import roc_curve, auc

classfier=DecisionTreeClassifier(max_depth=best_maxdepth,min_samples_split=best_minsamplesspli
classfier.fit(X_train_tfidf,y_train)

y_train_pred=classfier.predict_proba(X_train_tfidf)[:,1]
y_test_pred=classfier.predict_proba(X_test_tfidf)[:,1]

train_fpr, train_tpr, train_thresolds = roc_curve(y_train,y_train_pred)
test_fpr, test_tpr, test_thresolds = roc_curve(y_test,y_test_pred)

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr,␣
 ↪train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))␣
 ↪#plotting ROC Curves for train and test datasets
plt.legend()
plt.xlabel("FPR")
plt.ylabel("TPR")
plt.title("ROC Curve on Train and Test Data")
plt.grid()
plt.show()
```



[24]:
```
print("AUC score on Train data is ")
print(auc(train_fpr, train_tpr))
print("AUC score on Test data is ")
print(auc(test_fpr, test_tpr))
```

```
AUC score on Train data is
0.7081710260683459
AUC score on Test data is
0.6480433816599807
```

[25]:
```
# we are writing our own function for predict, with defined thresould
# we will pick a threshold that will give the least fpr
def find_best_thresold(thresold, fpr, tpr):
    t = thresold[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr) is ", max(tpr*(1-fpr)), "for␣
 ↪thresold", np.round(t,3))
    return t

def predict_with_best_t(proba,thresold):
    predictions = []
    for i in proba:
        if i>=thresold:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

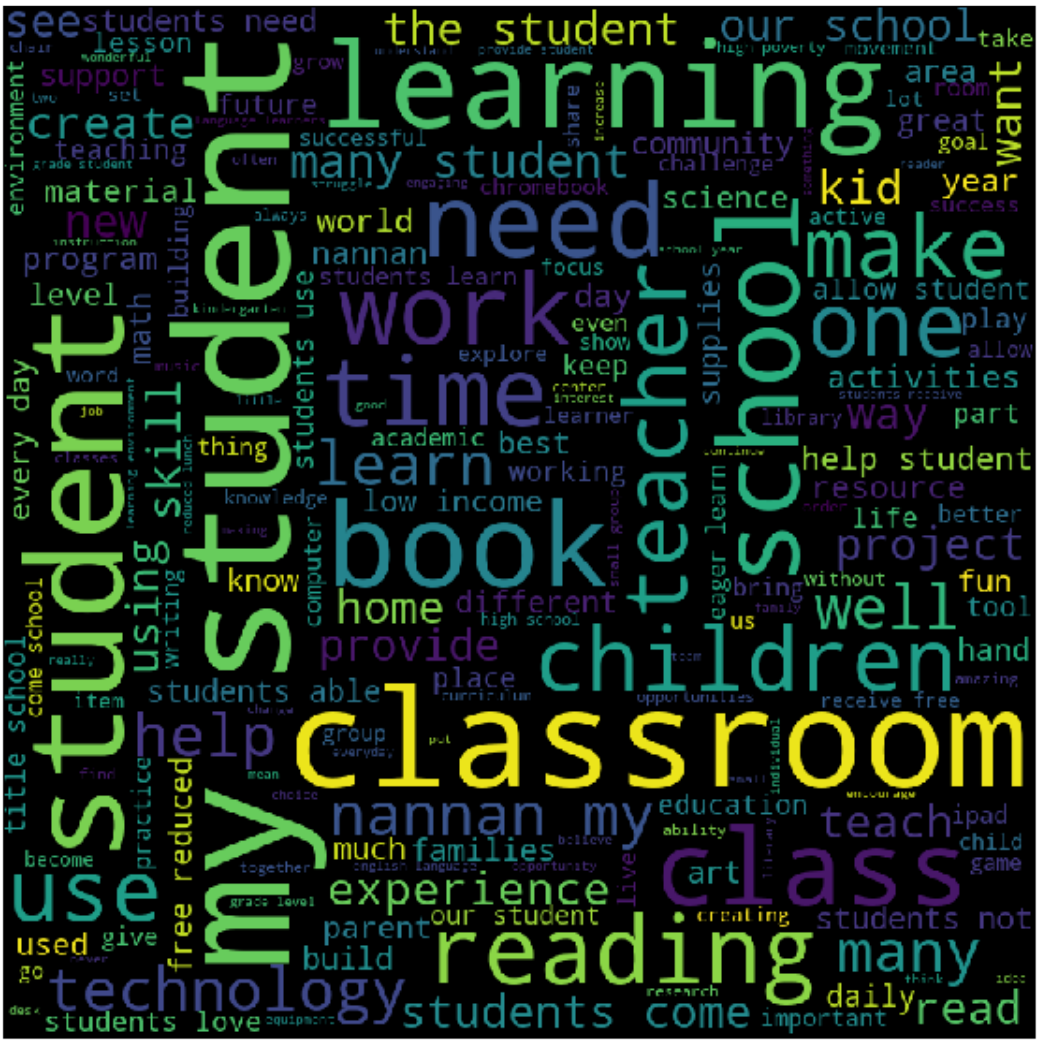
[26]:
```
from sklearn.metrics import confusion_matrix
best_t = find_best_thresold(train_thresolds, train_fpr, train_tpr)
print("Train confusion matrix")
print(confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t)))
print("Test confusion matrix")
print(confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))
```

```
the maximum value of tpr*(1-fpr) is  0.4234925664701732 for thresold 0.476
Train confusion matrix
[[ 8286  3293]
 [26490 38404]]
Test confusion matrix
[[ 3371  1592]
 [12374 15438]]
```

