Naive Bayes

February 27, 2021

Naive Bayes

0.0.1 Importing necessary packages

[1]:
```
import numpy as np
import pandas as pd
import re
from nltk.corpus import stopwords
import pickle
from tqdm import tqdm
import os
import nltk
from tqdm import tqdm

from sklearn.model_selection import train_test_split
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.metrics import confusion_matrix
from sklearn import metrics
from sklearn.metrics import roc_curve, auc
from collections import Counter
from sklearn.preprocessing import Normalizer
from scipy.sparse import hstack
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import roc_auc_score
from sklearn.model_selection import GridSearchCV
import math

%matplotlib inline
import matplotlib.pyplot as plt
import seaborn as sns
import warnings
warnings.filterwarnings("ignore")
from chart_studio import plotly
import plotly.offline as offline
import plotly.graph_objs as go
offline.init_notebook_mode()
from prettytable import PrettyTable
```

0.1 1.1 Loading Data

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

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

[3]:
```
  school_state teacher_prefix project_grade_category  \
0           ca            mrs          grades_prek_2

   teacher_number_of_previously_posted_projects clean_categories  \
0                                            53     math_science

                  clean_subcategories  \
0  appliedsciences health_lifescience

                                                 essay   price
0  i fortunate enough use fairy tale stem kits cl…  725.05
```

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

[4]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.33,␣
↪stratify=y)
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train, test_size=0.
↪33, stratify=y_train)
```

1.3 Encoding Data

0.2 Encoding essays using Bag of Words

[5]:
```
print(X_train.shape, y_train.shape)
print(X_cv.shape, y_cv.shape)
print(X_test.shape, y_test.shape)

print("="*100)

vectorizer_bow = CountVectorizer(min_df=10,ngram_range=(1,4), max_features=5000)
vectorizer_bow.fit(X_train['essay'].values)

X_train_essay_bow = vectorizer_bow.transform(X_train['essay'].values)
X_cv_essay_bow = vectorizer_bow.transform(X_cv['essay'].values)
X_test_essay_bow = vectorizer_bow.transform(X_test['essay'].values)

print("After vectorizations")
print(X_train_essay_bow.shape, y_train.shape)
print(X_cv_essay_bow.shape, y_cv.shape)
print(X_test_essay_bow.shape, y_test.shape)
```

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

```
(49041, 8) (49041,)
(24155, 8) (24155,)
(36052, 8) (36052,)
==========================================================================================
====================
After vectorizations
(49041, 5000) (49041,)
(24155, 5000) (24155,)
(36052, 5000) (36052,)
==========================================================================================
====================
```

0.3 Encoding essays using TFIDF

[6]:
```
print(X_train.shape, y_train.shape)
print(X_cv.shape, y_cv.shape)
print(X_test.shape, y_test.shape)

print("="*100)

vectorizer_tfidf = TfidfVectorizer(min_df=10,ngram_range=(1,4),␣
 ↪max_features=5000)
vectorizer_tfidf.fit(X_train['essay'].values)

X_train_essay_tfidf = vectorizer_tfidf.transform(X_train['essay'].values)
X_cv_essay_tfidf = vectorizer_tfidf.transform(X_cv['essay'].values)
X_test_essay_tfidf = vectorizer_tfidf.transform(X_test['essay'].values)

print("After vectorizations")
print(X_train_essay_tfidf.shape, y_train.shape)
print(X_cv_essay_tfidf.shape, y_cv.shape)
print(X_test_essay_tfidf.shape, y_test.shape)
print("="*100)
```

```
(49041, 8) (49041,)
(24155, 8) (24155,)
(36052, 8) (36052,)
==========================================================================================
====================
After vectorizations
(49041, 5000) (49041,)
(24155, 5000) (24155,)
(36052, 5000) (36052,)
==========================================================================================
====================
```

0.4 Encoding the State of the Project

[7]:
```
vectorizer_state = CountVectorizer()
vectorizer_state.fit(X_train['school_state'].values) # fit has to happen only␣
 ↪on train data

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

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

```
After vectorizations
(49041, 51) (49041,)
(24155, 51) (24155,)
(36052, 51) (36052,)
['ak', 'al', 'ar', 'az', 'ca', 'co', 'ct', 'dc', 'de', 'fl', 'ga', 'hi', 'ia',
'id', 'il', 'in', 'ks', 'ky', 'la', 'ma', 'md', 'me', 'mi', 'mn', 'mo', 'ms',
'mt', 'nc', 'nd', 'ne', 'nh', 'nj', 'nm', 'nv', 'ny', 'oh', 'ok', 'or', 'pa',
'ri', 'sc', 'sd', 'tn', 'tx', 'ut', 'va', 'vt', 'wa', 'wi', 'wv', 'wy']
====================================================================================
====================
```

0.5 Encoding the Grade of the Project

[8]:
```
vectorizer_grade = CountVectorizer()
vectorizer_grade.fit(X_train['project_grade_category'].values) # fit has to␣
 ↪happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
X_train_project_category_ohe = vectorizer_grade.
 ↪transform(X_train['project_grade_category'].values)
X_cv_project_category_ohe = vectorizer_grade.
 ↪transform(X_cv['project_grade_category'].values)
X_test_project_category_ohe = vectorizer_grade.
 ↪transform(X_test['project_grade_category'].values)

print("After vectorizations")
print(X_train_project_category_ohe.shape, y_train.shape)
```

```
print(X_cv_project_category_ohe.shape, y_cv.shape)
print(X_test_project_category_ohe.shape, y_test.shape)
print(vectorizer_grade.get_feature_names())
print("="*100)
```

```
After vectorizations
(49041, 4) (49041,)
(24155, 4) (24155,)
(36052, 4) (36052,)
['grades_3_5', 'grades_6_8', 'grades_9_12', 'grades_prek_2']
====================================================================================
====================
```

0.6 Encoding the Prefix/Surname of the Teacher

[9]:
```
vectorizer_teacher_prefix = CountVectorizer()
vectorizer_teacher_prefix.fit(X_train['teacher_prefix'].values) # fit has to␣
↪happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
X_train_teacher_prefix_ohe = vectorizer_teacher_prefix.
↪transform(X_train['teacher_prefix'].values)
X_cv_teacher_prefix_ohe = vectorizer_teacher_prefix.
↪transform(X_cv['teacher_prefix'].values)
X_test_teacher_prefix_ohe = vectorizer_teacher_prefix.
↪transform(X_test['teacher_prefix'].values)

print("After vectorizations")
print(X_train_teacher_prefix_ohe.shape, y_train.shape)
print(X_cv_teacher_prefix_ohe.shape, y_cv.shape)
print(X_test_teacher_prefix_ohe.shape, y_test.shape)
print(vectorizer_teacher_prefix.get_feature_names())
print("="*100)
```

```
After vectorizations
(49041, 5) (49041,)
(24155, 5) (24155,)
(36052, 5) (36052,)
['dr', 'mr', 'mrs', 'ms', 'teacher']
====================================================================================
====================
```

0.7 Encoding the Categories of the Project

[10]:
```
vectorizer_cat = CountVectorizer()
vectorizer_cat.fit(X_train['clean_categories'].values) # fit has to happen only␣
↪on train data
```

```
# we use the fitted CountVectorizer to convert the text to vector
X_train_clean_categories_ohe = vectorizer_cat.
 ↪transform(X_train['clean_categories'].values)
X_cv_clean_categories_ohe = vectorizer_cat.transform(X_cv['clean_categories'].
 ↪values)
X_test_clean_categories_ohe = vectorizer_cat.
 ↪transform(X_test['clean_categories'].values)

print("After vectorizations")
print(X_train_clean_categories_ohe.shape, y_train.shape)
print(X_cv_clean_categories_ohe.shape, y_cv.shape)
print(X_test_clean_categories_ohe.shape, y_test.shape)
print(vectorizer_cat.get_feature_names())
print("="*100)
```

```
After vectorizations
(49041, 9) (49041,)
(24155, 9) (24155,)
(36052, 9) (36052,)
['appliedlearning', 'care_hunger', 'health_sports', 'history_civics',
'literacy_language', 'math_science', 'music_arts', 'specialneeds', 'warmth']
============================================================================
====================
```

0.8 Encoding the Subcategories of the Project

[11]:
```
vectorizer_subcat = CountVectorizer()
vectorizer_subcat.fit(X_train['clean_subcategories'].values) # fit has to␣
 ↪happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
X_train_clean_subcategories_ohe = vectorizer_subcat.
 ↪transform(X_train['clean_subcategories'].values)
X_cv_clean_subcategories_ohe = vectorizer_subcat.
 ↪transform(X_cv['clean_subcategories'].values)
X_test_clean_subcategories_ohe = vectorizer_subcat.
 ↪transform(X_test['clean_subcategories'].values)

print("After vectorizations")
print(X_train_clean_subcategories_ohe.shape, y_train.shape)
print(X_cv_clean_subcategories_ohe.shape, y_cv.shape)
print(X_test_clean_subcategories_ohe.shape, y_test.shape)
print(vectorizer_subcat.get_feature_names())
print("="*100)
```

```
After vectorizations
(49041, 30) (49041,)
```

```
(24155, 30) (24155,)
(36052, 30) (36052,)
['appliedsciences', 'care_hunger', 'charactereducation', 'civics_government',
'college_careerprep', 'communityservice', 'earlydevelopment', 'economics',
'environmentalscience', 'esl', 'extracurricular', 'financialliteracy',
'foreignlanguages', 'gym_fitness', 'health_lifescience', 'health_wellness',
'history_geography', 'literacy', 'literature_writing', 'mathematics', 'music',
'nutritioneducation', 'other', 'parentinvolvement', 'performingarts',
'socialsciences', 'specialneeds', 'teamsports', 'visualarts', 'warmth']
==========================================================================
====================
```

0.9 Encoding the Price required for the project

[12]:
```
normalizer = Normalizer()
normalizer.fit(X_train['price'].values.reshape(1,-1))

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


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

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

0.10 Encoding the Number of Previous Projects trained by the Teacher

[13]:
```
normalizer = Normalizer()
normalizer.fit(X_train['teacher_number_of_previously_posted_projects'].values.
 ↪reshape(1,-1))

X_train_prev_projects_norm = normalizer.
 ↪transform(X_train['teacher_number_of_previously_posted_projects'].values.
 ↪reshape(-1,1))
X_cv_prev_projects_norm = normalizer.
 ↪transform(X_cv['teacher_number_of_previously_posted_projects'].values.
 ↪reshape(-1,1))
```

```
X_test_prev_projects_norm = normalizer.
 ↪transform(X_test['teacher_number_of_previously_posted_projects'].values.
 ↪reshape(-1,1))


print("After vectorizations")
print(X_train_prev_projects_norm.shape, y_train.shape)
print(X_cv_prev_projects_norm.shape, y_cv.shape)
print(X_test_prev_projects_norm.shape, y_test.shape)
print("="*100)
```

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

0.11 Stacking all features into two different datasets.

0.12 1. Bag of Words

0.13 2. TFIDF

[14]:
```
X_tr_bow = hstack((X_train_state_ohe, X_train_project_category_ohe,␣
 ↪X_train_teacher_prefix_ohe, X_train_clean_categories_ohe,␣
 ↪X_train_clean_subcategories_ohe, X_train_price_norm,␣
 ↪X_train_prev_projects_norm, X_train_essay_bow)).tocsr()
X_cr_bow = hstack((X_cv_state_ohe, X_cv_project_category_ohe,␣
 ↪X_cv_teacher_prefix_ohe, X_cv_clean_categories_ohe,␣
 ↪X_cv_clean_subcategories_ohe, X_cv_price_norm, X_cv_prev_projects_norm,␣
 ↪X_cv_essay_bow)).tocsr()
X_te_bow = hstack((X_test_state_ohe, X_test_project_category_ohe,␣
 ↪X_test_teacher_prefix_ohe, X_test_clean_categories_ohe,␣
 ↪X_test_clean_subcategories_ohe, X_test_price_norm,␣
 ↪X_test_prev_projects_norm, X_test_essay_bow)).tocsr()