1.4 Word Cloud

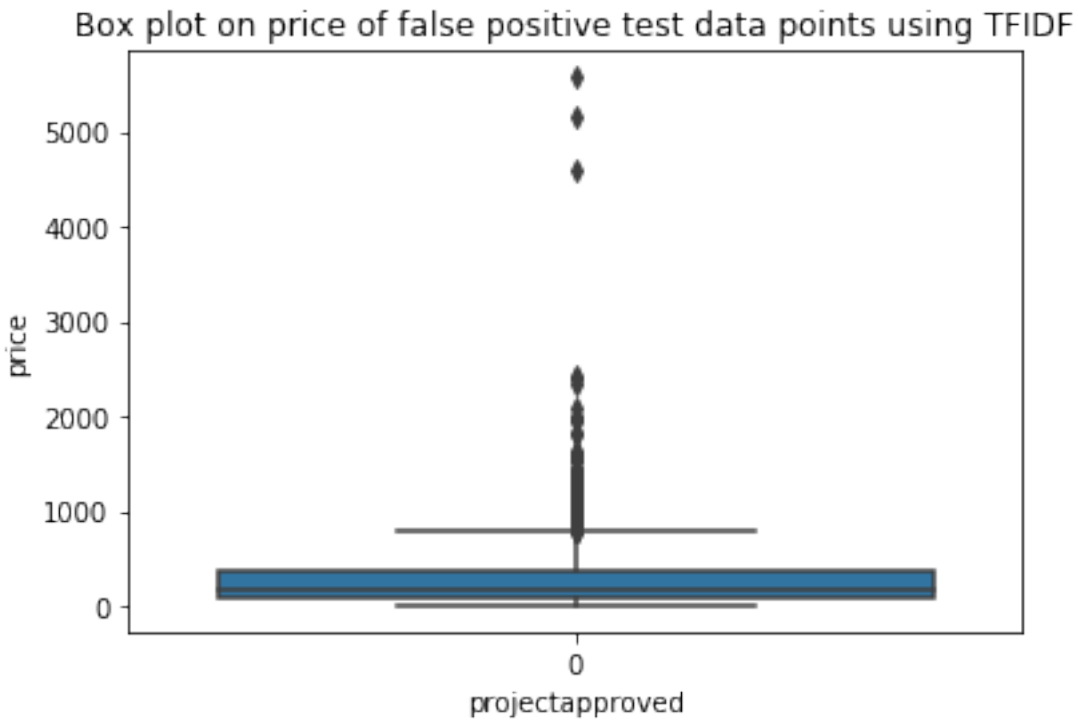
[27]:
```
X_testessay=X_test['essay'].values
predictions=predict_with_best_t(y_test_pred,best_t)
y_actual=y_test.values
essay_words=' '
index=[]
for i in range(len(y_test)):
    if predictions[i]==1 and y_actual[i]==0: #false positive
        index.append(i)
        tokens=X_testessay[i].split() ## split the each false positive essayword
        essay_words+=" ".join(tokens)+" "
```

[28]:
```
from wordcloud import WordCloud, STOPWORDS
stopwords = set(STOPWORDS)

wordcloud=WordCloud(width = 800, height = 800,stopwords=stopwords,min_font_size␣
 ↪= 10).generate(essay_words)

# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```



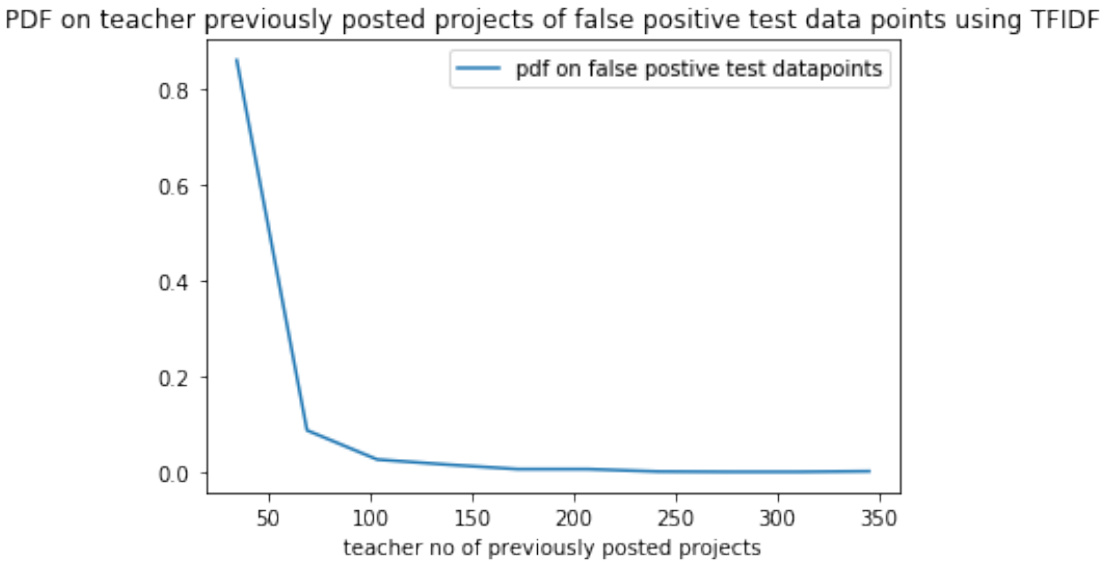
1.5 Box Plot

[29]:
```
price=X_test['price'].values
fp_prices=np.take(price,index)
sns.boxplot(data=fp_prices)
plt.xlabel("projectapproved")
plt.ylabel("price")
plt.title("Box plot on price of false positive test data points using TFIDF")
plt.show()
```



1.6 PDF

[30]:
```
prevprojects=X_test['teacher_number_of_previously_posted_projects'].values
fp_prevprojects=np.take(prevprojects,index)