X_tr_tfidf = hstack((X_train_state_ohe, X_train_project_category_ohe,␣
 ↪X_train_teacher_prefix_ohe, X_train_clean_categories_ohe,␣
 ↪X_train_clean_subcategories_ohe, X_train_price_norm,␣
 ↪X_train_prev_projects_norm, X_train_essay_tfidf)).tocsr()
X_cr_tfidf = hstack((X_cv_state_ohe, X_cv_project_category_ohe,␣
 ↪X_cv_teacher_prefix_ohe, X_cv_clean_categories_ohe,␣
 ↪X_cv_clean_subcategories_ohe, X_cv_price_norm, X_cv_prev_projects_norm,␣
 ↪X_cv_essay_tfidf)).tocsr()
```

```
X_te_tfidf = hstack((X_test_state_ohe, X_test_project_category_ohe,␣
↪X_test_teacher_prefix_ohe, X_test_clean_categories_ohe,␣
↪X_test_clean_subcategories_ohe, X_test_price_norm,␣
↪X_test_prev_projects_norm, X_test_essay_tfidf)).tocsr()

print("Final Data matrix: BoW")
print(X_tr_bow.shape, y_train.shape)
print(X_cr_bow.shape, y_cv.shape)
print(X_te_bow.shape, y_test.shape)

print("="*100)

print("Final Data matrix: TFIDF")
print(X_tr_tfidf.shape, y_train.shape)
print(X_cr_tfidf.shape, y_cv.shape)
print(X_te_tfidf.shape, y_test.shape)
```

```
Final Data matrix: BoW
(49041, 5101) (49041,)
(24155, 5101) (24155,)
(36052, 5101) (36052,)
====================================================================================
====================
Final Data matrix: TFIDF
(49041, 5101) (49041,)
(24155, 5101) (24155,)
(36052, 5101) (36052,)
```

1.5 Appling NB on both these datasets

0.14 Bag of Words

[15]:
```
def batch_predict(clf, data):
    # roc_auc_score(y_true, y_score) the 2nd parameter should be probability␣
↪estimates of the positive class
    # not the predicted outputs

    y_data_pred = []
    tr_loop = data.shape[0] - data.shape[0]%1000
    # consider you X_tr shape is 49041, then your tr_loop will be 49041 -␣
↪49041%1000 = 49000
    # in this for loop we will iterate unti the last 1000 multiplier
    for i in range(0, tr_loop, 1000):
        y_data_pred.extend(clf.predict_proba(data[i:i+1000])[:,1])
    # we will be predicting for the last data points
    if data.shape[0]%1000 !=0:
        y_data_pred.extend(clf.predict_proba(data[tr_loop:])[:,1])
```

```
    return y_data_pred
```

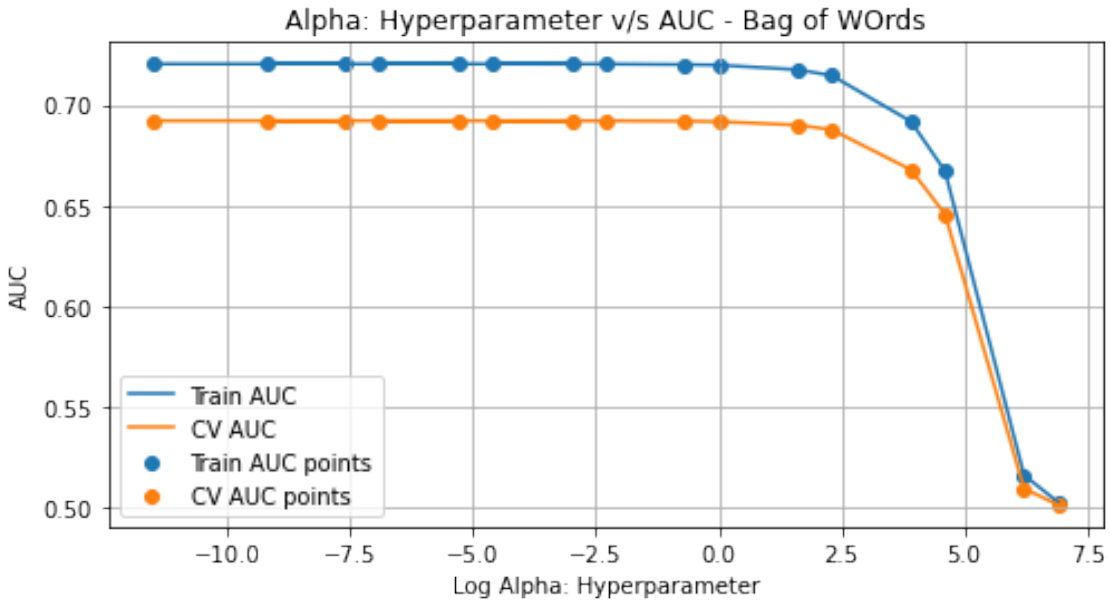
0.14.1 Using various alpha values to calculate the AUC Scores to find the best Alpha value

[16]:
```
train_aucs_bow = []
cv_aucs_bow = []
log_alphas_bow = []
alphas = [0.00001,0.0005, 0.0001,0.005,0.001,0.05,0.01,0.1,0.
 ↪5,1,5,10,50,100,500,1000]

for alpha in tqdm(alphas):
    nb = MultinomialNB(alpha = alpha,class_prior=[0.5,0.5])
    nb.fit(X_tr_bow, y_train)
    y_train_pred_bow = batch_predict(nb, X_tr_bow)
    y_cv_pred_bow = batch_predict(nb, X_cr_bow)

    train_aucs_bow.append(roc_auc_score(y_train,y_train_pred_bow))
    cv_aucs_bow.append(roc_auc_score(y_cv, y_cv_pred_bow))

for a in tqdm(alphas):
    b = math.log(a)
    log_alphas_bow.append(b)
```

```
100%|      | 16/16 [00:02<00:00,  6.59it/s]
100%|      | 16/16 [00:00<00:00, 387912.51it/s]
```

0.14.2 Plotting the log of Alphas vs AUC Scores with that Alpha

[17]:
```
plt.figure(figsize=(8,4))
plt.plot(log_alphas_bow, train_aucs_bow, label='Train AUC')
plt.plot(log_alphas_bow, cv_aucs_bow, label='CV AUC')