counts,bin_edges = np.histogram(fp_prevprojects,bins=10,density=True)
pdf=counts/(sum(counts))
plt.plot(bin_edges[1:],pdf,label="pdf on false postive test datapoints")

plt.title("PDF on teacher previously posted projects of false positive test␣
 ↪data points using TFIDF")
plt.xlabel("teacher no of previously posted projects")

plt.legend()
plt.show()
```



2 Applying Decision Tree Set 2 Essay-TFIDF W2V

2.1 Hyper Parameter Tuning

[31]:
```
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import roc_auc_score

dtclf=DecisionTreeClassifier(class_weight='balanced')

parameters={'max_depth':[1, 5, 10, 50],'min_samples_split':[5, 10, 100, 500]}
clf=GridSearchCV(dtclf,parameters,cv=3,scoring='roc_auc',return_train_score='True')
clf.fit(X_train_tfidfw2v,y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_max_depth','param_min_samples_split'])

train_auc= results['mean_train_score']
cv_auc = results['mean_test_score']
max_depth= results['param_max_depth']
min_samples_split= results['param_min_samples_split']

results.head()
```

[31]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	\
0	3.153565	0.097813	0.246674	0.014778	
1	2.991999	0.049474	0.246342	0.005642	

```
2       3.129298      0.388402         0.258654        0.020972
3       3.067143      0.267386         0.238018        0.001704
4      13.536797      0.112376         0.255982        0.014042

  param_max_depth param_min_samples_split  \
0               1                       5
1               1                      10
2               1                     100
3               1                     500
4               5                       5

                                      params  split0_test_score  \
0    {'max_depth': 1, 'min_samples_split': 5}           0.543328
1   {'max_depth': 1, 'min_samples_split': 10}           0.543328
2  {'max_depth': 1, 'min_samples_split': 100}           0.543328
3  {'max_depth': 1, 'min_samples_split': 500}           0.543328
4    {'max_depth': 5, 'min_samples_split': 5}           0.623902

   split1_test_score  split2_test_score  mean_test_score  std_test_score  \
0           0.541953           0.550895         0.545392        0.003931
1           0.541953           0.550895         0.545392        0.003931
2           0.541953           0.550895         0.545392        0.003931
3           0.541953           0.550895         0.545392        0.003931
4           0.628123           0.633426         0.628484        0.003897

   rank_test_score  split0_train_score  split1_train_score  \
0               11            0.543324            0.551316
1               11            0.543324            0.551316
2               11            0.543324            0.551316
3               11            0.543324            0.551316
4                1            0.660767            0.661864

   split2_train_score  mean_train_score  std_train_score
0            0.546895          0.547178         0.003269
1            0.546895          0.547178         0.003269
2            0.546895          0.547178         0.003269
3            0.546895          0.547178         0.003269
4            0.657276          0.659969         0.001956
```

[32]:
```
clf.best_params_
```

[32]:
```
{'max_depth': 5, 'min_samples_split': 5}
```

[33]:
```
best_maxdepth=clf.best_params_['max_depth']
best_minsamplessplit=clf.best_params_['min_samples_split']
print(best_maxdepth,best_minsamplessplit)
```

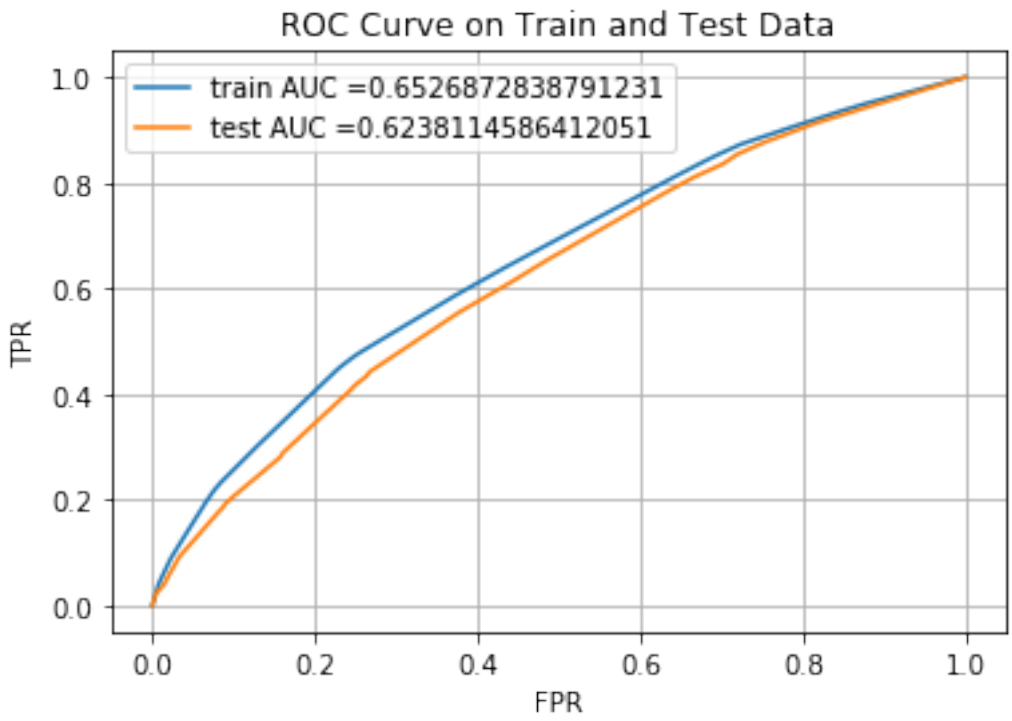
5 5

2.2 Representation of Results

[34]:
```
# https://plot.ly/python/3d-axes/
trace1 = go.Scatter3d(x=min_samples_split,y=max_depth,z=train_auc, name =␣
 ↪'train')
trace2 = go.Scatter3d(x=min_samples_split,y=max_depth,z=cv_auc, name = 'Cross␣
 ↪validation')
data = [trace1, trace2]

layout = go.Layout(scene = dict(
        xaxis = dict(title='min_samples_split'),
        yaxis = dict(title='max_depth'),
        zaxis = dict(title='AUC'),))

fig = go.Figure(data=data, layout=layout)
offline.iplot(fig, filename='3d-scatter-colorscale')
```

2.3 Testing Performance of the Model with Best Hyper Parameters

[35]:
```
from sklearn.metrics import roc_curve, auc

classfier=DecisionTreeClassifier(max_depth=best_maxdepth,min_samples_split=best_minsamplesspli
classfier.fit(X_train_tfidfw2v,y_train)