plt.scatter(log_alphas_bow, train_aucs_bow, label='Train AUC points')
plt.scatter(log_alphas_bow, cv_aucs_bow, label='CV AUC points')

plt.legend()
plt.xlabel("Log Alpha: Hyperparameter")
plt.ylabel("AUC")
plt.title("Alpha: Hyperparameter v/s AUC - Bag of WOrds")
plt.grid()
plt.show()
```



0.14.3 The curves fall steeply and join after Alpha = 50 (Fourth dot from the right = 50)

0.14.4 Using GridSearchCV to get the best parameter possible

[18]:
```
nb_bow = MultinomialNB(class_prior=[0.5,0.5])

parameters = {'alpha':[0.00001,0.0005, 0.0001,0.005,0.001,0.05,0.01,0.1,0.
↪5,1,5,10,50,100,500,1000]}

clf_bow = GridSearchCV(nb_bow, parameters, cv= 10,␣
↪scoring='roc_auc',return_train_score=True,verbose=2)

clf_bow.fit(X_tr_bow, y_train)

train_auc_bow = clf_bow.cv_results_['mean_train_score']
train_auc_std_bow = clf_bow.cv_results_['std_train_score']
cv_auc_bow = clf_bow.cv_results_['mean_test_score']
cv_auc_std_bow = clf_bow.cv_results_['std_test_score']
```

```
Fitting 10 folds for each of 16 candidates, totalling 160 fits
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.1s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …

[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
```

```
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    0.1s remaining:    0.0s

[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.1s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
```

```
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.1s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
```

```
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.1s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.1s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
```

```
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.1s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
```

```
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.1s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.1s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
```

```
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
```

```
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.1s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s

[Parallel(n_jobs=1)]: Done 160 out of 160 | elapsed:   13.3s finished
```

0.14.5 GridSearchCV gives the best parameter as 0.0001

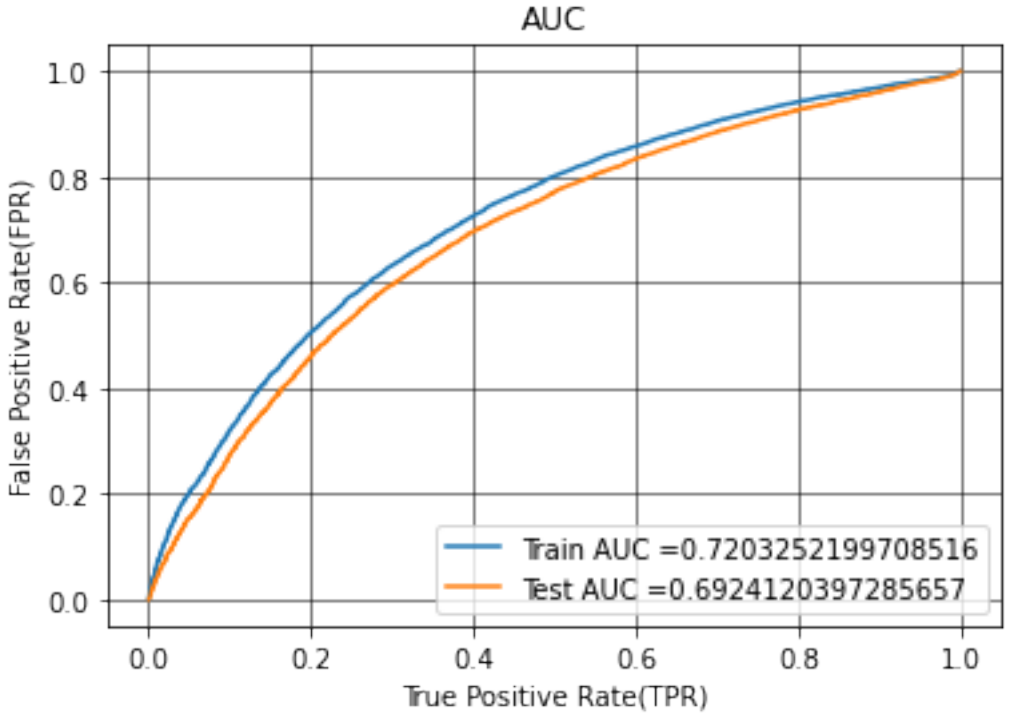
[19]:
```
clf_bow.best_params_
```

[19]:
```
{'alpha': 0.0001}
```

0.14.6 Plotting the AUC Graph with the obtained best hyperparameter

[43]:
```
nb_bow = MultinomialNB(alpha = 0.0001,class_prior=[0.5,0.5])

nb_bow.fit(X_tr_bow, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability␣
 ↪estimates of the positive class
# not the predicted outputs

y_train_pred_bow = batch_predict(nb_bow, X_tr_bow)
```

```
y_test_pred_bow = batch_predict(nb_bow, X_te_bow)

train_fpr_bow, train_tpr_bow, tr_thresholds_bow = roc_curve(y_train,␣
 ↪y_train_pred_bow)
test_fpr_bow, test_tpr_bow, te_thresholds_bow = roc_curve(y_test,␣
 ↪y_test_pred_bow)

plt.plot(train_fpr_bow, train_tpr_bow, label="Train AUC␣
 ↪="+str(auc(train_fpr_bow, train_tpr_bow)))
plt.plot(test_fpr_bow, test_tpr_bow, label="Test AUC ="+str(auc(test_fpr_bow,␣
 ↪test_tpr_bow)))
plt.legend()
plt.xlabel("True Positive Rate(TPR)")
plt.ylabel("False Positive Rate(FPR)")
plt.title("AUC")
plt.grid(color='black', linestyle='-', linewidth=0.5)
plt.show()
```



[44]:
```
def find_best_threshold(threshould, fpr, tpr):
    t = threshould[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for␣
 ↪threshold", np.round(t,3))
```