#y_train_pred=batch_predict(classfier,X_train_tfidf)
#y_test_pred=batch_predict(classfier,X_test_tfidf)
y_train_pred=classfier.predict_proba(X_train_tfidfw2v)[:,1]
y_test_pred=classfier.predict_proba(X_test_tfidfw2v)[:,1]

train_fpr, train_tpr, train_thresolds = roc_curve(y_train,y_train_pred)
test_fpr, test_tpr, test_thresolds = roc_curve(y_test,y_test_pred)

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr,␣
 ↪train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))␣
 ↪#plotting ROC Curves for train and test datasets
plt.legend()
plt.xlabel("FPR")
plt.ylabel("TPR")
plt.title("ROC Curve on Train and Test Data")
plt.grid()
plt.show()
```



[36]:
```
print("AUC score on Train data is ")
print(auc(train_fpr, train_tpr))
print("AUC score on Test data is ")
print(auc(test_fpr, test_tpr))
```

```
AUC score on Train data is
0.6526872838791231
AUC score on Test data is
0.6238114586412051
```

[37]:
```
# we are writing our own function for predict, with defined thresould
# we will pick a threshold that will give the least fpr
def find_best_thresold(thresold, fpr, tpr):
    t = thresold[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr) is ", max(tpr*(1-fpr)), "for␣
 ↪thresold", np.round(t,3))
    return t

def predict_with_best_t(proba,thresold):
    predictions = []
    for i in proba:
        if i>=thresold:
```

```
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

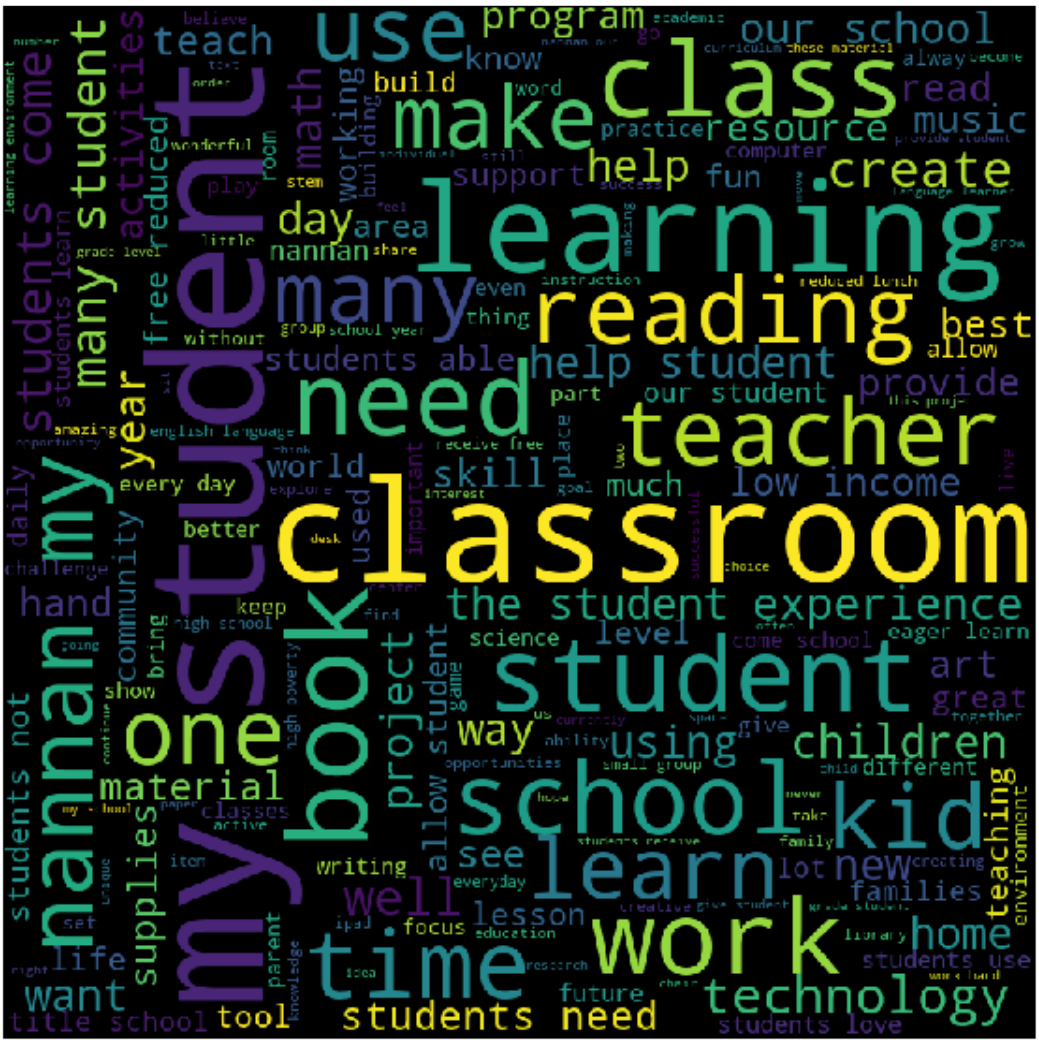
[38]:
```
from sklearn.metrics import confusion_matrix
best_t = find_best_thresold(train_thresolds, train_fpr, train_tpr)
print("Train confusion matrix")
print(confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t)))
print("Test confusion matrix")
print(confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))
```

```
the maximum value of tpr*(1-fpr) is  0.36815747329133447 for thresold 0.479
Train confusion matrix
[[ 7269  4310]
 [26837 38057]]
Test confusion matrix
[[ 3084  1879]
 [12340 15472]]
```