```
    return t

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

0.14.7 Calculating the Confusion Matrix on Train Data

[45]:
```
best_threshold = find_best_threshold(tr_thresholds_bow, train_fpr_bow,␣
↪train_tpr_bow)

conf_mat_train_bow = confusion_matrix(y_train,␣
↪predict_with_best_t(y_train_pred_bow, best_threshold))
print("Train confusion matrix")
print(conf_mat_train_bow)
```

```
the maximum value of tpr*(1-fpr) 0.44416003288192635 for threshold 0.538
Train confusion matrix
[[ 5017  2409]
 [14256 27359]]
```

0.14.8 Displaying the Confusion Matrix

[53]:
```
df_cm = pd.DataFrame(conf_mat_train_bow, index = ["Pred: 0", "Pred: 1"],␣
↪columns = ["Actual: 0", "Actual: 1"])
plt.figure(figsize = (10,7))
sns.heatmap(df_cm, annot=True, fmt='g')
```

[53]:
```
<AxesSubplot:>
```

True Positives : 27539

True Negatives : 5017

False Positives : 14256

False Negatives : 2409

0.14.9 Calculating the Confusion Matrix on Test Data

[47]:
```
conf_mat_test_bow = confusion_matrix(y_test,␣
↪predict_with_best_t(y_test_pred_bow, best_threshold))
print("Test confusion matrix")
print(conf_mat_test_bow)
```

```
Test confusion matrix
[[ 3531  1928]
 [10671 19922]]
```

0.14.10 Displaying the Confusion Matrix

[54]:
```
df_cm = pd.DataFrame(conf_mat_test_bow, index = ["Pred: 0", "Pred: 1"], columns␣
↪= ["Actual: 0", "Actual: 1"])
plt.figure(figsize = (10,7))
sns.heatmap(df_cm, annot=True, fmt='g')
```

[54]: <AxesSubplot:>

True Positives : 19922

True Negatives : 3531

False Positives : 10671

False Negatives : 1928

0.15 TFIDF

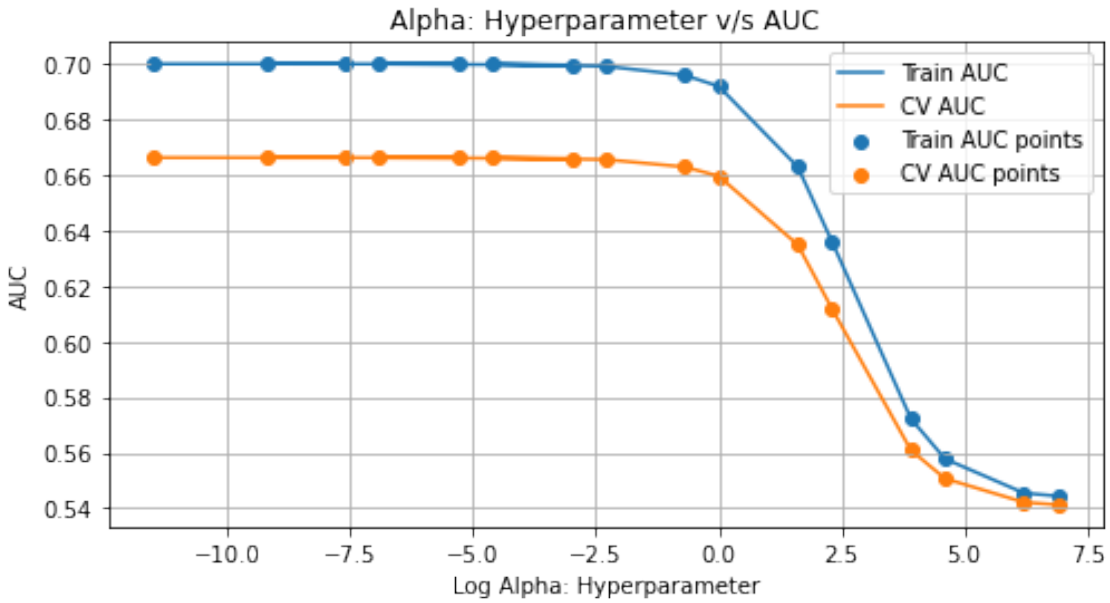
0.15.1 Using various alpha values to calculate the AUC Scores to find the best Alpha value

[26]:
```
train_aucs_tfidf = []
cv_aucs_tfidf = []
log_alphas_tfidf = []
alphas = [0.00001,0.0005, 0.0001,0.005,0.001,0.05,0.01,0.1,0.
 ↪5,1,5,10,50,100,500,1000]

for alpha in tqdm(alphas):
    nb_tfidf = MultinomialNB(alpha = alpha,class_prior=[0.5,0.5])
    nb_tfidf.fit(X_tr_tfidf, y_train)
    y_train_pred_tfidf = batch_predict(nb_tfidf, X_tr_tfidf)
    y_cv_pred_tfidf = batch_predict(nb_tfidf, X_cr_tfidf)

    train_aucs_tfidf.append(roc_auc_score(y_train,y_train_pred_tfidf))
    cv_aucs_tfidf.append(roc_auc_score(y_cv, y_cv_pred_tfidf))

for a in tqdm(alphas):
    b = math.log(a)
    log_alphas_tfidf.append(b)
```

```
100%|      | 16/16 [00:03<00:00,  4.53it/s]
100%|      | 16/16 [00:00<00:00, 167772.16it/s]
```

0.15.2 Plotting the log of Alphas vs AUC Scores with that Alpha

[27]:
```
plt.figure(figsize=(8,4))
plt.plot(log_alphas_tfidf, train_aucs_tfidf, label='Train AUC')
plt.plot(log_alphas_tfidf, cv_aucs_tfidf, label='CV AUC')

plt.scatter(log_alphas_tfidf, train_aucs_tfidf, label='Train AUC points')
plt.scatter(log_alphas_tfidf, cv_aucs_tfidf, label='CV AUC points')

plt.legend()
plt.xlabel("Log Alpha: Hyperparameter")
plt.ylabel("AUC")
plt.title("Alpha: Hyperparameter v/s AUC")
plt.grid()
plt.show()
```