2.4 Word Cloud

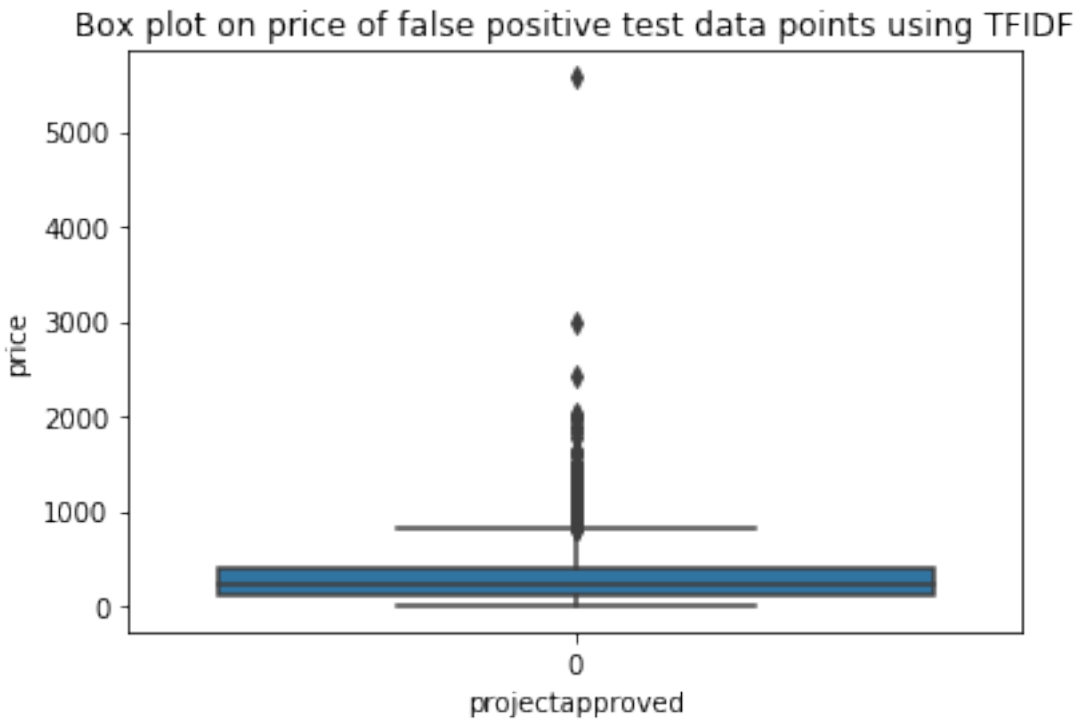
[39]:
```
X_testessay=X_test['essay'].values
predictions=predict_with_best_t(y_test_pred,best_t)
y_actual=y_test.values
essay_words=' '
index=[]
for i in range(len(y_test)):
    if predictions[i]==1 and y_actual[i]==0: #false positive
        index.append(i)
        tokens=X_testessay[i].split() ## split the each false positive essayword
        essay_words+=" ".join(tokens)+" "
```

[40]:
```
from wordcloud import WordCloud, STOPWORDS
stopwords = set(STOPWORDS)

wordcloud=WordCloud(width = 800, height = 800,stopwords=stopwords,min_font_size␣
 ↪= 10).generate(essay_words)

# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```



2.5 Box Plot

[41]:
```
price=X_test['price'].values
fp_prices=np.take(price,index)
sns.boxplot(data=fp_prices)
plt.xlabel("projectapproved")
plt.ylabel("price")
plt.title("Box plot on price of false positive test data points using TFIDF")
plt.show()
```



2.6 PDF

[42]:
```
prevprojects=X_test['teacher_number_of_previously_posted_projects'].values
fp_prevprojects=np.take(prevprojects,index)

counts,bin_edges = np.histogram(fp_prevprojects,bins=10,density=True)
pdf=counts/(sum(counts))
plt.plot(bin_edges[1:],pdf,label="pdf on false postive test datapoints")

plt.title("PDF on teacher previously posted projects of false positive test␣
 ↪data points using TFIDF")
plt.xlabel("teacher no of previously posted projects")

plt.legend()
plt.show()
```

Getting top features using `feature_importances_`

[43]:
```
from sklearn.tree import DecisionTreeClassifier
dtclf=DecisionTreeClassifier(class_weight='balanced')
dtclf.fit(X_train_tfidf,y_train)
```

[43]:
```
DecisionTreeClassifier(ccp_alpha=0.0, class_weight='balanced', criterion='gini',
                       max_depth=None, max_features=None, max_leaf_nodes=None,
                       min_impurity_decrease=0.0, min_impurity_split=None,
                       min_samples_leaf=1, min_samples_split=2,
                       min_weight_fraction_leaf=0.0, presort='deprecated',
                       random_state=None, splitter='best')
```

[44]:
```
len(dtclf.feature_importances_)
```

[44]:
```
14577
```

[45]:
```
feature_imp=dtclf.feature_importances_

ind=[]
for i in range(len(feature_imp)):
    if feature_imp[i]>0:
        ind.append(i)

print(len(ind))
```

2547

[46]:
```
X_train_fimp=X_train_tfidf[:,ind]
X_test_fimp=X_test_tfidf[:,ind]

print("shape of matrix after feature importance")
print(X_train_fimp.shape)
print(X_test_fimp.shape)
```

```
shape of matrix after feature importance
(76473, 2547)
(32775, 2547)
```

3 Applying Decision Tree on top features

3.1 Hyper Parameter Tuning

[47]:
```
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import roc_auc_score

dtclf=DecisionTreeClassifier(class_weight='balanced')

parameters={'max_depth':[1, 5, 10, 50],'min_samples_split':[5, 10, 100, 500]}
clf=GridSearchCV(dtclf,parameters,cv=3,scoring='roc_auc',return_train_score='True')
clf.fit(X_train_fimp,y_train)

results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_max_depth','param_min_samples_split'])

train_auc= results['mean_train_score']
cv_auc = results['mean_test_score']
max_depth= results['param_max_depth']
min_samples_split= results['param_min_samples_split']

results.head()
```

[47]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	\
0	0.773245	0.011205	0.025610	9.321660e-04	
1	0.820472	0.077819	0.025944	1.664420e-05	
2	0.762960	0.001628	0.024934	4.052337e-07	
3	0.825127	0.079469	0.025609	9.541485e-04	
4	3.439468	0.080169	0.026950	1.591800e-05	

	param_max_depth	param_min_samples_split	\
0	1	5	
1	1	10	
2	1	100	
3	1	500	

```
4               5                         5

                                      params  split0_test_score  \
0    {'max_depth': 1, 'min_samples_split': 5}           0.543328
1   {'max_depth': 1, 'min_samples_split': 10}           0.543328
2  {'max_depth': 1, 'min_samples_split': 100}           0.543328
3  {'max_depth': 1, 'min_samples_split': 500}           0.543328
4    {'max_depth': 5, 'min_samples_split': 5}           0.626387

   split1_test_score  split2_test_score  mean_test_score  std_test_score  \
0           0.541953           0.550895         0.545392        0.003931
1           0.541953           0.550895         0.545392        0.003931
2           0.541953           0.550895         0.545392        0.003931
3           0.541953           0.550895         0.545392        0.003931
4           0.625112           0.626631         0.626043        0.000666

   rank_test_score  split0_train_score  split1_train_score  \
0               13            0.543324            0.551316
1               13            0.543324            0.551316
2               13            0.543324            0.551316
3               13            0.543324            0.551316
4                6            0.647073            0.652929

   split2_train_score  mean_train_score  std_train_score
0            0.546895          0.547178         0.003269
1            0.546895          0.547178         0.003269
2            0.546895          0.547178         0.003269
3            0.546895          0.547178         0.003269
4            0.639338          0.646446         0.005566
```

[48]:
```
clf.best_params_
```

[48]:
```
{'max_depth': 10, 'min_samples_split': 500}
```

[49]:
```
best_maxdepth=clf.best_params_['max_depth']
best_minsamplessplit=clf.best_params_['min_samples_split']
print(best_maxdepth,best_minsamplessplit)
```

```
10 500
```

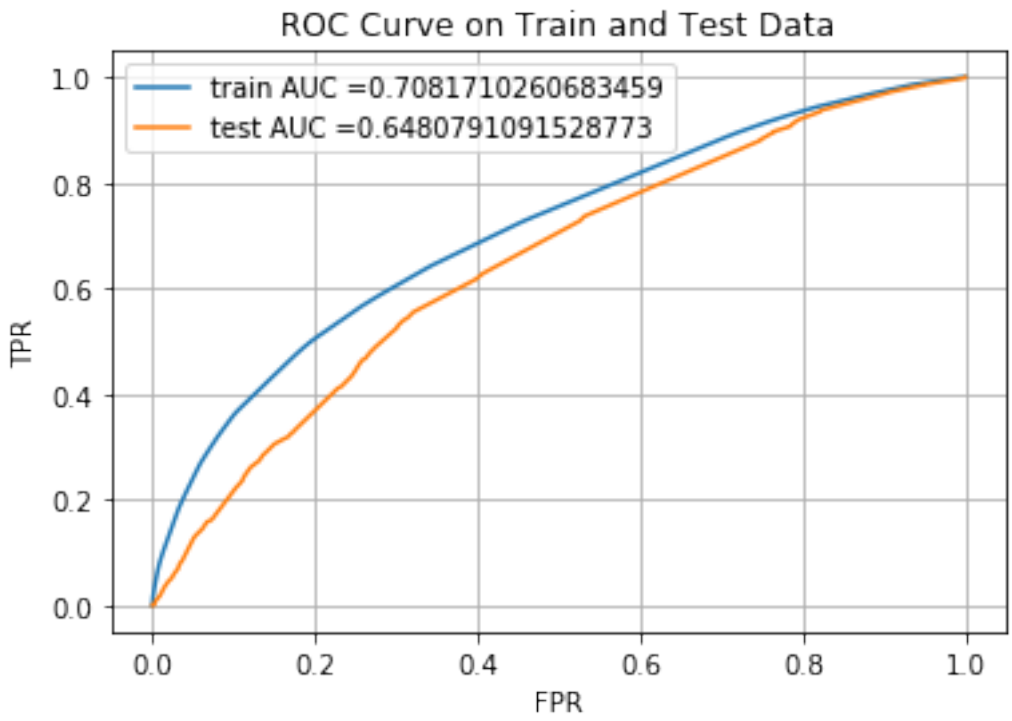
3.2 Representation of Results

[50]:
```
# https://plot.ly/python/3d-axes/
trace1 = go.Scatter3d(x=min_samples_split,y=max_depth,z=train_auc, name =␣
↪'train')
trace2 = go.Scatter3d(x=min_samples_split,y=max_depth,z=cv_auc, name = 'Cross␣
↪validation')
```