0.15.3 The curves fall steeply and join after Alpha = 1 (Seventh dot from the right = 50)

0.15.4 Using GridSearchCV to get the best parameter possible

[28]:
```
nb_tfidf = MultinomialNB(class_prior=[0.5,0.5])

parameters = {'alpha':[0.00001,0.0005, 0.0001,0.005,0.001,0.05,0.01,0.1,0.
↪5,1,5,10,50,100,500,1000]}

clf_tfidf = GridSearchCV(nb_tfidf, parameters, cv= 10,␣
↪scoring='roc_auc',return_train_score=True,verbose=2)

clf_tfidf.fit(X_tr_tfidf, y_train)

train_auc_tfidf = clf_tfidf.cv_results_['mean_train_score']
train_auc_std_tfidf = clf_tfidf.cv_results_['std_train_score']
cv_auc_tfidf = clf_tfidf.cv_results_['mean_test_score']
cv_auc_std_tfidf = clf_tfidf.cv_results_['std_test_score']
```

```
Fitting 10 folds for each of 16 candidates, totalling 160 fits
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.1s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …

[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
```

```
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    0.1s remaining:    0.0s
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=1e-05 …
[CV] … alpha=1e-05, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0005 …
[CV] … alpha=0.0005, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
```

```
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.0001 …
[CV] … alpha=0.0001, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.005 …
[CV] … alpha=0.005, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.001 …
```

```
[CV] … alpha=0.001, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.05 …
[CV] … alpha=0.05, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.0s
[CV] alpha=0.01 …
[CV] … alpha=0.01, total=   0.1s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
```

```
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.1 …
[CV] … alpha=0.1, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=0.5 …
[CV] … alpha=0.5, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
```

```
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=1 …
[CV] … alpha=1, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=5 …
[CV] … alpha=5, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=10 …
[CV] … alpha=10, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
```

```
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=50 …
[CV] … alpha=50, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.1s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=100 …
[CV] … alpha=100, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
```

```
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=500 …
[CV] … alpha=500, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s
[CV] alpha=1000 …
[CV] … alpha=1000, total=   0.0s

[Parallel(n_jobs=1)]: Done 160 out of 160 | elapsed:   13.1s finished
```

[29]:

```
clf_tfidf.best_params_
```

[29]:

```
{'alpha': 1e-05}
```

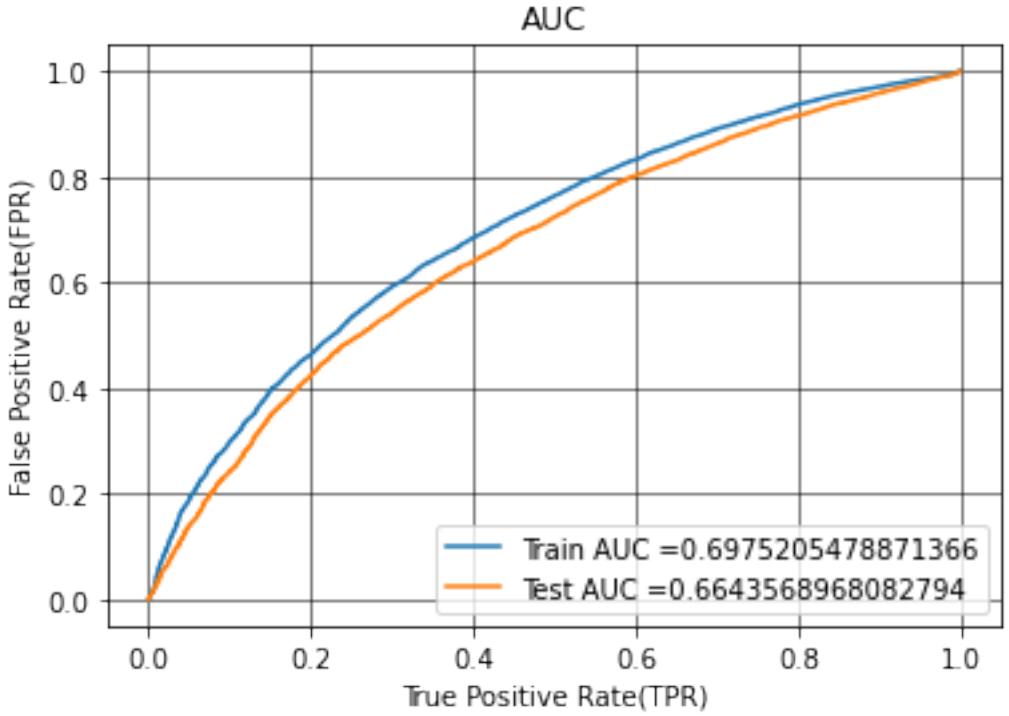
0.15.5 GridSearchCV gives the best parameter as 0.00001

0.15.6 Plotting the AUC Graph with the obtained best hyperparameter

[30]:

```
nb_tfidf = MultinomialNB(alpha = 0.00001,class_prior=[0.5,0.5])

nb_tfidf.fit(X_tr_tfidf, y_train)
# roc_auc_score(y_true, y_score) the 2nd parameter should be probability␣
↪estimates of the positive class
# not the predicted outputs

y_train_pred_tfidf = batch_predict(nb_bow, X_tr_tfidf)
```

```
y_test_pred_tfidf = batch_predict(nb_bow, X_te_tfidf)

train_fpr_tfidf, train_tpr_tfidf, tr_thresholds_tfidf = roc_curve(y_train,␣
 ↪y_train_pred_tfidf)
test_fpr_tfidf, test_tpr_tfidf, te_thresholds_tfidf = roc_curve(y_test,␣
 ↪y_test_pred_tfidf)

plt.plot(train_fpr_tfidf, train_tpr_tfidf, label="Train AUC␣
 ↪="+str(auc(train_fpr_tfidf, train_tpr_tfidf)))
plt.plot(test_fpr_tfidf, test_tpr_tfidf, label="Test AUC␣
 ↪="+str(auc(test_fpr_tfidf, test_tpr_tfidf)))
plt.legend()
plt.xlabel("True Positive Rate(TPR)")
plt.ylabel("False Positive Rate(FPR)")
plt.title("AUC")
plt.grid(color='black', linestyle='-', linewidth=0.5)
plt.show()
```



0.15.7 Calculating the Confusion Matrix on Train Data

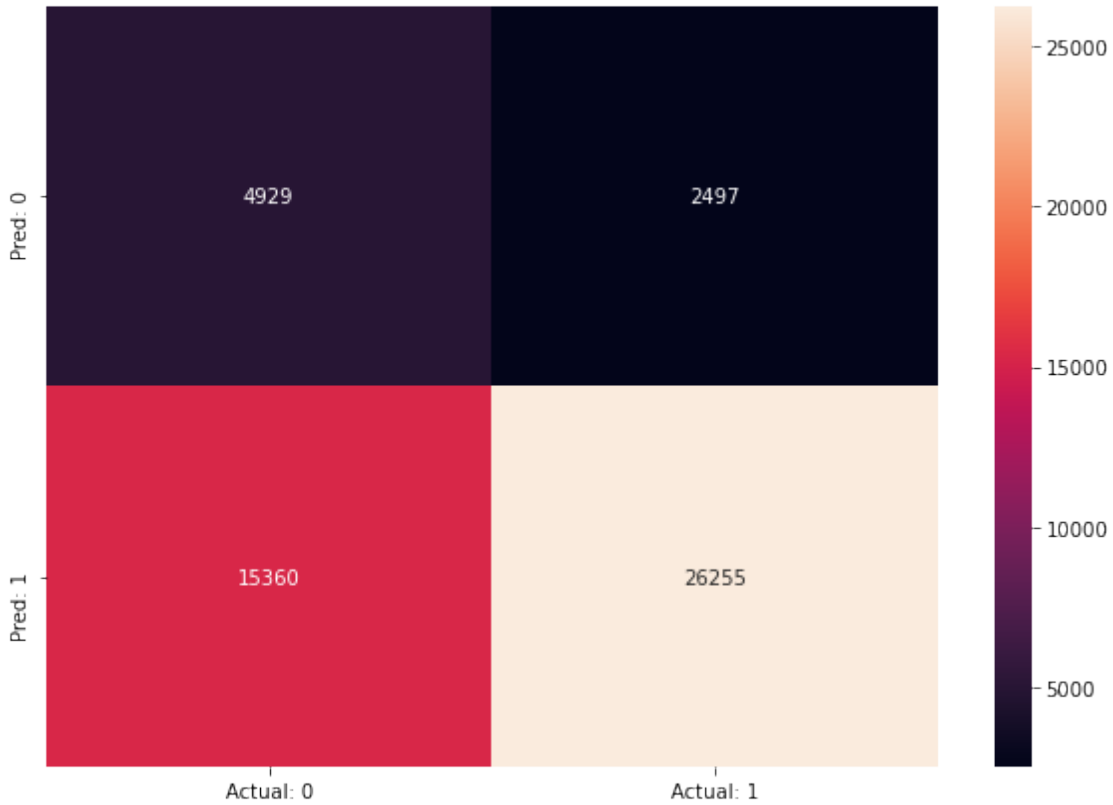
[31]:
```
best_threshold = find_best_threshold(tr_thresholds_tfidf, train_fpr_tfidf,␣
↪train_tpr_tfidf)

conf_mat_train_tfidf = confusion_matrix(y_train,␣
↪predict_with_best_t(y_train_pred_tfidf, best_threshold))
print("Train confusion matrix")
print(conf_mat_train_tfidf)
```

```
the maximum value of tpr*(1-fpr) 0.4187607769642976 for threshold 0.44
Train confusion matrix
[[ 4929  2497]
 [15360 26255]]
```

0.16 Plotting the Confusion Matrix

[55]:
```
df_cm = pd.DataFrame(conf_mat_train_tfidf, index = ["Pred: 0", "Pred: 1"],␣
↪columns = ["Actual: 0", "Actual: 1"])
plt.figure(figsize = (10,7))
sns.heatmap(df_cm, annot=True, fmt='g')
```

[55]: <AxesSubplot:>



True Positives : 26255

True Negatives : 4929

False Positives : 15360

False Negatives : 2497

0.16.1 Calculating the Confusion Matrix on Test Data

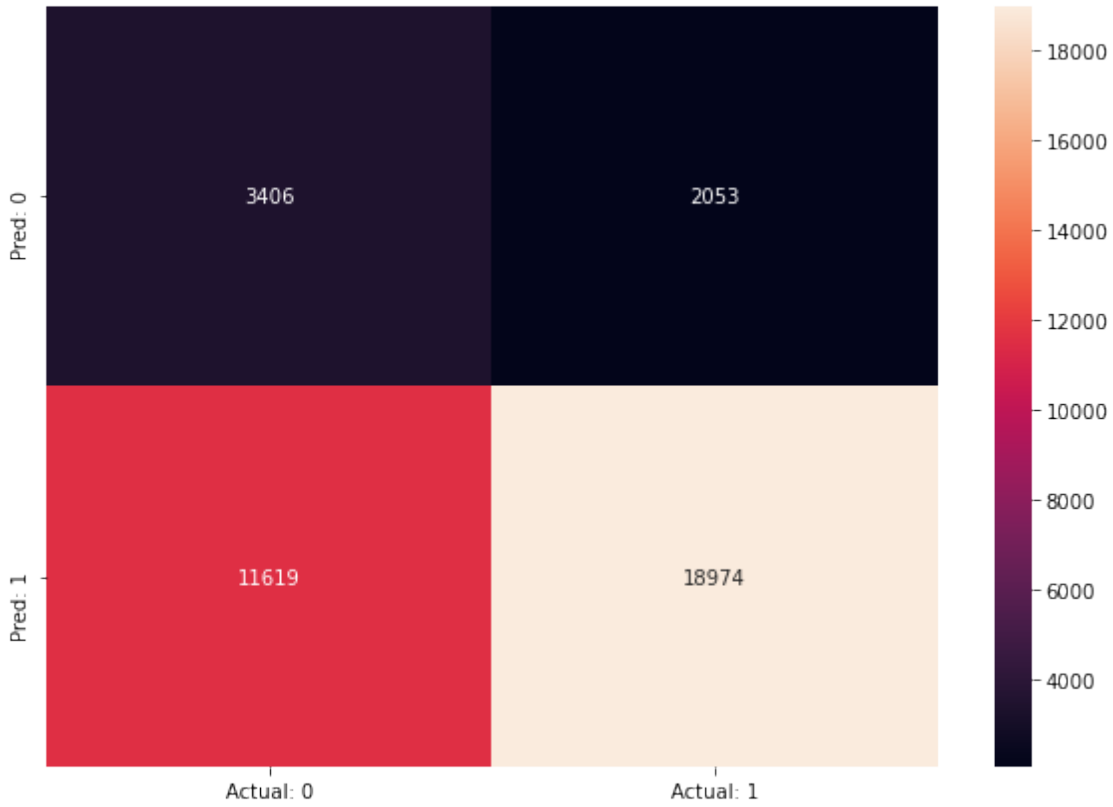
[33]:
```
conf_mat_test_tfidf = confusion_matrix(y_test,␣
↪predict_with_best_t(y_test_pred_tfidf, best_threshold))
print("Test confusion matrix")
print(conf_mat_test_tfidf)
```

```
Test confusion matrix
[[ 3406  2053]
 [11619 18974]]
```

0.17 Plotting the Confusion Matrix

[57]:
```
df_cm = pd.DataFrame(conf_mat_test_tfidf, index = ["Pred: 0", "Pred: 1"],␣
↪columns = ["Actual: 0", "Actual: 1"])
plt.figure(figsize = (10,7))
sns.heatmap(df_cm, annot=True, fmt='g')
```

[57]:
```
<AxesSubplot:>
```



True Positives : 18974

True Negatives : 3406

False Positives : 11619

False Negatives : 2053

3. Summary

0.18 Getting the top positive and negative features

[35]:
```
bow_features = []

for feature in vectorizer_state.get_feature_names():
    bow_features.append(feature)
for feature in vectorizer_grade.get_feature_names():
    bow_features.append(feature)
for feature in vectorizer_teacher_prefix.get_feature_names():
    bow_features.append(feature)
for feature in vectorizer_cat.get_feature_names():
    bow_features.append(feature)
for feature in vectorizer_subcat.get_feature_names():
```

```
    bow_features.append(feature)

bow_features.append("price")
bow_features.append("prev_proj")

for feature in vectorizer_bow.get_feature_names():
    bow_features.append(feature)
```

[36]:
```
len(bow_features)
```

[36]: 5101

[37]:
```
pos_class_prob_sorted = nb_bow.feature_log_prob_[1, :].argsort()[::-1]
for i in pos_class_prob_sorted[:30]:
    print(bow_features[i])
```

```
students
school
my
learning
classroom
the
they
not
my students
learn
help
price
many
nannan
we
need
reading
work
use
prev_proj
love
able
day
come
class
would
technology
our
also
books
```

[38]:
```
neg_class_prob_sorted_tfidf = nb_bow.feature_log_prob_[0, :].argsort()[::-1]
for i in neg_class_prob_sorted_tfidf[:30]:
    print(bow_features[i])
```

```
students
school
learning
my
classroom
not
learn
help
they
my students
the
price
nannan
many
we
need
work
come
prev_proj
love
able
materials
reading
use
skills
day
class
our
want
year
```

[39]:
```
tfidf_features = []

for feature in vectorizer_state.get_feature_names():
    tfidf_features.append(feature)
for feature in vectorizer_grade.get_feature_names():
    tfidf_features.append(feature)
for feature in vectorizer_teacher_prefix.get_feature_names():
    tfidf_features.append(feature)
for feature in vectorizer_cat.get_feature_names():
    tfidf_features.append(feature)
for feature in vectorizer_subcat.get_feature_names():
    tfidf_features.append(feature)
```

```
tfidf_features.append("price")
tfidf_features.append("prev_proj")

for feature in vectorizer_tfidf.get_feature_names():
    tfidf_features.append(feature)
```

[40]:
```
pos_class_prob_sorted = nb_tfidf.feature_log_prob_[0, :].argsort()[::-1]
for i in pos_class_prob_sorted[:30]:
    print(tfidf_features[i])
```

```
price
prev_proj
mrs
literacy_language
grades_prek_2
math_science
ms
grades_3_5
mathematics
literacy
literature_writing
grades_6_8
specialneeds
specialneeds
health_sports
ca
appliedlearning
students
appliedsciences
grades_9_12
mr
music_arts
health_wellness
tx
fl
visualarts
environmentalscience
ny
history_civics
earlydevelopment
```

[41]:
```
pos_class_prob_sorted = nb_tfidf.feature_log_prob_[1, :].argsort()[::-1]
for i in pos_class_prob_sorted[:30]:
    print(tfidf_features[i])
```

```
price
prev_proj
mrs
```

```
literacy_language
grades_prek_2
math_science
ms
grades_3_5
literacy
mathematics
literature_writing
grades_6_8
ca
health_sports
students
specialneeds
specialneeds
appliedlearning
grades_9_12
appliedsciences
mr
health_wellness
music_arts
ny
tx
fl
history_civics
visualarts
environmentalscience
nc
```

0.19 Printing the Summary Table

[49]:
```
x = PrettyTable()
x.field_names = ["Vectorizer", "Model", "Alpha", " Test AUC"]

x.add_row(["BOW", "Naive Bayes", 0.0001, 0.69])
x.add_row(["TFIDF", "Naive Bayes", 1e-05, 0.66])

print(x)
```

```
+------------+-------------+--------+-----------+
| Vectorizer |    Model    | Alpha  |  Test AUC |
+------------+-------------+--------+-----------+
|    BOW     | Naive Bayes | 0.0001 |    0.69   |
|   TFIDF    | Naive Bayes | 1e-05  |    0.66   |
+------------+-------------+--------+-----------+
```

0.20 Conclusions

0.21 1. There are similar words in top positive and negative features of both models

0.22 2. Bag of Words gives a better Test AUC Score thatn TFIDF

1 References Used:

1. http://zetcode.com/python/prettytable/
2. https://scikit-learn.org/stable/modules/generated/sklearn.metrics.roc_curve.html