```
data = [trace1, trace2]

layout = go.Layout(scene = dict(
        xaxis = dict(title='min_samples_split'),
        yaxis = dict(title='max_depth'),
        zaxis = dict(title='AUC'),))

fig = go.Figure(data=data, layout=layout)
offline.iplot(fig, filename='3d-scatter-colorscale')
```

3.3 Testing Performance of the Model with Best Hyper Parameters

[51]:
```
from sklearn.metrics import roc_curve, auc

classfier=DecisionTreeClassifier(max_depth=best_maxdepth,min_samples_split=best_minsamplesspli
classfier.fit(X_train_fimp,y_train)

y_train_pred=classfier.predict_proba(X_train_fimp)[:,1]
y_test_pred=classfier.predict_proba(X_test_fimp)[:,1]

train_fpr, train_tpr, train_thresolds = roc_curve(y_train,y_train_pred)
test_fpr, test_tpr, test_thresolds = roc_curve(y_test,y_test_pred)

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr,␣
 ↪train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))␣
 ↪#plotting ROC Curves for train and test datasets
plt.legend()
plt.xlabel("FPR")
plt.ylabel("TPR")
plt.title("ROC Curve on Train and Test Data")
plt.grid()
plt.show()
```



[52]:
```
print("AUC score on Train data is ")
print(auc(train_fpr, train_tpr))
print("AUC score on Test data is ")
print(auc(test_fpr, test_tpr))
```

```
AUC score on Train data is
0.7081710260683459
AUC score on Test data is
0.6480791091528773
```

[53]:
```
# we are writing our own function for predict, with defined thresould
# we will pick a threshold that will give the least fpr
def find_best_thresold(thresold, fpr, tpr):
    t = thresold[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr) is ", max(tpr*(1-fpr)), "for␣
 ↪thresold", np.round(t,3))
    return t

def predict_with_best_t(proba,thresold):
    predictions = []
    for i in proba:
        if i>=thresold:
```

```
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

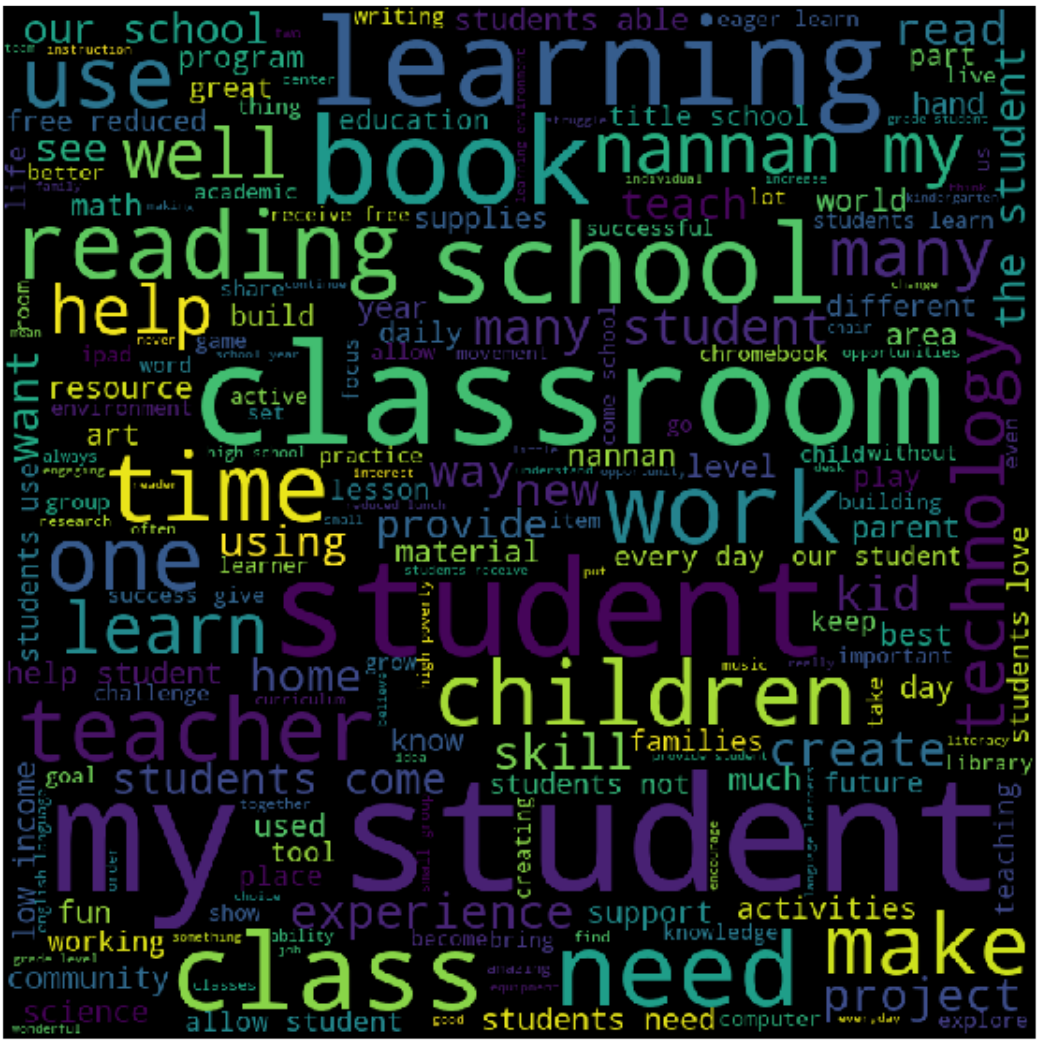
[54]:
```
from sklearn.metrics import confusion_matrix
best_t = find_best_thresold(train_thresolds, train_fpr, train_tpr)
print("Train confusion matrix")
print(confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t)))
print("Test confusion matrix")
print(confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))
```

```
the maximum value of tpr*(1-fpr) is  0.4234925664701732 for thresold 0.476
Train confusion matrix
[[ 8286  3293]
 [26490 38404]]
Test confusion matrix
[[ 3371  1592]
 [12373 15439]]
```

3.4 Word Cloud

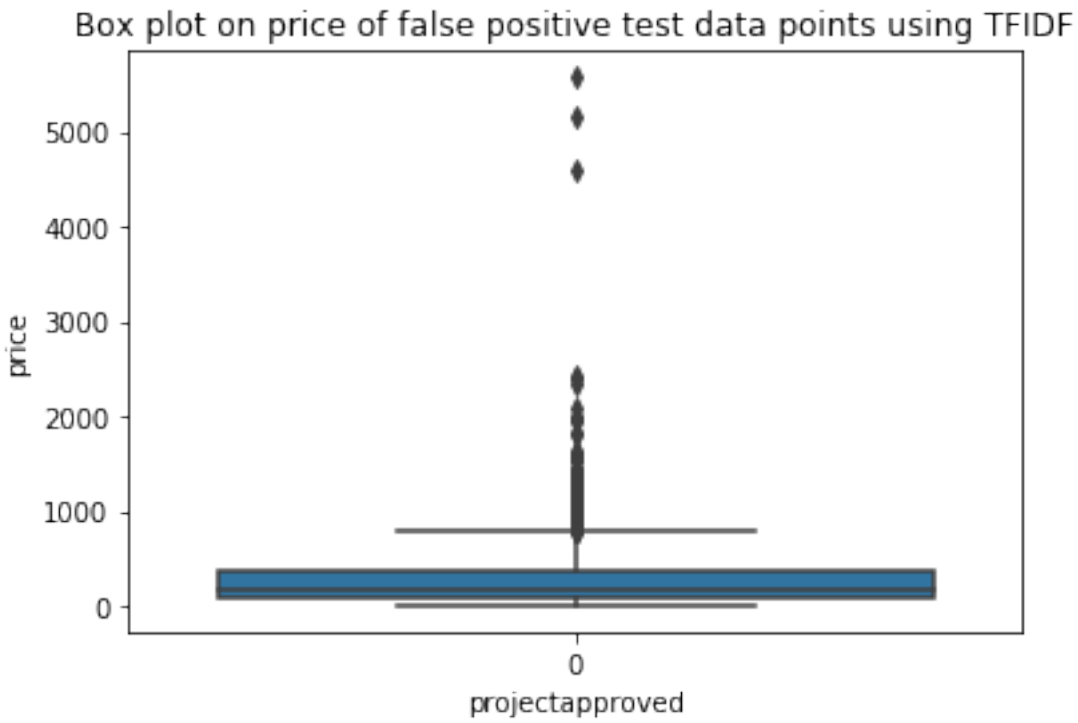
[55]:
```
X_testessay=X_test['essay'].values
predictions=predict_with_best_t(y_test_pred,best_t)
y_actual=y_test.values
essay_words=' '
index=[]
for i in range(len(y_test)):
    if predictions[i]==1 and y_actual[i]==0: #false positive
        index.append(i)
        tokens=X_testessay[i].split() ## split the each false positive essayword
        essay_words+=" ".join(tokens)+" "
```

[56]:
```
from wordcloud import WordCloud, STOPWORDS
stopwords = set(STOPWORDS)

wordcloud=WordCloud(width = 800, height = 800,stopwords=stopwords,min_font_size␣
 ↪= 10).generate(essay_words)

# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```



3.5 Box Plot

[57]:
```
price=X_test['price'].values
fp_prices=np.take(price,index)
sns.boxplot(data=fp_prices)
plt.xlabel("projectapproved")
plt.ylabel("price")
plt.title("Box plot on price of false positive test data points using TFIDF")
plt.show()
```



3.6 PDF

[58]:
```
prevprojects=X_test['teacher_number_of_previously_posted_projects'].values
fp_prevprojects=np.take(prevprojects,index)

counts,bin_edges = np.histogram(fp_prevprojects,bins=10,density=True)
pdf=counts/(sum(counts))
plt.plot(bin_edges[1:],pdf,label="pdf on false postive test datapoints")

plt.title("PDF on teacher previously posted projects of false positive test␣
 ↪data points using TFIDF")
plt.xlabel("teacher no of previously posted projects")

plt.legend()
plt.show()
```

Summary

[59]:
```
from prettytable import PrettyTable
t = PrettyTable(['Vectorizer', 'Model','Hyper Parameter','AUC'])
t.add_row(['TFIDF', 'Decision Tree Classfier','max_depth:10,min_samples_split:
 ↪500',0.6480])
t.add_row(['TFIDF W2V','Decision Tree Classfier','max_depth:5,min_samples_split:
 ↪5',0.6238])
t.add_row(['TFIDF top_features','Decision Tree Classfier','max_depth:
 ↪10,min_samples_split:500',0.6480])
print(t)
```

```
+--------------------+------------------------+--------------------------------
----+--------+
|     Vectorizer     |          Model         |          Hyper Parameter
|  AUC   |
+--------------------+------------------------+--------------------------------
----+--------+
|       TFIDF        | Decision Tree Classfier |
max_depth:10,min_samples_split:500 | 0.648  |
|     TFIDF W2V      | Decision Tree Classfier |
max_depth:5,min_samples_split:5   | 0.6238 |
| TFIDF top_features | Decision Tree Classfier |
max_depth:10,min_samples_split:500 | 0.648  |
+--------------------+------------------------+--------------------------------
----+--------+
```

[ ]: