EE219 Project 1: End-to-End Pipeline to Classify News Articles

January 25, 2022

1 Binary Classification

[ ]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import random

np.random.seed(42)
random.seed(42)

pd.options.mode.chained_assignment = None  # default='warn'
```

[ ]:
```
df = pd.read_csv("Project_1_dataset_01_01_2022.csv")
df.head()
```

[ ]:
```
   Unnamed: 0  ... root_label
0         590  ...     sports
1         388  ...     sports
2         423  ...     sports
3         563  ...     sports
4         634  ...     sports

[5 rows x 9 columns]
```

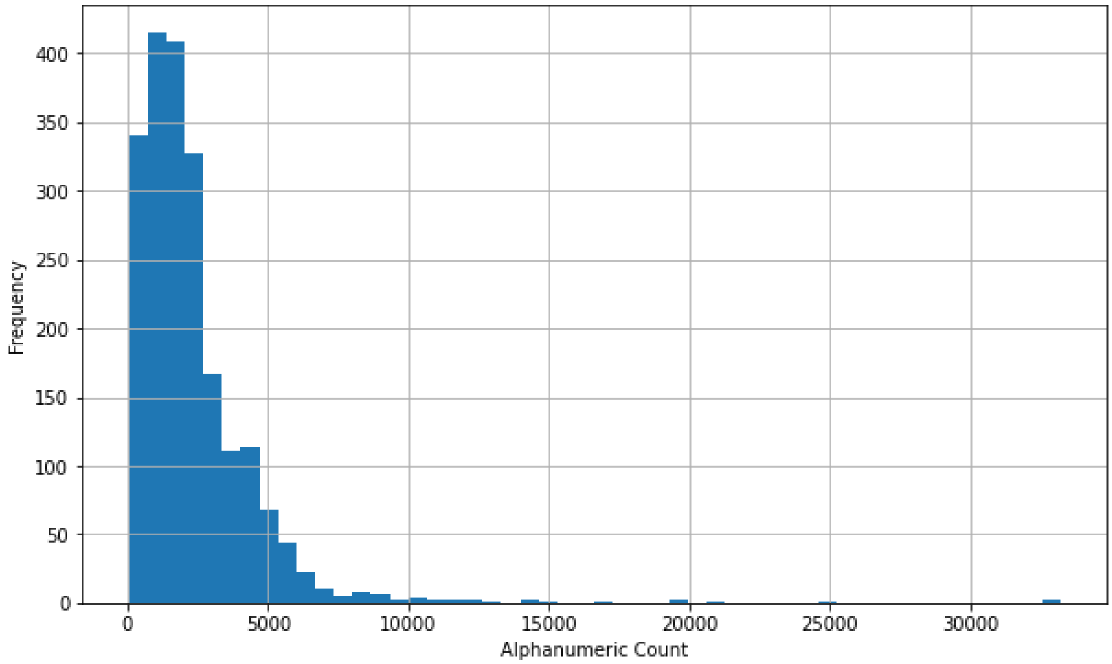
[ ]:
```
df.shape
```

[ ]:
```
(2072, 9)
```

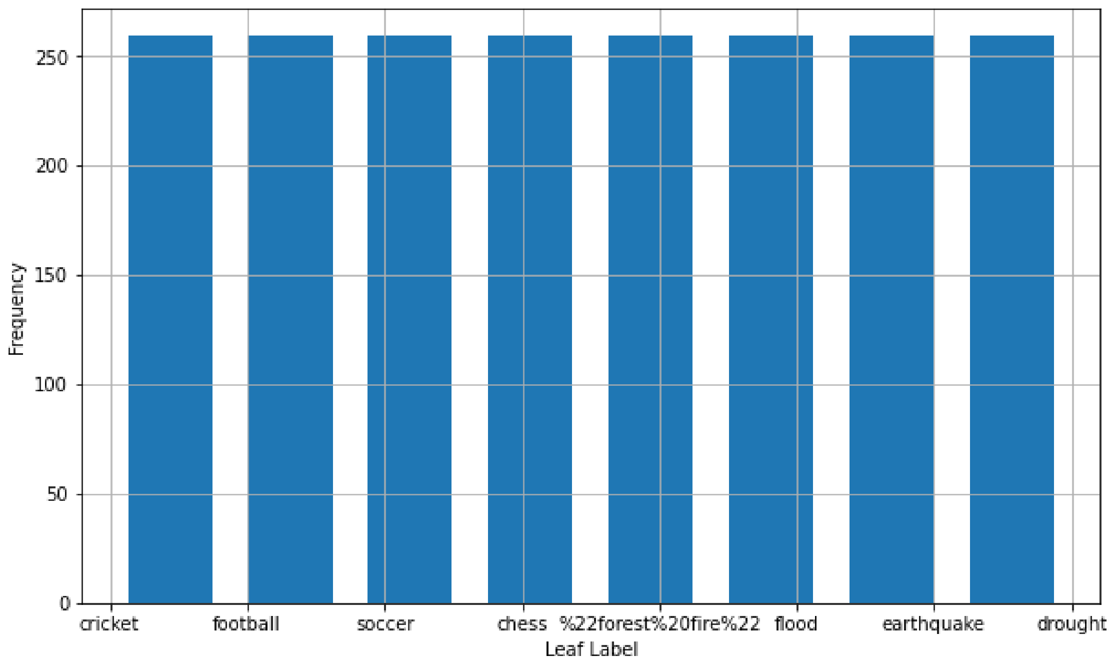
Question 1: The dataset contains 2072 samples (rows) and 9 features (columns).

[ ]:
```
# histogram of alphanumeric characters

df["alnum_count"] = df['full_text'].str.count('[A-Za-z0-9]') # alphanumeric␣
↪count feature to dataset
```

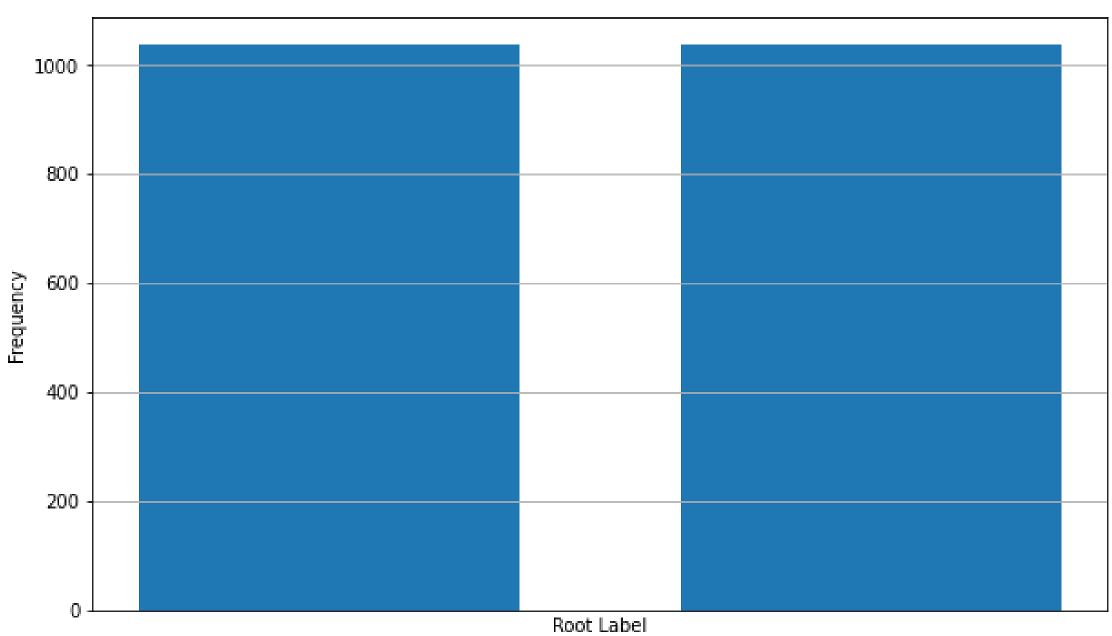
```
ax = df["alnum_count"].hist(bins=50, figsize=(10,6)) # experiment with 50-100␣
↪bins
ax.set_xlabel("Alphanumeric Count")
ax.set_ylabel("Frequency")

plt.show()
```



[ ]:
```
# histogram of leaf labels

ax = df["leaf_label"].hist(bins=8, figsize=(10,6), rwidth=0.7)
ax.set_xlabel("Leaf Label")
ax.set_ylabel("Frequency")
plt.show()
```



[ ]:
```
# histogram of root labels

ax = df["root_label"].hist(bins=2, figsize=(10,6), rwidth=0.7)
ax.set_xlabel("Root Label")
ax.set_ylabel("Frequency")
plt.show()
```



Question 1: The histogram of alphanumeric characters in full_text follows a skewed bell-shaped curve, where the highest frequencies occur at around 2000 alphanumeric characters, and the frequency tapers off for higher alphanumeric counts, with documents containing more than approximately 7000 occuring very rarely. The histograms for leaf_label and root_label show that frequencies of the labels are the same across all classes, so the classes are balanced in this dataset.

1.1 Splitting entire dataset

[ ]:
```
from sklearn.model_selection import train_test_split

df_1 = df[["full_text","root_label"]] # data for part 1
train, test = train_test_split(df_1, test_size=0.2)

print(train.shape)
print(test.shape)
```

```
(1657, 2)
(415, 2)
```

Question 2: There are 1657 training samples and 415 testing samples.

1.2 Feature extraction

[ ]:
```
import re
def clean(text):
    # removes many HTML artefacts from the crawler's output
    # text = re.sub(r'^https?:\/\/.*[\r\n]*', '', text, flags=re.MULTILINE)
    texter = re.sub(r'http\S+', '', text, flags=re.MULTILINE) # remove URLs (e.g.
 ↪ in sample 2)
    texter = re.sub(r'\S+\.com', '', texter, flags=re.MULTILINE) # remove URLs␣
↪ending in .com that were not removed by previous lines (e.g. in sample 11)
    texter = re.sub(r'www\S+', '', texter, flags=re.MULTILINE) # remove URLs␣
↪ending in with www that were not removed by previous lines (e.g. in sample 18)
    texter = re.sub(r"<br />", " ", texter)
    texter = re.sub(r"&quot;", "\"",texter)
    texter = re.sub('&#39;', "\"", texter)
    texter = re.sub('\n', " ", texter)
    texter = re.sub(' u '," you ", texter)
    texter = re.sub('`',"", texter)
    texter = re.sub(r"(!)\1+", r"!", texter)
    texter = re.sub(r"(\?)\1+", r"?", texter)
    texter = re.sub('&amp;', 'and', texter)
    texter = re.sub('\r', ' ', texter)
    texter = re.sub(r'\d+th', '', texter) # remove number terms like "1st",␣
↪"2nd", "3rd", etc.
```

```
    texter = re.sub(r'\d+st', '', texter)
    texter = re.sub(r'\d+nd', '', texter)
    texter = re.sub(r'\d+rd', '', texter)
    texter = re.sub(r'\d+s', '', texter) # remove years like "1970s"
    texter = re.sub(r'(?<=[a-zA-Z])\-(?=[a-zA-Z])', ' ', texter) # replace␣
↪hyphens joining two words
    # texter = re.sub(r'(?<=[a-zA-Z])\'(?=[a-zA-Z])', '', texter) # remove␣
↪apostrophes in words
    # texter = re.sub(r'(?<=[a-zA-Z])\.(?=[a-zA-Z])', '', texter) # remove␣
↪periods within acronyms
    texter = re.sub(r'(?<=[a-zA-Z])/(?=[a-zA-Z])', ' ', texter) # replace␣
↪slashes joining two words
    texter = re.sub(r'\b[^a-z0-9 ]*\d+[^a-z0-9 ]*\b', '', texter) # remove all␣
↪numbers
    texter = re.sub(r'\b[^a-z0-9 ]*\d+\.\d+[^a-z0-9 ]*\b', '', texter)
    texter = re.sub(r'\ba\d+', '', texter)
    texter = re.sub(r'\d+(a|p)m', '', texter)
    texter = re.sub(r'__', ' ', texter) # remove __
    texter = re.sub(' +', ' ', texter)
    clean = re.compile('<.*?>')
    texter = texter.encode('ascii', 'ignore').decode('ascii')
    texter = re.sub(clean, '', texter)
    if texter == "":
        texter = ""
    return texter
```

[ ]:
```
train["clean_text"] = train["full_text"].apply(clean)
train
```

[ ]:
```
                                                full_text  ...
clean_text
1431  More than 1 million Washingtonians participate...  ...  More than million
Washingtonians participated ...
1567  A 4.7-magnitude earthquake rattled northwest S...  ...  A magnitude
earthquake rattled northwest San L...
1044  More campgrounds are coming to the Auburn Stat...  ...  More campgrounds
are coming to the Auburn Stat...
175   Retro gamers will be able to relive all the jo...  ...  Retro gamers will
be able to relive all the jo...
1610  SAN SIMEON, Calif. (KGTV) - An earthquake with...  ...  SAN SIMEON, Calif.
(KGTV)  An earthquake with ...
...                                                 ...  ...
...
1638  The redesigned Ford Ranger made its debut on W...  ...  The redesigned
Ford Ranger made its debut on W...
1095  (Newser) - A family that died on a hike in Cal...  ...  (Newser)  A family
that died on a hike in Cali...
```

```
1130  --News Direct--\n\nPano AI , the leader in wil...  ...  --News Direct--
Pano AI , the leader in wildfi...
1294  EAST TAWAS, Mich. - The public is invited to a...  ...  EAST TAWAS, Mich.
The public is invited to a ...
860   If there's a central theme to Edgar Wright's n...  ...  If theres a
central theme to Edgar Wrights new...

[1657 rows x 3 columns]
```

[ ]:
```
test["clean_text"] = test["full_text"].apply(clean)
test
```

[ ]:
```
                                              full_text  ...
clean_text
1351  Houston is getting a wet start to the weekend...  ...  Houston is getting
a wet start to the weekend...
733   CLEMSON, S.C. - Oskar Ågren scored the game-wi...  ...  CLEMSON, S.C.
Oskar gren scored the game winn...
678   The SoB started in the mid-2000s, soccer fans ...  ...  The SoB started in
the mid-, soccer fans who r...
1460  Lauren Rautenkranz, Tim Deegan, Makayla Lucero...  ...  Lauren
Rautenkranz, Tim Deegan, Makayla Lucero...
411   Huge second quarter leads Sacramento State to ...  ...  Huge second
quarter leads Sacramento State to ...
...                                                 ...  ...
...
772   © Provided by Independent Online (IOL)\n\nCape...  ...   Provided by
Independent Online (IOL) Cape Tow...
593   © Provided by The South African\n\nFIFA appear...  ...   Provided by The
South African FIFA appears wi...
1674  The major earthquakes that jolted Hawaii and A...  ...  The major
earthquakes that jolted Hawaii and A...
881   AT&T and Twitch have launched a mentorship pro...  ...  AT&T and Twitch
have launched a mentorship pro...
2027  San Francisco officials have declared a water ...  ...  San Francisco
officials have declared a water ...

[415 rows x 3 columns]
```

[ ]:
```
from nltk.tokenize import WhitespaceTokenizer
from nltk.tag import pos_tag
import nltk
from nltk.tokenize import sent_tokenize

def lem_analyzer(text):
    words = []
    for sent in sent_tokenize(text):
```

```
        words += lemmatize_sent(sent)
    return " ".join(words)

wnl = nltk.wordnet.WordNetLemmatizer()
def lemmatize_sent(text):
    # lemmatize a sentence as a list of words
    w_tokenizer = WhitespaceTokenizer()
    return [wnl.lemmatize(word.lower(), pos=penn2morphy(tag)) for word, tag in␣
 ↪pos_tag(w_tokenizer.tokenize(text)) if word not in combined_stopwords and not␣
 ↪word.isdigit()]

morphy_tag = {'NN':'n', 'JJ':'a',
              'VB':'v', 'RB':'r'}
def penn2morphy(penntag):
    """ Converts Penn Treebank tags to WordNet. """
    return morphy_tag.get(penntag[:2], 'n')
```

[ ]:
```
nltk.download('averaged_perceptron_tagger')
nltk.download('wordnet')
nltk.download('punkt')
nltk.download('stopwords')
```

```
[nltk_data] Downloading package averaged_perceptron_tagger to
[nltk_data]     /root/nltk_data...
[nltk_data]   Unzipping taggers/averaged_perceptron_tagger.zip.
[nltk_data] Downloading package wordnet to /root/nltk_data...
[nltk_data]   Unzipping corpora/wordnet.zip.
[nltk_data] Downloading package punkt to /root/nltk_data...
[nltk_data]   Unzipping tokenizers/punkt.zip.
[nltk_data] Downloading package stopwords to /root/nltk_data...
[nltk_data]   Unzipping corpora/stopwords.zip.
```

[ ]: True

[ ]:
```
from sklearn.feature_extraction import text
from nltk.corpus import stopwords
from string import punctuation

stop_words_skt = text.ENGLISH_STOP_WORDS
stop_words_en = stopwords.words('english')

combined_stopwords = set.
 ↪union(set(stop_words_en),set(punctuation),set(stop_words_skt))
combined_stopwords
```

[ ]:
```
{'!',
 '"',
 '#',
```

```
'$',
'%',
'&',
"'",
'(',
')',
'*',
'+',
',',
'-',
'.',
'/',
':',
';',
'<',
'=',
'>',
'?',
'@',
'[',
'\\',
']',
'^',
'_',
'`',
'a',
'about',
'above',
'across',
'after',
'afterwards',
'again',
'against',
'ain',
'all',
'almost',
'alone',
'along',
'already',
'also',
'although',
'always',
'am',
'among',
'amongst',
'amoungst',
'amount',
```

```
'an',
'and',
'another',
'any',
'anyhow',
'anyone',
'anything',
'anyway',
'anywhere',
'are',
'aren',
"aren't",
'around',
'as',
'at',
'back',
'be',
'became',
'because',
'become',
'becomes',
'becoming',
'been',
'before',
'beforehand',
'behind',
'being',
'below',
'beside',
'besides',
'between',
'beyond',
'bill',
'both',
'bottom',
'but',
'by',
'call',
'can',
'cannot',
'cant',
'co',
'con',
'could',
'couldn',
"couldn't",
'couldnt',
```

```
'cry',
'd',
'de',
'describe',
'detail',
'did',
'didn',
"didn't",
'do',
'does',
'doesn',
"doesn't",
'doing',
'don',
"don't",
'done',
'down',
'due',
'during',
'each',
'eg',
'eight',
'either',
'eleven',
'else',
'elsewhere',
'empty',
'enough',
'etc',
'even',
'ever',
'every',
'everyone',
'everything',
'everywhere',
'except',
'few',
'fifteen',
'fifty',
'fill',
'find',
'fire',
'first',
'five',
'for',
'former',
'formerly',
```

```
'forty',
'found',
'four',
'from',
'front',
'full',
'further',
'get',
'give',
'go',
'had',
'hadn',
"hadn't",
'has',
'hasn',
"hasn't",
'hasnt',
'have',
'haven',
"haven't",
'having',
'he',
'hence',
'her',
'here',
'hereafter',
'hereby',
'herein',
'hereupon',
'hers',
'herself',
'him',
'himself',
'his',
'how',
'however',
'hundred',
'i',
'ie',
'if',
'in',
'inc',
'indeed',
'interest',
'into',
'is',
'isn',
```

```
"isn't",
'it',
"it's",
'its',
'itself',
'just',
'keep',
'last',
'latter',
'latterly',
'least',
'less',
'll',
'ltd',
'm',
'ma',
'made',
'many',
'may',
'me',
'meanwhile',
'might',
'mightn',
"mightn't",
'mill',
'mine',
'more',
'moreover',
'most',
'mostly',
'move',
'much',
'must',
'mustn',
"mustn't",
'my',
'myself',
'name',
'namely',
'needn',
"needn't",
'neither',
'never',
'nevertheless',
'next',
'nine',
'no',
```

```
'nobody',
'none',
'noone',
'nor',
'not',
'nothing',
'now',
'nowhere',
'o',
'of',
'off',
'often',
'on',
'once',
'one',
'only',
'onto',
'or',
'other',
'others',
'otherwise',
'our',
'ours',
'ourselves',
'out',
'over',
'own',
'part',
'per',
'perhaps',
'please',
'put',
'rather',
're',
's',
'same',
'see',
'seem',
'seemed',
'seeming',
'seems',
'serious',
'several',
'shan',
"shan't",
'she',
"she's",
```

```
'should',
"should've",
'shouldn',
"shouldn't",
'show',
'side',
'since',
'sincere',
'six',
'sixty',
'so',
'some',
'somehow',
'someone',
'something',
'sometime',
'sometimes',
'somewhere',
'still',
'such',
'system',
't',
'take',
'ten',
'than',
'that',
"that'll",
'the',
'their',
'theirs',
'them',
'themselves',
'then',
'thence',
'there',
'thereafter',
'thereby',
'therefore',
'therein',
'thereupon',
'these',
'they',
'thick',
'thin',
'third',
'this',
'those',
```

```
'though',
'three',
'through',
'throughout',
'thru',
'thus',
'to',
'together',
'too',
'top',
'toward',
'towards',
'twelve',
'twenty',
'two',
'un',
'under',
'until',
'up',
'upon',
'us',
've',
'very',
'via',
'was',
'wasn',
"wasn't",
'we',
'well',
'were',
'weren',
"weren't",
'what',
'whatever',
'when',
'whence',
'whenever',
'where',
'whereafter',
'whereas',
'whereby',
'wherein',
'whereupon',
'wherever',
'whether',
'which',
'while',
```

```
 'whither',
 'who',
 'whoever',
 'whole',
 'whom',
 'whose',
 'why',
 'will',
 'with',
 'within',
 'without',
 'won',
 "won't",
 'would',
 'wouldn',
 "wouldn't",
 'y',
 'yet',
 'you',
 "you'd",
 "you'll",
 "you're",
 "you've",
 'your',
 'yours',
 'yourself',
 'yourselves',
 '{',
 '|',
 '}',
 '~'}
```

[ ]:
```
train["lem_text"] = train["clean_text"].apply(lem_analyzer)
train
```

[ ]:
```
                                              full_text  ...
lem_text
1431  More than 1 million Washingtonians participate...  ...  more million
washingtonian participate "the gr...
1567  A 4.7-magnitude earthquake rattled northwest S...  ...  a magnitude
earthquake rattle northwest san lu...
1044  More campgrounds are coming to the Auburn Stat...  ...  more campground
come auburn state recreation a...
175   Retro gamers will be able to relive all the jo...  ...  retro gamers able
relive joy classic zx spectr...
1610  SAN SIMEON, Calif. (KGTV) - An earthquake with...  ...  san simeon, calif.
(kgtv) an earthquake prelim...
```

```
...                                                    ...  ...
...
1638  The redesigned Ford Ranger made its debut on W...  ...  the redesigned
ford ranger debut wednesday, he...
1095  (Newser) - A family that died on a hike in Cal...  ...  (newser) a family
die hike california's sierra...
1130  --News Direct--\n\nPano AI , the leader in wil...  ...  --news direct--
pano ai leader wildfire early ...
1294  EAST TAWAS, Mich. - The public is invited to a...  ...  east tawas, mich.
the public invite forum disc...
860   If there’s a central theme to Edgar Wright’s n...  ...  if there central
theme edgar wright new horror...

[1657 rows x 4 columns]
```

[ ]:
```
test["lem_text"] = test["clean_text"].apply(lem_analyzer)
test
```

[ ]:
```
                                              full_text  ...
lem_text
1351  Houston is getting a wet start to the weekend...  ...  houston get wet
start weekend. forecaster nati...
733   CLEMSON, S.C. - Oskar Ågren scored the game-wi...  ...  clemson, s.c.
oskar gren score game winning go...
678   The SoB started in the mid-2000s, soccer fans ...  ...  the sob start
mid-, soccer fan really, really ...
1460  Lauren Rautenkranz, Tim Deegan, Makayla Lucero...  ...  lauren
rautenkranz, tim deegan, makayla lucero...
411   Huge second quarter leads Sacramento State to ...  ...  huge second
quarter lead sacramento state rout...
...                                                    ...  ...
...
772   © Provided by Independent Online (IOL)\n\nCape...  ...  provide
independent online (iol) cape town sou...
593   © Provided by The South African\n\nFIFA appear...  ...  provide the south
african fifa appear willing ...
1674  The major earthquakes that jolted Hawaii and A...  ...  the major
earthquake jolt hawaii alaska past d...
881   AT&T and Twitch have launched a mentorship pro...  ...  at&t twitch launch
mentorship program aspire t...
2027  San Francisco officials have declared a water ...  ...  san francisco
official declare water shortage ...

[415 rows x 4 columns]
```

[ ]:
```
from sklearn.feature_extraction.text import CountVectorizer
```

```
vectorizer = CountVectorizer(stop_words='english', min_df=3, max_df=0.7)
X_train_counts = vectorizer.fit_transform(train["lem_text"])
X_test_counts = vectorizer.transform(test["lem_text"])
print(X_train_counts.shape)
print(X_test_counts.shape)
```

```
(1657, 11060)
(415, 11060)
```

[ ]:
```
print(vectorizer.get_feature_names_out()[0:100])
```

```
['08837phone' '10km' '247sports' '25m' '49ers' '5km' 'aap' 'aaron' 'ab'
 'abandon' 'abated' 'abbott' 'abby' 'abc' 'abdul' 'abhishek' 'abide'
 'abilities' 'ability' 'abject' 'ablate' 'able' 'abnormally' 'abolish'
 'aboriginal' 'abraham' 'abrahamyan' 'abroad' 'abrupt' 'absence' 'absent'
 'absolute' 'absolutely' 'absorb' 'abstract' 'abu' 'abundance' 'abundant'
 'abundantly' 'abuse' 'abuses' 'abusive' 'ac' 'academic' 'academy' 'acc'
 'accelerate' 'accent' 'accents' 'accept' 'acceptable' 'acceptance'
 'access' 'accessibility' 'accessible' 'accessories' 'accessory'
 'accident' 'accolade' 'accomack' 'accommodation' 'accompany' 'accomplish'
 'accomplished' 'accomplishment' 'accord' 'accordance' 'according'
 'accordingly' 'account' 'accountability' 'accountable' 'accounting'
 'accounts' 'accumulate' 'accumulation' 'accuracy' 'accurate' 'accurately'
 'accusation' 'accuse' 'accuweather' 'ace' 'achieve' 'achievement'
 'achievements' 'acid' 'acknowledge' 'acknowledgment' 'acl' 'acoustic'
 'acquire' 'acquisition' 'acquisitions' 'acre' 'acreage' 'acres' 'act'
 'acting' 'action']
```

[ ]:
```
from sklearn.feature_extraction.text import TfidfTransformer

tfidf_transformer = TfidfTransformer(smooth_idf=False)
X_train_tfidf = tfidf_transformer.fit_transform(X_train_counts)
X_test_tfidf = tfidf_transformer.transform(X_test_counts)
print(X_train_tfidf.shape)
print(X_test_tfidf.shape)
```

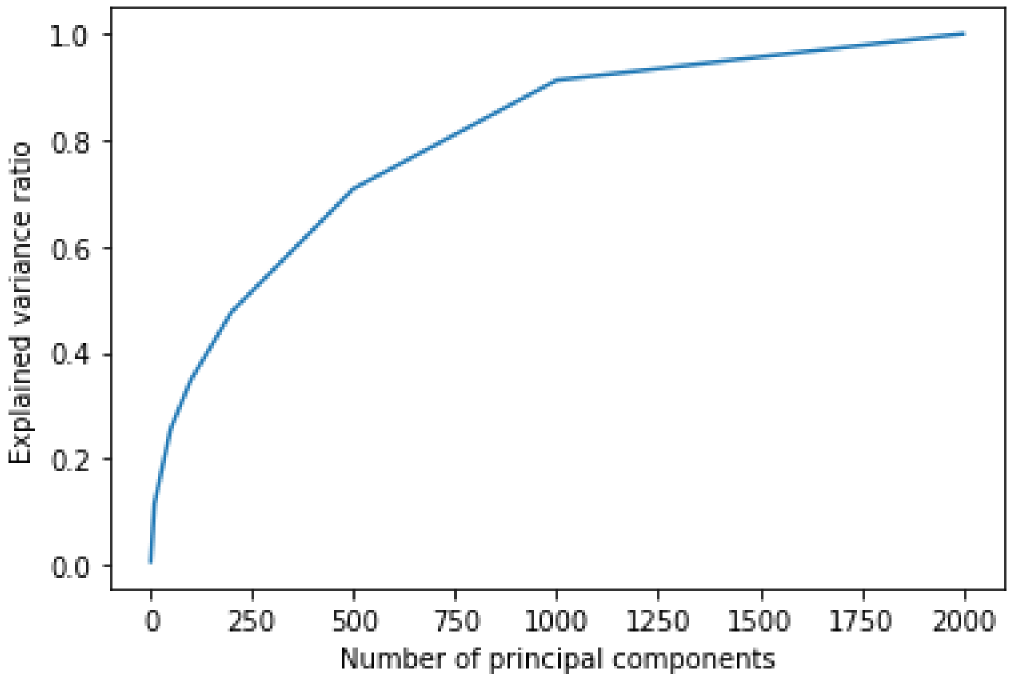
```
(1657, 11060)
(415, 11060)
```

Question 3: * Stemming simply removes the rightmost characters of words, which can result in non-existent and incorrect word stems. It can be useful for simplifying a database of words when many terms have the same meaning but with different affixes. Lemmatizing uses linguistic rules to find a root word, guarantees that the result is a real word, but may return a different word with a similar meaning. For example, "better" will be lemmatized to "good" when the part of speech is specified as an adjective. Stemming can produce a dictionary of a smaller size than lemmatizing, because it is more aggressive at simplifying words than lemmatization is. Lemmatization leaves the word unchanged if it cannot find a lemma for it, whereas stemming will apply a set of rules to all words to reduce them as much as possible. * Decreasing min_df would increase the size of the dictionary, so the number of columns in the TF-IDF matrix would increase. A min_df of 1 is equivalent to adding all distinct terms that occur in the training data to the dictionary. Increasing min_df would decrease the size of the dictionary, since it omits more rare words that occur only in a few documents. With a min_df of 3, the dictionary size is 11060, where as min_df of 1 produces a dictionary size of 31242, and min_df of 5 produces a dictionary size of 7387. * Stopwords should be removed after lemmatizing, because some stopwords in the text may occur in various forms that do not match the defined set of stopwords exactly. For example, the sklearn set of stopwords includes "name" but not "names". Punctuation should be removed before lemmatizing, as words with puntuation are not lemmatized correctly. For instance "hours," is not lemmatized to "hour" since the comma is included. Lemmatizing before stopwords would remove variations of stopwords as intended. However, punctuation should not be removed during cleaning, since puncutation is needed to tokenize documents into sentences, as the parts-of-speech tagger operates more accurately on sentences than on individual words. Numbers were removed in the clean() function before lemmatizing, since lemmatizing operates on words and not number terms, and lemmatizing a number simply returns the same number, so removing numbers first avoids unecessary processing. * The TF-IDF-processed train matrix has shape (1657,11060), and the TF-IDF-processed test matrix has shape (415,11060). Since they have 11060 columns, the dictionary contains 11060 words after cleaning and lemmatizing.

1.3 Dimensionality reduction

[ ]:
```
from sklearn.decomposition import TruncatedSVD

k_list = [1, 10, 50, 100, 200, 500, 1000, 2000]
var_list = []

for k in k_list:
    lsi = TruncatedSVD(n_components=k, n_iter=100)
    lsi.fit(X_train_tfidf)
    var_list.append(lsi.explained_variance_ratio_.sum())
```

[ ]:
```
plt.figure()
plt.plot(k_list, var_list)
plt.xlabel("Number of principal components")
plt.ylabel("Explained variance ratio")
plt.show()
```



Question 4: The plot is an increasing curve that rises quickly at small k and slowly at large k. The concavity suggests that the principal components corresponding to the largest few singular values contain more of the information about the dataset than the same number of components corresponding to smaller singular values. After about 1000 features, keeping more features has diminishing returns with respect to the explained variance ratio and would likely not improve classification performance much.

[ ]:
```
k = 50
lsi = TruncatedSVD(n_components=k, n_iter=100)
X_train_lsi = lsi.fit_transform(X_train_tfidf)
print(X_train_lsi.shape)
```

```
(1657, 50)
```

[ ]:
```
U = X_train_lsi / lsi.singular_values_
Sigma_matrix = np.diag(lsi.singular_values_)
VT = lsi.components_
Xk = np.matmul(U, np.matmul(Sigma_matrix,VT)) # approximate X from SVD
Xk.shape
```

[ ]: `(1657, 11060)`

[ ]:
```
# reconstruction residual of LSI
np.linalg.norm(X_train_tfidf-Xk, ord='fro')**2
```

[ ]: `1196.2560881345225`

[ ]:
```
from sklearn.decomposition import NMF

k = 50
nmf_model = NMF(n_components=k, init='random', max_iter=500)
W_train = nmf_model.fit_transform(X_train_tfidf)
print(W_train.shape)

H = nmf_model.components_
print(H.shape)
```

```
(1657, 50)
(50, 11060)
```

[ ]:
```
# reconstruction residual of NMF
np.linalg.norm(X_train_tfidf-np.matmul(W_train,H), ord='fro')**2
```

[ ]:
```
1218.0264817498776
```

Question 4: The reconstruction residual MSE error is larger in NMF because optimization problem in NMF is not convex, and the local minimum that NMF converges to is highly dependent on initial conditions. In contrast, SVD is more deterministic since it tries to compute the eigenvectors and eigenvalues of the training data.

1.4 Classification algorithms

[ ]:
```
from sklearn import svm
from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import recall_score
from sklearn.metrics import precision_score
from sklearn.metrics import f1_score
from sklearn.metrics import roc_curve
from sklearn.metrics import auc
```

[ ]:
```
X_test_lsi = lsi.transform(X_test_tfidf)
print(X_test_lsi.shape)
```

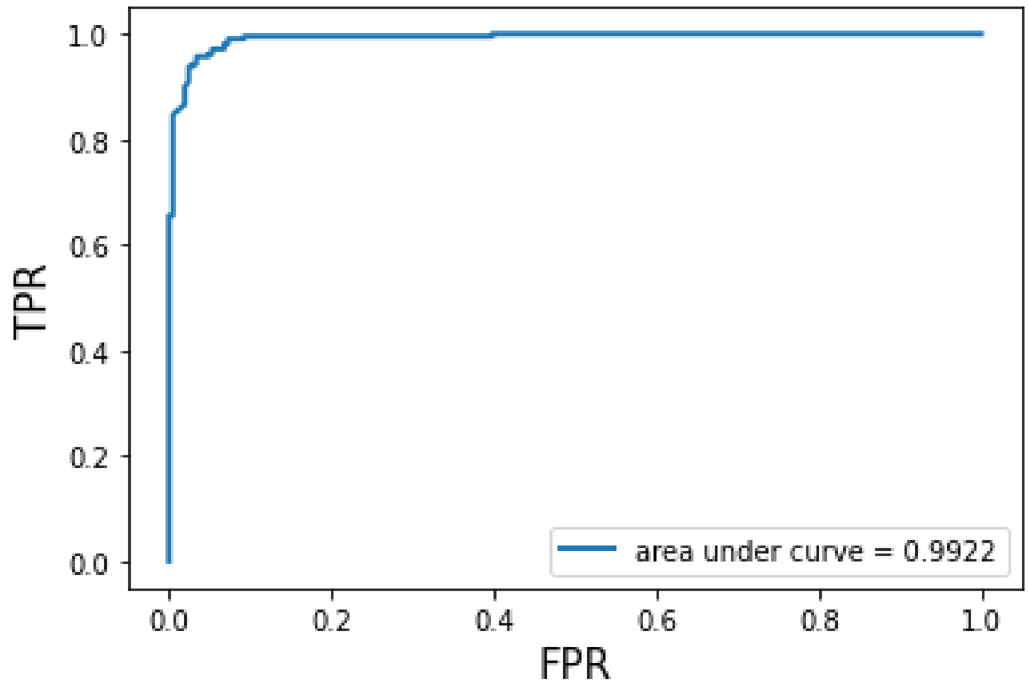
```
(415, 50)
```

[ ]:
```
def score_and_roc_svm(c, X_train_lsi, X_test_lsi, train_root_label,␣
 ↪test_root_label):
    # confusion matrix
    svmc = svm.SVC(C=c, probability=True)
    svmc.fit(X_train_lsi.tolist(), train_root_label.tolist())
    test_pred = svmc.predict(X_test_lsi.tolist())
    test_pred_proba = svmc.predict_proba(X_test_lsi)

    print('confusion matrix')
```

```
    print(confusion_matrix(test_root_label, test_pred))
    print('accuracy: {}'.format(accuracy_score(test_root_label, test_pred)))
    print('recall: {}'.format(recall_score(test_root_label, test_pred,␣
 ↪pos_label='sports')))
    print('precision: {}'.format(precision_score(test_root_label, test_pred,␣
 ↪pos_label='sports')))
    print('f1 score: {}'.format(f1_score(test_root_label, test_pred,␣
 ↪pos_label='sports' )))

    fpr, tpr, thresholds = roc_curve(test["root_label"], test_pred_proba[:,1],␣
 ↪pos_label='sports')
    roc_auc = auc(fpr,tpr)
    print('AUC: {}'.format(roc_auc))
    plt.plot(fpr, tpr, lw=2, label='area under curve = %0.4f' % roc_auc)
    plt.xlabel('FPR',fontsize=15)
    plt.ylabel('TPR',fontsize=15)
    plt.legend(loc="lower right")
```

[ ]:
```
# hard margin
score_and_roc_svm(1000, X_train_lsi, X_test_lsi, train["root_label"],␣
 ↪test["root_label"])
```

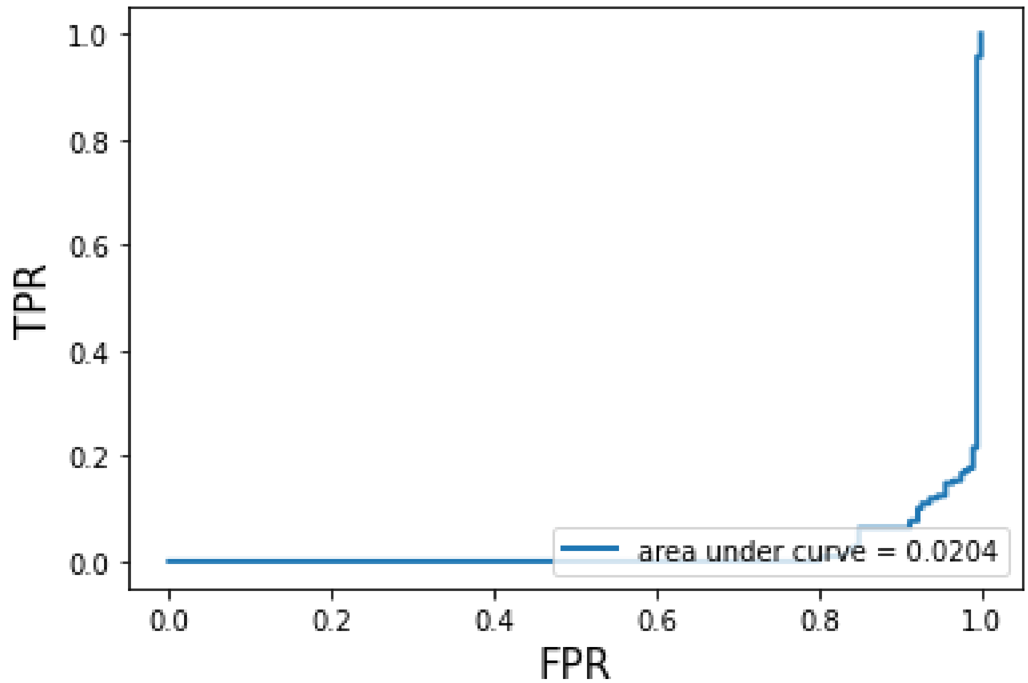
```
confusion matrix
[[197   9]
 [  9 200]]
accuracy: 0.9566265060240964
recall: 0.9569377990430622
precision: 0.9569377990430622
f1 score: 0.9569377990430622
AUC: 0.9922190737213732
```



[ ]:
```
# soft margin
score_and_roc_svm(0.0001, X_train_lsi, X_test_lsi, train["root_label"],␣
 ↪test["root_label"])
```

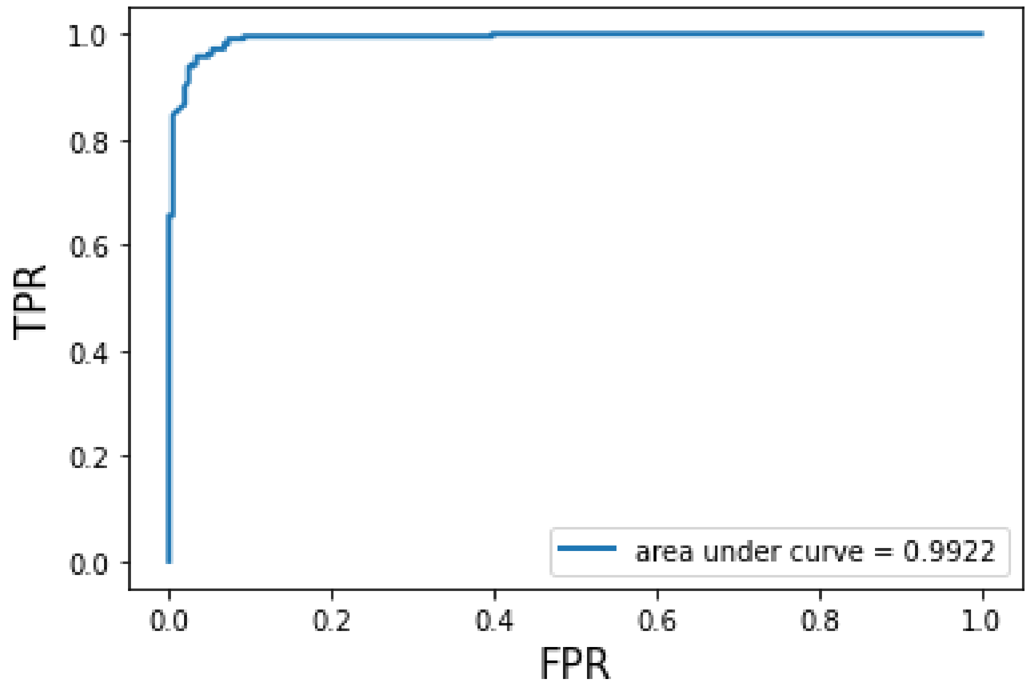
```
confusion matrix
[[206   0]
 [209   0]]
accuracy: 0.4963855421686747
recall: 0.0
precision: 0.0
f1 score: 0.0
AUC: 0.020392994843684675
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/metrics/_classification.py:1318:
UndefinedMetricWarning: Precision is ill-defined and being set to 0.0 due to no
predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```



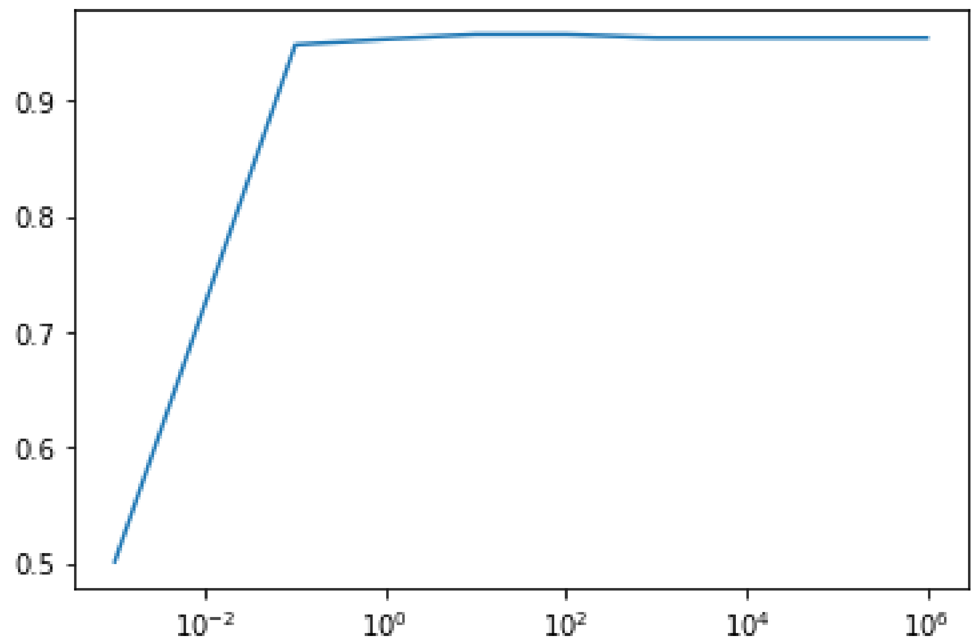
[ ]:
```
score_and_roc_svm(100000, X_train_lsi, X_test_lsi, train["root_label"],␣
 ↪test["root_label"])
```

```
confusion matrix
[[197   9]
 [  9 200]]
accuracy: 0.9566265060240964
recall: 0.9569377990430622
precision: 0.9569377990430622
f1 score: 0.9569377990430622
AUC: 0.9922190737213732
```




```
[ ]: from sklearn.model_selection import cross_val_score

     c_list = np.logspace(-3, 6, 10)
     acc_list = []
     for c in c_list:
         clf = svm.SVC(C=c, probability=True)
         scores = cross_val_score(clf, X_train_lsi.tolist(), train["root_label"].
      ↪tolist(), cv=5, scoring='accuracy')
         acc_list.append(scores.mean())
```

```
[ ]: plt.axes(xscale='log')
     plt.plot(c_list, acc_list)
     plt.show()
```

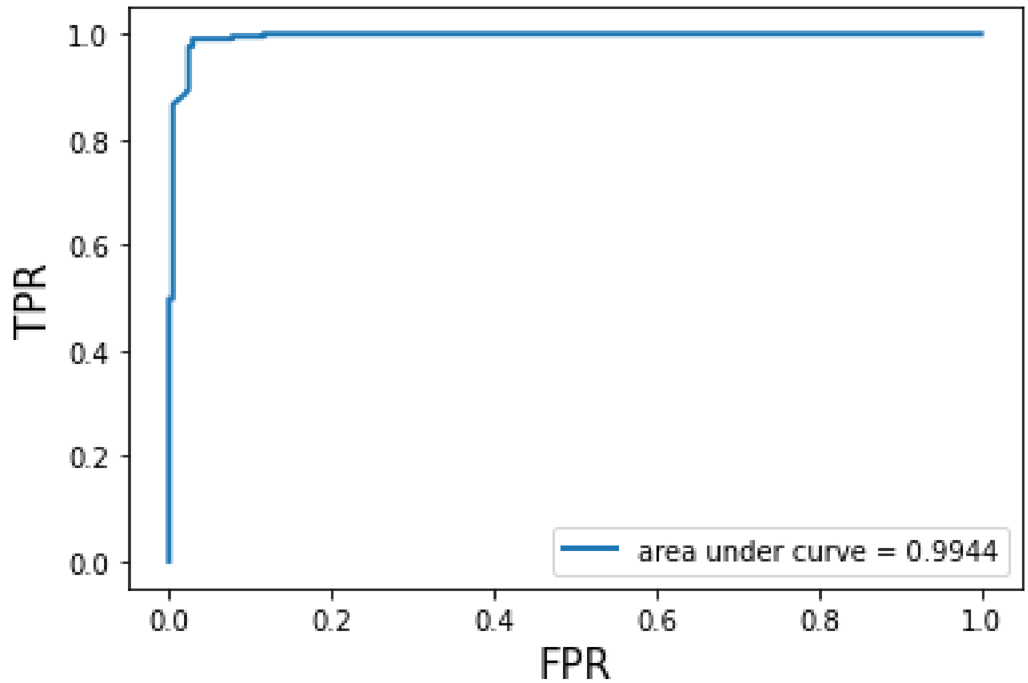


[ ]:
```
opt_c = c_list[np.argmax(acc_list)]
print('Optimal gamma from cross-validation: {}'.format(opt_c))
```

```
Optimal gamma from cross-validation: 10.0
```

[ ]:
```
score_and_roc_svm(opt_c, X_train_lsi, X_test_lsi, train["root_label"],␣
↪test["root_label"])
```

```
confusion matrix
[[200   6]
 [  4 205]]
accuracy: 0.9759036144578314
recall: 0.9808612440191388
precision: 0.9715639810426541
f1 score: 0.9761904761904763
AUC: 0.9944488316997259
```



Question 5: * The confusion matrix, accuracy, recall, precision, and F1 score of the three SVM classifiers are reported above. SVM with $\gamma = 1000$ performs as well as SVM with $\gamma = 100000$, and both of these are much better than SVM with $\gamma = 0.0001$. * For soft margin SVM, $\gamma = 0.0001$ is too small, so misclassification of training data is very lightly penalized. All predicted results are labeled as 'climate', so in the confusion matrix, TP=206, FP=209, FN=TN=0. The model has an accuracy of 0.49, and precision, recall, and F1 score are all zero. * ROC curve's AUC of soft margin SVM is about 0.02, indicating poor performance. The ROC curve shows that the TPR stays close to zero until the FPR is close to one, so the soft margin SVM has very poor separability between classes. * The best value of γ is 100. The confusion matrix, accuracy, recall, precision, and F1 score for this best SVM are reported above.

[ ]:
```
from sklearn.linear_model import LogisticRegression

def score_and_roc_logreg(c, X_train_lsi, X_test_lsi, train_root_label,␣
 ↪test_root_label, pe):
    # confusion matrix
    logreg = LogisticRegression(penalty=pe, C=c, solver="saga", max_iter=4000)
    logreg.fit(X_train_lsi.tolist(), train_root_label.tolist())
    test_pred=logreg.predict(X_test_lsi.tolist())
    test_pred_proba = logreg.predict_proba(X_test_lsi.tolist())

    print('confusion matrix')
    print(confusion_matrix(test_root_label, test_pred))
    print('accuracy: {}'.format(accuracy_score(test_root_label, test_pred)))
```

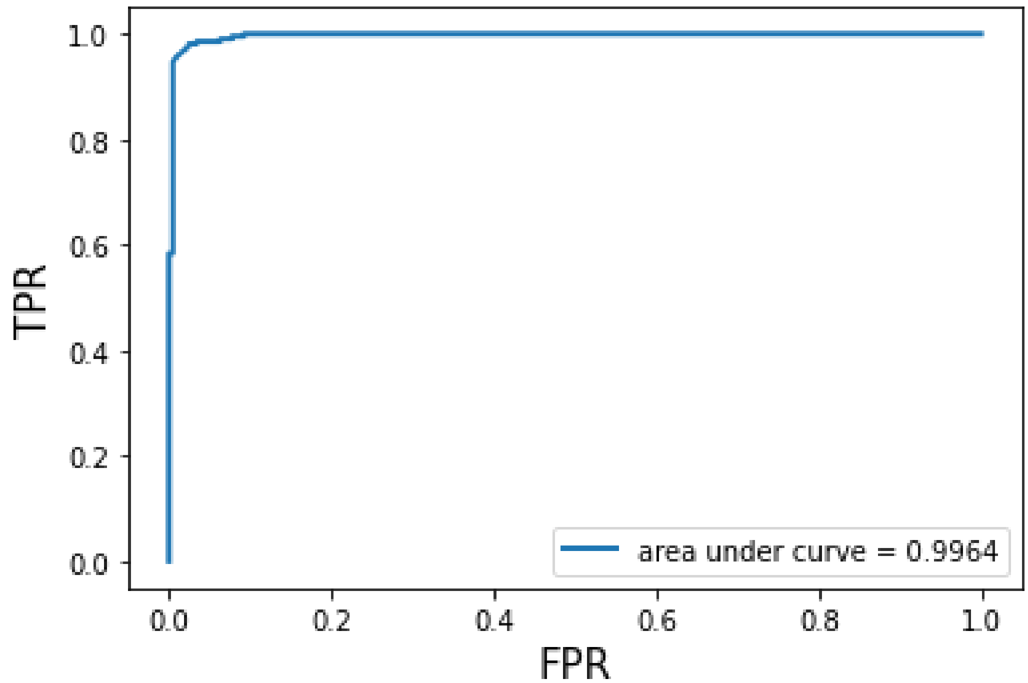
```
    print('recall: {}'.format(recall_score(test_root_label, test_pred,␣
↪pos_label='sports')))
    print('precision: {}'.format(precision_score(test_root_label, test_pred,␣
↪pos_label='sports')))
    print('f1 score: {}'.format(f1_score(test_root_label, test_pred,␣
↪pos_label='sports' )))

    fpr, tpr, thresholds = roc_curve(test["root_label"], test_pred_proba[:,1],␣
↪pos_label='sports')
    roc_auc = auc(fpr,tpr)
    print('AUC: {}'.format(roc_auc))
    plt.plot(fpr, tpr, lw=2, label='area under curve = %0.4f' % roc_auc)
    plt.xlabel('FPR',fontsize=15)
    plt.ylabel('TPR',fontsize=15)
    plt.legend(loc="lower right")
```

[ ]:

```
# logistic classifier without regularization
score_and_roc_logreg(1e42, X_train_lsi, X_test_lsi, train["root_label"],␣
↪test["root_label"], 'none')
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/linear_model/_logistic.py:1484:
UserWarning: Setting penalty='none' will ignore the C and l1_ratio parameters
  "Setting penalty='none' will ignore the C and l1_ratio parameters"
```

```
confusion matrix
[[199   7]
 [  3 206]]
accuracy: 0.9759036144578314
recall: 0.9856459330143541
precision: 0.9671361502347418
f1 score: 0.976303317535545
AUC: 0.9964463232220003
```



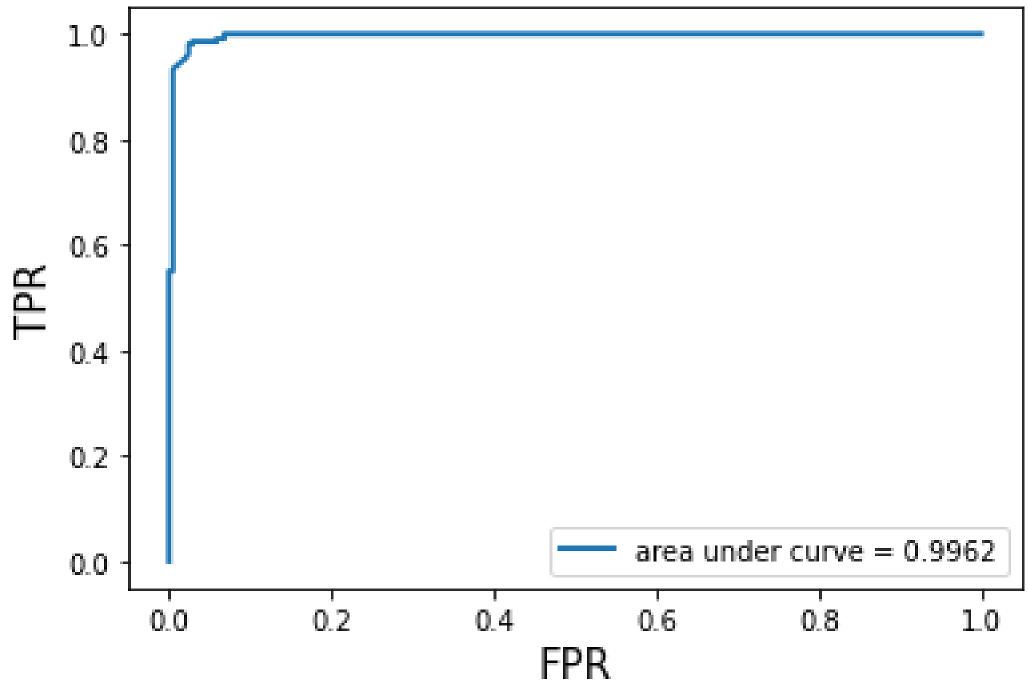
[ ]:
```
# 5-fold CV on optimal regularization strength for L1 and L2 regularization

reg_list = ['l1','l2']
c_range = np.logspace(-4, 4, 9)

for reg in reg_list:
    acc_list = []
    for c in c_range:
        logreg = LogisticRegression(penalty=reg, C=c, solver="saga",␣
 ↪max_iter=4000)
        scores = cross_val_score(logreg, X_train_lsi.tolist(),␣
 ↪train["root_label"].tolist(), cv=5, scoring='accuracy')
        acc_list.append(scores.mean())

    opt_c = c_range[np.argmax(acc_list)]
    print("Regularization: {}, optimal coefficient: {}".format(reg, opt_c))
```

```
Regularization: l1, optimal coefficient: 10.0
Regularization: l2, optimal coefficient: 10.0
```

[ ]:
```
# L1 regularization with optimal gamma
score_and_roc_logreg(10, X_train_lsi, X_test_lsi, train["root_label"],␣
 ↪test["root_label"], 'l1')
```

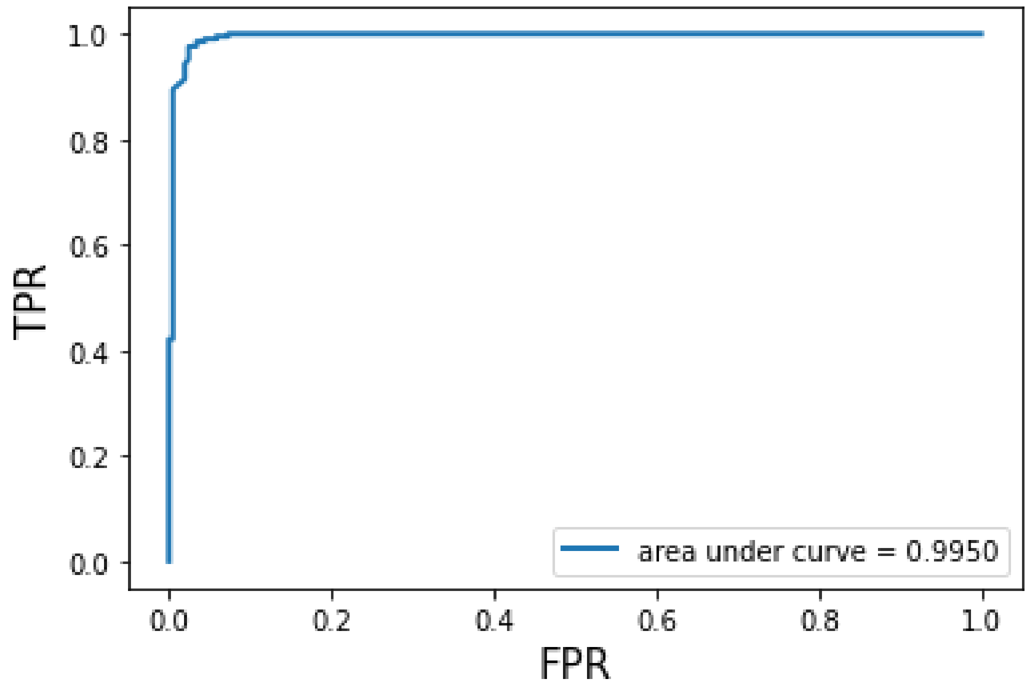
```
confusion matrix
```

```
[[199   7]
 [  3 206]]
accuracy: 0.9759036144578314
recall: 0.9856459330143541
precision: 0.9671361502347418
f1 score: 0.976303317535545
AUC: 0.9961676034747062
```



[ ]:
```python
# L2 regularization with optimal gamma
score_and_roc_logreg(10, X_train_lsi, X_test_lsi, train["root_label"],␣
 ↪test["root_label"], 'l2')
```

```
confusion matrix
[[199   7]
 [  3 206]]
accuracy: 0.9759036144578314
recall: 0.9856459330143541
precision: 0.9671361502347418
f1 score: 0.976303317535545
AUC: 0.9949598179030985
```



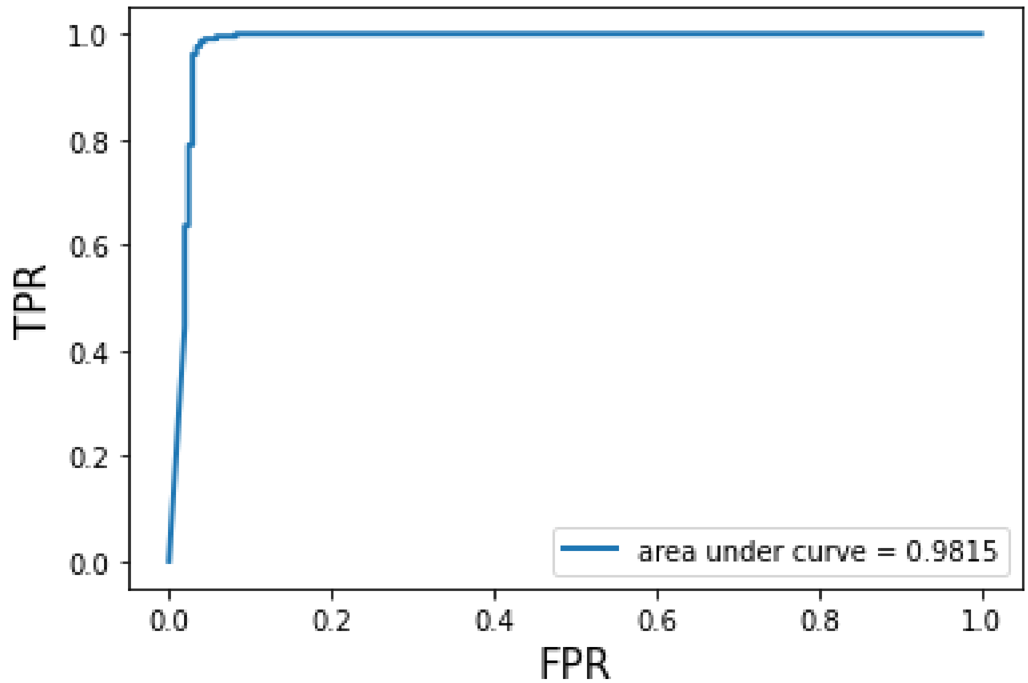
Question 6: * The optimal regularization strength found from 5-fold cross-validation for L1 regularization and L2 regularization are both 10. * All three classifiers – no regularization, L1 regularization with $k = 10$, and L2 regularization with $k = 10$ – all perform well. The AUC for each are all greater than 0.99, and accuracies, recalls, precisions, and F1 scores are also all avove 0.96. * When the regularization parameter is increased, the test error will first increase and then decrease. Some regularization can help avoid overfitting, but when regularization is too strong, it causes underfitting. When the regularization parameter is increased, the learnt coefficients tend to smaller values. L1 and L2 are different kinds of regularization. L1 is least absolute deviation so it penalizes differently sized errors equally, while L2 is least squares error and penalizes large errors more. L1 can also be helpful in feature selection. * The loss functions of SVM and logistic regression are different. The loss fuction of SVM is hinge loss, while for logistic regression uses logistic loss. SVM only considers support vectors, while logistic regression considers all data points with different weights. Logistic regression could have the problem of over-fitting, while SVM does not. According to the ROC curves above, the performances of SVM and logistic regression do not differ significantly.

[ ]:
```
from sklearn.naive_bayes import GaussianNB

def score_and_roc_gau(X_train_lsi, X_test_lsi, train_root_label,␣
 ↪test_root_label):
    # confusion matrix
    clf = GaussianNB()
    clf.fit(X_train_lsi.tolist(), train_root_label.tolist())
    test_pred = clf.predict(X_test_lsi.tolist())
```

```
    test_pred_proba = clf.predict_proba(X_test_lsi.tolist())

    print('confusion matrix')
    print(confusion_matrix(test_root_label, test_pred))
    print('accuracy: {}'.format(accuracy_score(test_root_label, test_pred)))
    print('recall: {}'.format(recall_score(test_root_label, test_pred,␣
↪pos_label='sports')))
    print('precision: {}'.format(precision_score(test_root_label, test_pred,␣
↪pos_label='sports')))
    print('f1 score: {}'.format(f1_score(test_root_label, test_pred,␣
↪pos_label='sports' )))

    fpr, tpr, thresholds = roc_curve(test["root_label"], test_pred_proba[:,1],␣
↪pos_label='sports')
    roc_auc = auc(fpr,tpr)
    print('AUC: {}'.format(roc_auc))
    plt.plot(fpr, tpr, lw=2, label='area under curve = %0.4f' % roc_auc)
    plt.xlabel('FPR',fontsize=15)
    plt.ylabel('TPR',fontsize=15)
    plt.legend(loc="lower right")
```

[ ]:
```
score_and_roc_gau(X_train_lsi, X_test_lsi, train["root_label"],␣
↪test["root_label"])
```

```
confusion matrix
[[200   6]
 [  9 200]]
accuracy: 0.963855421686747
recall: 0.9569377990430622
precision: 0.970873786407767
f1 score: 0.9638554216867469
AUC: 0.9814883634505505
```



Question 7: The Roc curve, confusion matrix, accuracy, recall, precision and F1 score are above.

1.5 Gridsearch of parameters

[ ]:
```
from tempfile import mkdtemp
from shutil import rmtree
import nltk
from sklearn.pipeline import Pipeline
from sklearn.preprocessing import StandardScaler
import joblib
from joblib import Memory
from sklearn.model_selection import GridSearchCV
#from pipelinehelper import PipelineHelper
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.feature_extraction.text import TfidfTransformer
from nltk.stem.snowball import FrenchStemmer
from sklearn.naive_bayes import GaussianNB
from sklearn.decomposition import TruncatedSVD
from sklearn.decomposition import NMF
from sklearn import svm
from sklearn import linear_model
# clean vs not clean
# clean: train["clean_text"]
# not clean: train["full_text"]
```

```python
import time
full_time = time.time()

wnl = nltk.wordnet.WordNetLemmatizer()
analyzer = CountVectorizer().build_analyzer()
tfidf = TfidfTransformer()
scaler = StandardScaler(with_mean=False) # not absolutely required but does help
gaussian = GaussianNB()
stemmer = FrenchStemmer()
location = "cachedir"
memory = Memory(location=location, verbose=10)


def stemmed_words(doc):
    return (stemmer.stem(w) for w in analyzer(doc))
#def stem_rmv_punc(doc):
#    return (word for word in stemmed_words(analyzer(doc)) if word not in␣
 ↪combined_stopwords and not word.isdigit())

def lemmatize_sent(text):
    # lemmatize a sentence as a list of words
    return [wnl.lemmatize(word.lower(), pos=penn2morphy(tag)) for word, tag in␣
 ↪pos_tag(text)]
def lem_analyzer(text):
    return (word for word in lemmatize_sent(analyzer(text)) if word not in␣
 ↪combined_stopwords and not word.isdigit())

pipe = Pipeline(steps=[
                       ("vect", CountVectorizer()),
                       ("tfidf", TfidfTransformer()),
                       ("scaler", StandardScaler(with_mean=False)),
                       ('dim_redu', None),
                       ('clf', None),
                        ], memory=memory)

k_list=[5, 50, 500]
optc_svm=100
optc_l1=10
optc_l2=10
min_dif=[3, 5]

param_grid = [{

        'vect': [
            CountVectorizer(min_df=3, analyzer=lem_analyzer),
            #CountVectorizer(min_df=3, analyzer=stemmed_words),
            CountVectorizer(min_df=5, analyzer=lem_analyzer),
```

```
            #CountVectorizer(min_df=5, analyzer=stemmed_words)
        ],


        'dim_redu': [
                TruncatedSVD(n_components=5, n_iter=100, random_state=42),
                TruncatedSVD(n_components=50, n_iter=100, random_state=42),
                NMF(n_components=5, init='random',random_state=42),
                NMF(n_components=50, init='random',random_state=42),

        ],


        'clf': [
               svm.SVC(C=optc_svm, probability=True,random_state=42),
               linear_model.LogisticRegression(penalty='l1', C=optc_l1,␣
 ↪solver="saga", max_iter=4000,random_state=42),
               linear_model.LogisticRegression(penalty='l2', C=optc_l2,␣
 ↪solver="saga", max_iter=4000,random_state=42)]



    }]

search = GridSearchCV(pipe, param_grid=param_grid,␣
 ↪cv=5,scoring='accuracy',error_score="raise")
search.fit(train["clean_text"].tolist(), train["root_label"].tolist())
print("Best parameter (CV score=%0.3f):" % search.best_score_)
print(search.best_params_)

memory.clear(warn=False)
rmtree(location)
print("--- %s seconds ---" % (time.time() - full_time))

import pandas as pd
result = pd.DataFrame(search.cv_results_)
result.sort_values(by='rank_test_score')
#pd.DataFrame(search.cv_results_)
```

```
[Memory]0.0s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/7713bf1406828cf10689487f42cae0b6
___________________________________fit_transform_one cache loaded - 0.1s, 0.0min
[Memory]0.1s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/f15bf5cc6fe40d79c32098b1327a1aae
___________________________________fit_transform_one cache loaded - 0.0s, 0.0min
[Memory]0.2s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/777d8c1072b0bfba0c98b8966e8b721f
```

```
___________________________________fit_transform_one cache loaded - 0.0s, 0.0min
[Memory]0.2s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
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[Memory]0.0s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
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[Memory]0.1s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
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[Memory]0.2s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
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___________________________________fit_transform_one cache loaded - 0.0s, 0.0min
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[Memory]0.0s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/f26f31fe09e4c0baa75d0bd373b11401
___________________________________fit_transform_one cache loaded - 0.1s, 0.0min
[Memory]0.2s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/0f5cb12df585e3e9f36fedd7507eefcf
___________________________________fit_transform_one cache loaded - 0.0s, 0.0min
[Memory]0.2s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/0410caf36f909ca4236d17b4f30c42b5
___________________________________fit_transform_one cache loaded - 0.0s, 0.0min
[Memory]0.2s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/7064570afe46a0458d9bb2458c31c37d
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[Memory]0.0s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/313ae626aad40e891d5a390f5e2cc778
___________________________________fit_transform_one cache loaded - 0.1s, 0.0min
[Memory]0.2s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/7fd6e5010e9282f636fa99592f847e1d
___________________________________fit_transform_one cache loaded - 0.0s, 0.0min
[Memory]0.2s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/64d0adc23e8b78ea1462e251492b6fae
___________________________________fit_transform_one cache loaded - 0.0s, 0.0min
[Memory]0.2s, 0.0min    : Loading _fit_transform_one from cachedir/joblib/sklear
n/pipeline/_fit_transform_one/7a4ef5d0bda83a2125475c43e5ae0710
___________________________________fit_transform_one cache loaded - 0.0s, 0.0min
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[Memory] Calling sklearn.pipeline._fit_transform_one...
_fit_transform_one(CountVectorizer(analyzer=<function lem_analyzer at
0x7f94f2d7cf80>, min_df=3), [ 'More than million Washingtonians participated in
"The Great ShakeOut," the '
  'largest earthquake and tsunami drill in the world. SEATTLE  Are you '
  'prepared if an earthquake hits Washington state? On Thursday, more than '
  'million Washingtonians participated in "The Great ShakeOut," the largest '
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  'earthquake and tsunami drill in the world. The annual earthquake drill was '
  'at a.m. PT Thursday. State emergency officials encouraged the public to '
  'participate as a reminder of what to do in an earthquake: drop, cover and '
  'hold on. The drill is widely practiced in schools, businesses and '
  'government agencies. At least million Washingtonians are registered to '
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_______________________________________________fit_transform_one - 42.9s, 0.7min
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[Memory] Calling sklearn.pipeline._fit_transform_one...
_fit_transform_one(TfidfTransformer(), <1657x10004 sparse matrix of type '<class
'numpy.int64'>'
        with 222430 stored elements in Compressed Sparse Row format>,
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________________________________________________fit_transform_one - 0.1s, 0.0min
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[Memory] Calling sklearn.pipeline._fit_transform_one...
_fit_transform_one(StandardScaler(with_mean=False), <1657x10004 sparse matrix of
type '<class 'numpy.float64'>'
        with 222430 stored elements in Compressed Sparse Row format>,
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None, message_clsname='Pipeline', message=None)
________________________________________________fit_transform_one - 0.1s, 0.0min
________________________________________________________________________________
[Memory] Calling sklearn.pipeline._fit_transform_one...
```

```
_fit_transform_one(TruncatedSVD(n_components=50, n_iter=100, random_state=42),
<1657x10004 sparse matrix of type '<class 'numpy.float64'>'
        with 222430 stored elements in Compressed Sparse Row format>,
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None, message_clsname='Pipeline', message=None)
________________________________________________fit_transform_one - 6.5s, 0.1min
Best parameter (CV score=0.941):
{'clf': SVC(C=100, probability=True, random_state=42), 'dim_redu':
TruncatedSVD(n_components=50, n_iter=100, random_state=42), 'vect':
CountVectorizer(analyzer=<function lem_analyzer at 0x7f94f2d7cf80>, min_df=3)}
--- 1218.0298430919647 seconds ---
```

[ ]:

```
     mean_fit_time  std_fit_time  ...  std_test_score  rank_test_score
2         0.531304      0.253114  ...        0.011764                1
3         0.387948      0.011765  ...        0.013026                2
19        2.697049      0.827134  ...        0.011743                3
11        3.238855      0.990659  ...        0.011463                4
22        1.489608      0.227933  ...        0.015108                5
18        2.495429      0.908643  ...        0.014790                6
10        3.020311      1.090742  ...        0.014790                6
6         0.436136      0.016910  ...        0.009050                8
15        3.679011      0.405618  ...        0.006192                9
23        1.694759      0.213227  ...        0.008874               10
14        3.328627      0.256862  ...        0.016675               11
7         0.448016      0.009512  ...        0.011793               12
17        0.483318      0.074229  ...        0.007109               13
9         0.513453      0.081672  ...        0.007109               13
21        0.252493      0.009529  ...        0.010653               15
1         0.376215      0.014702  ...        0.016229               16
13        0.775213      0.129828  ...        0.008916               17
0         0.586475      0.372074  ...        0.019486               18
5         0.405036      0.016913  ...        0.013772               19
8         0.606559      0.039247  ...        0.009801               20
16        0.563161      0.029858  ...        0.009801               20
12        0.923911      0.066196  ...        0.072539               22
4         0.502856      0.089378  ...        0.077030               23
20        0.292803      0.035437  ...        0.088462               24

[24 rows x 16 columns]
```

Question 8: * Best combination: * clean data + lemmatization(min_df=3) + LSI(k=50) +

svm(C=100), mean_test_score: 0.94 * clean data + lemmatization(min_df=5) + LSI(k=50) + svm(C=100), mean_test_score: 0.933 * clean data + lemmatization(min_df=5) + LSI(k=50) + logistic regression(C=100, ‘l2’), mean_test_score: 0.933 * clean data + lemmatization(min_df=5) + LSI(k=50) + logistic regression(C=100, ‘l1’), mean_test_score: 0.932 * clean data + lemmatization(min_df=3) + NMF(k=50) + logistic regression(C=100, ‘l2’), mean_test_score: 0.93

2 Multiclass Classification

[ ]:
```
# X_train_lsi, X_test_lsi, train["leaf_label"], test["leaf_label"]
from sklearn.model_selection import train_test_split
train, test = train_test_split(df[["full_text","leaf_label"]], test_size=0.2)

train["clean_text"] = train["full_text"].apply(clean)
test["clean_text"] = test["full_text"].apply(clean)

train["lem_text"] = train["clean_text"].apply(lem_analyzer)
test["lem_text"] = test["clean_text"].apply(lem_analyzer)

from sklearn.feature_extraction.text import CountVectorizer

vectorizer = CountVectorizer(stop_words='english', min_df=3, max_df=0.7)
X_train_counts = vectorizer.fit_transform(train["lem_text"])
X_test_counts = vectorizer.transform(test["lem_text"])

from sklearn.feature_extraction.text import TfidfTransformer

tfidf_transformer = TfidfTransformer(smooth_idf=False)
X_train_tfidf = tfidf_transformer.fit_transform(X_train_counts)
X_test_tfidf = tfidf_transformer.transform(X_test_counts)


from sklearn.decomposition import TruncatedSVD
k = 50
lsi = TruncatedSVD(n_components=k, n_iter=100)
X_train_lsi = lsi.fit_transform(X_train_tfidf)
X_test_lsi = lsi.fit_transform(X_test_tfidf)
```

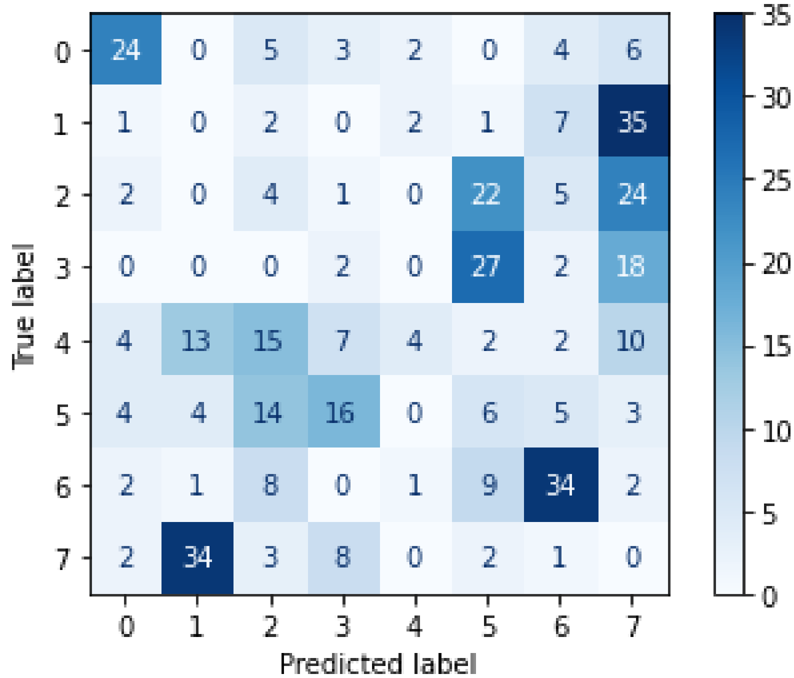
[ ]:
```
import matplotlib.pyplot as plt
from matplotlib import cm


def score(test_root_label,test_pred):
    print('confusion matrix')
    cm=confusion_matrix(test_root_label, test_pred, labels=['chess','cricket',␣
 ↪'soccer','football','%22forest%20fire%22','flood','earthquake','drought'])
    print(confusion_matrix(test_root_label, test_pred, labels=['chess','cricket',
```

```
↪'soccer','football','%22forest%20fire%22','flood','earthquake','drought']))
    print('accuracy')
    print(accuracy_score(test_root_label, test_pred))
    print('recall')
    print(recall_score(test_root_label, test_pred, average='weighted'))
    print('precision')
    print(precision_score(test_root_label, test_pred,average='weighted'))
    print('f1 score')
    print(f1_score(test_root_label, test_pred,average='weighted'))
    from sklearn.metrics import ConfusionMatrixDisplay
    disp =ConfusionMatrixDisplay(confusion_matrix=cm)
    import matplotlib.pyplot as plt
    from matplotlib import cm
    disp = disp.plot(cmap=plt.cm.Blues)
    plt.show()
```

[ ]:

```
# one vs one svm
from sklearn import svm
from sklearn.model_selection import GridSearchCV
from sklearn.multiclass import OneVsOneClassifier
params = {'estimator__C':[0.001,0.01,0.1,1,10,100,1000,10000]}
sm = OneVsOneClassifier(svm.SVC(random_state=42,class_weight='balanced'))
search = GridSearchCV(sm,params,cv=5,scoring='accuracy')
clf = search.fit(X_train_lsi.tolist(), train["leaf_label"].tolist())
test_pred=clf.best_estimator_.predict(X_test_lsi)
print(clf.best_estimator_)
score(test["leaf_label"], test_pred)
```

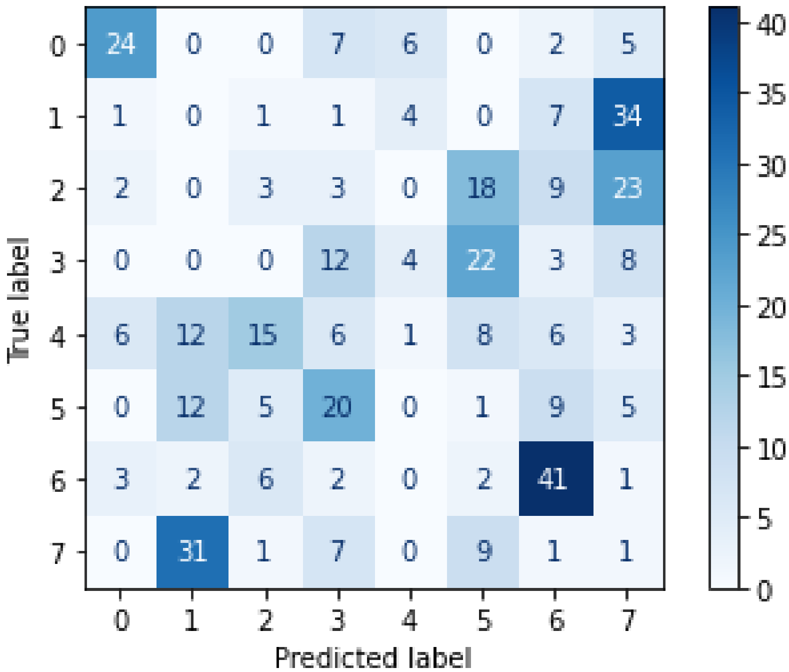
```
OneVsOneClassifier(estimator=SVC(C=10, class_weight='balanced',
                                 random_state=42))
confusion matrix
[[24  0  5  3  2  0  4  6]
 [ 1  0  2  0  2  1  7 35]
 [ 2  0  4  1  0 22  5 24]
 [ 0  0  0  2  0 27  2 18]
 [ 4 13 15  7  4  2  2 10]
 [ 4  4 14 16  0  6  5  3]
 [ 2  1  8  0  1  9 34  2]
 [ 2 34  3  8  0  2  1  0]]
accuracy
0.1783132530120482
recall
0.1783132530120482
precision
0.23236063565586257
f1 score
0.18596639630024436
```




```
[ ]: # one vs rest svm
from sklearn.multiclass import OneVsRestClassifier

params = {'estimator__C':[0.001,0.01,0.1,1,10,100,1000,10000]}
sm = OneVsRestClassifier(svm.SVC(random_state=42,class_weight='balanced'))
search = GridSearchCV(sm,params,cv=5,scoring='accuracy')
clf = search.fit(X_train_lsi.tolist(), train["leaf_label"].tolist())
test_pred=clf.best_estimator_.predict(X_test_lsi)
print(clf.best_estimator_)
score(test["leaf_label"], test_pred)
```

```
OneVsRestClassifier(estimator=SVC(C=1, class_weight='balanced',
                                  random_state=42))
confusion matrix
[[24  0  0  7  6  0  2  5]
 [ 1  0  1  1  4  0  7 34]
 [ 2  0  3  3  0 18  9 23]
 [ 0  0  0 12  4 22  3  8]
 [ 6 12 15  6  1  8  6  3]
 [ 0 12  5 20  0  1  9  5]
 [ 3  2  6  2  0  2 41  1]
 [ 0 31  1  7  0  9  1  1]]
accuracy
0.2
recall
```

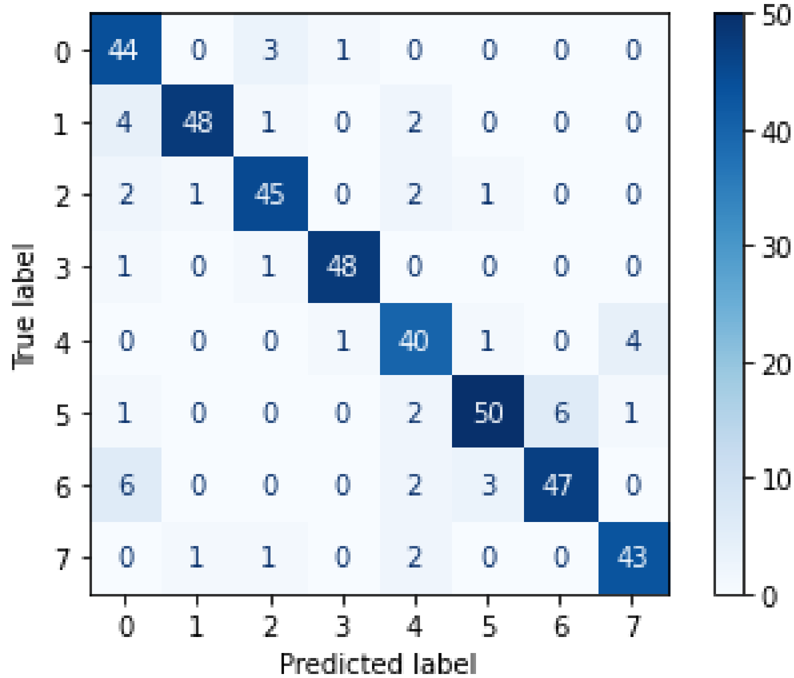
```
0.2
precision
0.19358403065500646
f1 score
0.19085331161088143
```




```
[ ]: # one vs one naive_bayes
from sklearn.naive_bayes import MultinomialNB
from sklearn.multiclass import OneVsOneClassifier
clf = OneVsOneClassifier(MultinomialNB(alpha=0.01)).fit(X_train_tfidf,␣
 ↪train["leaf_label"].tolist())
test_pred=clf.predict(X_test_tfidf)
score(test["leaf_label"].tolist(), test_pred.tolist())
```

```
confusion matrix
[[44  0  3  1  0  0  0  0]
 [ 4 48  1  0  2  0  0  0]
 [ 2  1 45  0  2  1  0  0]
 [ 1  0  1 48  0  0  0  0]
 [ 0  0  0  1 40  1  0  4]
 [ 1  0  0  0  2 50  6  1]
 [ 6  0  0  0  2  3 47  0]
 [ 0  1  1  0  2  0  0 43]]
accuracy
0.8795180722891566
```

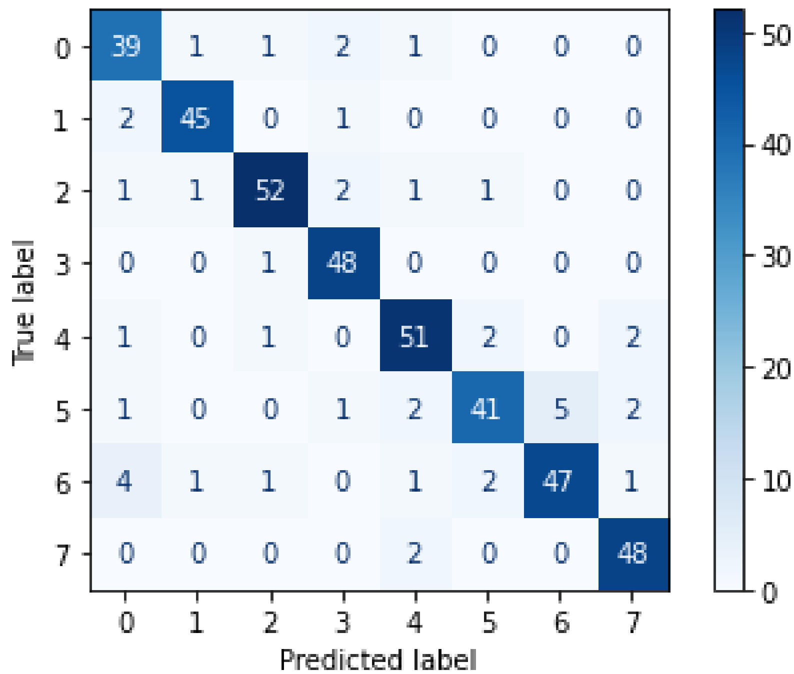
```
recall
0.8795180722891566
precision
0.8845719917583624
f1 score
0.8802566332637812
```




```
[ ]: # one vs rest naive_bayes
from sklearn.multiclass import OneVsRestClassifier
clf = OneVsRestClassifier(MultinomialNB(alpha=0.01)).fit(X_train_tfidf,␣
 ↪train["leaf_label"].tolist())
test_pred=clf.predict(X_test_tfidf)
score(test["leaf_label"], test_pred)
```

```
confusion matrix
[[39  1  1  2  1  0  0  0]
 [ 2 45  0  1  0  0  0  0]
 [ 1  1 52  2  1  1  0  0]
 [ 0  0  1 48  0  0  0  0]
 [ 1  0  1  0 51  2  0  2]
 [ 1  0  0  1  2 41  5  2]
 [ 4  1  1  0  1  2 47  1]
 [ 0  0  0  0  2  0  0 48]]
accuracy
0.8939759036144578
```

```
recall
0.8939759036144578
precision
0.8950203946794761
f1 score
0.8932799091844601
```



[ ]:
```
# merge  5 6
#train["leaf_label"].tolist()
merg_la={'earthquake':'flood'}
train_merg_leaf_la=[merg_la[i] if i in merg_la else i for i in␣
 ↪train["leaf_label"].tolist()]
test_merg_leaf_la=[merg_la[i] if i in merg_la else i for i in test["leaf_label"].
 ↪tolist()]
```

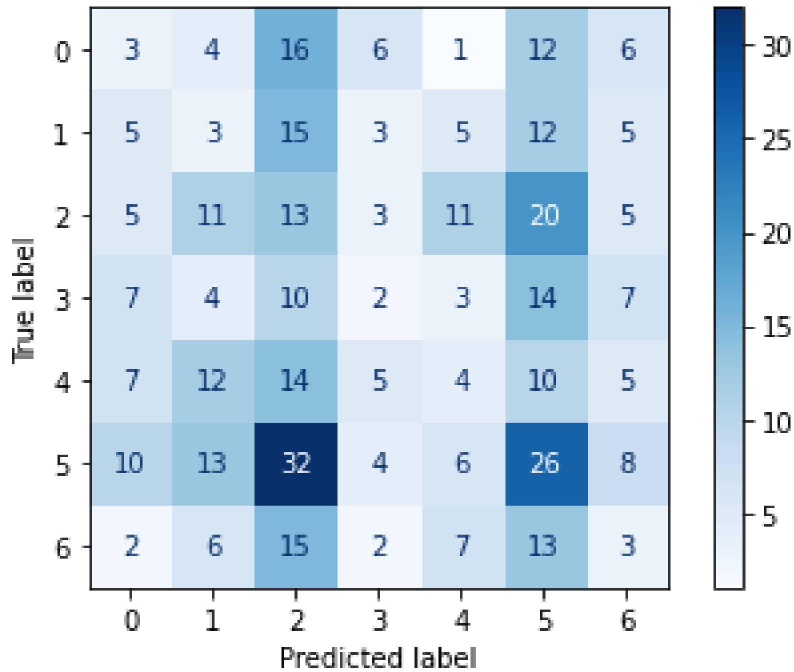
[ ]:
```
def merg_score(test_root_label,test_pred):
    print('confusion matrix')
    cm=confusion_matrix(test_root_label, test_pred, labels=['chess','cricket',
            'soccer','football','%22forest%20fire%22','flood','drought'])
    print(confusion_matrix(test_root_label, test_pred, labels=['chess','cricket',
            'soccer','football','%22forest%20fire%22','flood','drought']))
    print('accuracy')
    print(accuracy_score(test_root_label, test_pred))
    print('recall')
    print(recall_score(test_root_label, test_pred, average='weighted'))
```

```
    print('precision')
    print(precision_score(test_root_label, test_pred,average='weighted'))
    print('f1 score')
    print(f1_score(test_root_label, test_pred,average='weighted'))
    #cm=confusion_matrix(test["root_label"], test_pred)
    from sklearn.metrics import ConfusionMatrixDisplay
    disp =ConfusionMatrixDisplay(confusion_matrix=cm)
    disp.plot(cmap=plt.cm.Blues)
    plt.show()
```

[ ]:

```
# one vs one svm
from sklearn.multiclass import OneVsOneClassifier
params = {'estimator__C':[0.001,0.01,0.1,1,10,100,1000,10000]}
sm_mer = OneVsOneClassifier(svm.SVC(random_state=42,class_weight='balanced'))
search = GridSearchCV(sm_mer,params,cv=5,scoring='accuracy')
clf = search.fit(X_train_lsi.tolist(), train_merg_leaf_la)
test_pred=clf.best_estimator_.predict(X_test_lsi.tolist())
merg_score(test_merg_leaf_la, test_pred)
```

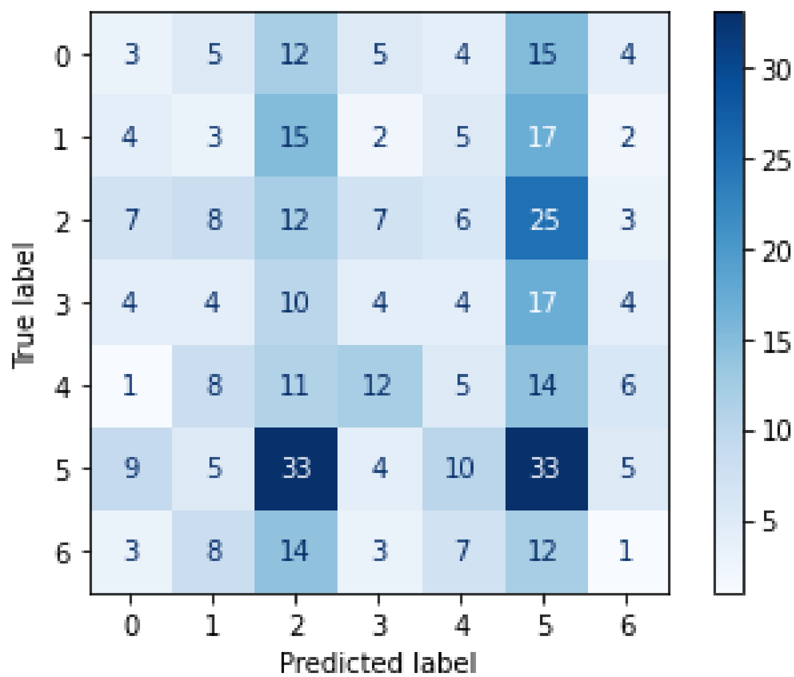
```
confusion matrix
[[ 3  4 16  6  1 12  6]
 [ 5  3 15  3  5 12  5]
 [ 5 11 13  3 11 20  5]
 [ 7  4 10  2  3 14  7]
 [ 7 12 14  5  4 10  5]
 [10 13 32  4  6 26  8]
 [ 2  6 15  2  7 13  3]]
accuracy
0.13012048192771083
recall
0.13012048192771083
precision
0.1247392529324031
f1 score
0.12430323660846719
```



[ ]:

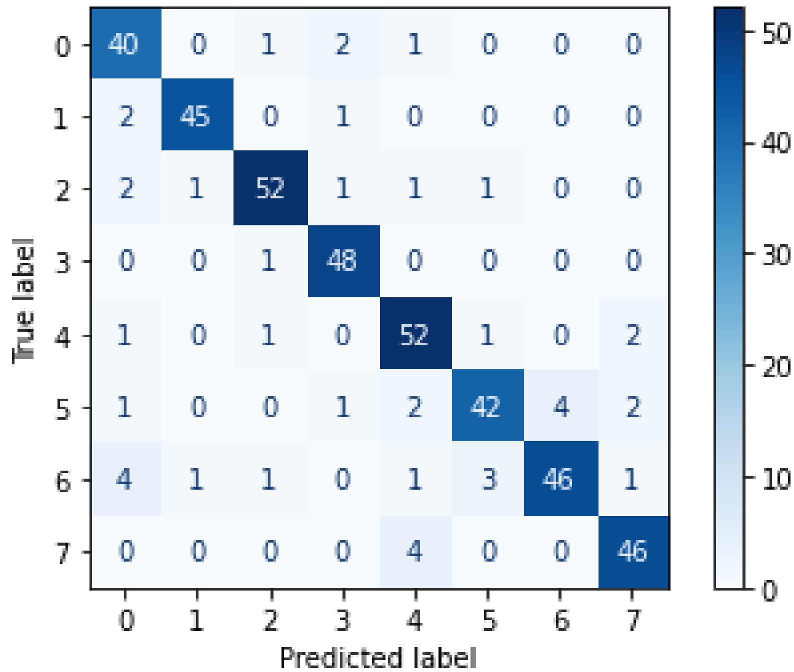
```
# one vs Rest svm
from sklearn.multiclass import OneVsRestClassifier
params = {'estimator__C':[0.001,0.01,0.1,1,10,100,1000,10000]}
sm_mer = OneVsRestClassifier(svm.SVC(random_state=42,class_weight='balanced'))
search = GridSearchCV(sm_mer,params,cv=5,scoring='accuracy')
clf = search.fit(X_train_lsi.tolist(), train_merg_leaf_la)
test_pred=clf.best_estimator_.predict(X_test_lsi.tolist())
merg_score(test_merg_leaf_la, test_pred)
```

```
confusion matrix
[[ 3  5 12  5  4 15  4]
 [ 4  3 15  2  5 17  2]
 [ 7  8 12  7  6 25  3]
 [ 4  4 10  4  4 17  4]
 [ 1  8 11 12  5 14  6]
 [ 9  5 33  4 10 33  5]
 [ 3  8 14  3  7 12  1]]
accuracy
0.14698795180722893
recall
0.14698795180722893
precision
0.13084273495008472
f1 score
0.1348882350977082
```



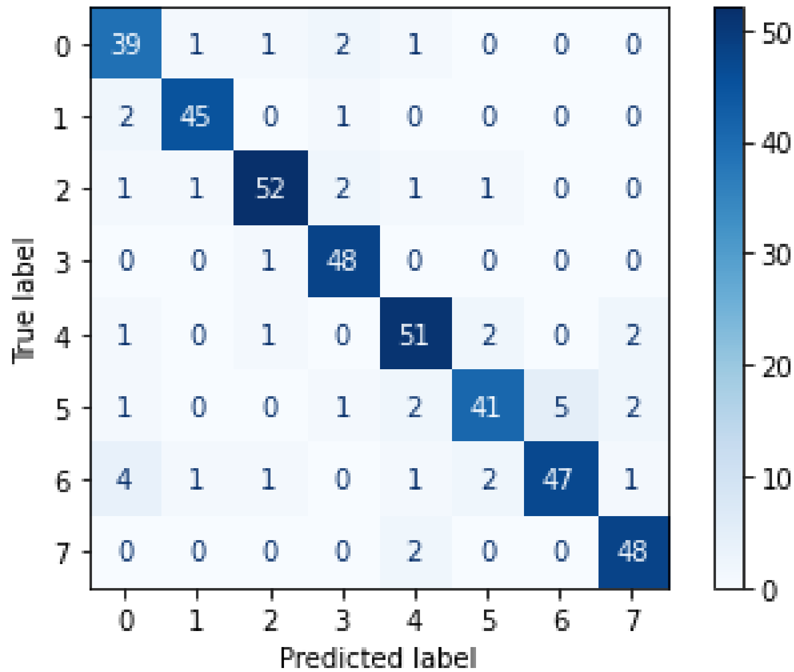
[ ]:
```
# one vs one naive_bayes
clf = OneVsOneClassifier(MultinomialNB(alpha=0.01)).fit(X_train_tfidf,␣
 ↪train["leaf_label"].tolist())
test_pred=clf.predict(X_test_tfidf)
score(test["leaf_label"].tolist(), test_pred.tolist())
```

```
confusion matrix
[[40  0  1  2  1  0  0  0]
 [ 2 45  0  1  0  0  0  0]
 [ 2  1 52  1  1  1  0  0]
 [ 0  0  1 48  0  0  0  0]
 [ 1  0  1  0 52  1  0  2]
 [ 1  0  0  1  2 42  4  2]
 [ 4  1  1  0  1  3 46  1]
 [ 0  0  0  0  4  0  0 46]]
accuracy
0.8939759036144578
recall
0.8939759036144578
precision
0.8963571961752169
f1 score
0.8936453517792432
```



[ ]:
```
# one vs rest naive_bayes
clf = OneVsRestClassifier(MultinomialNB(alpha=0.01)).fit(X_train_tfidf,␣
 ↪train["leaf_label"].tolist())
test_pred=clf.predict(X_test_tfidf)
score(test["leaf_label"].tolist(), test_pred.tolist())
```

```
confusion matrix
[[39  1  1  2  1  0  0  0]
 [ 2 45  0  1  0  0  0  0]
 [ 1  1 52  2  1  1  0  0]
 [ 0  0  1 48  0  0  0  0]
 [ 1  0  1  0 51  2  0  2]
 [ 1  0  0  1  2 41  5  2]
 [ 4  1  1  0  1  2 47  1]
 [ 0  0  0  0  2  0  0 48]]
accuracy
0.8939759036144578
recall
0.8939759036144578
precision
0.8950203946794761
f1 score
0.8932799091844601
```



[ ]:

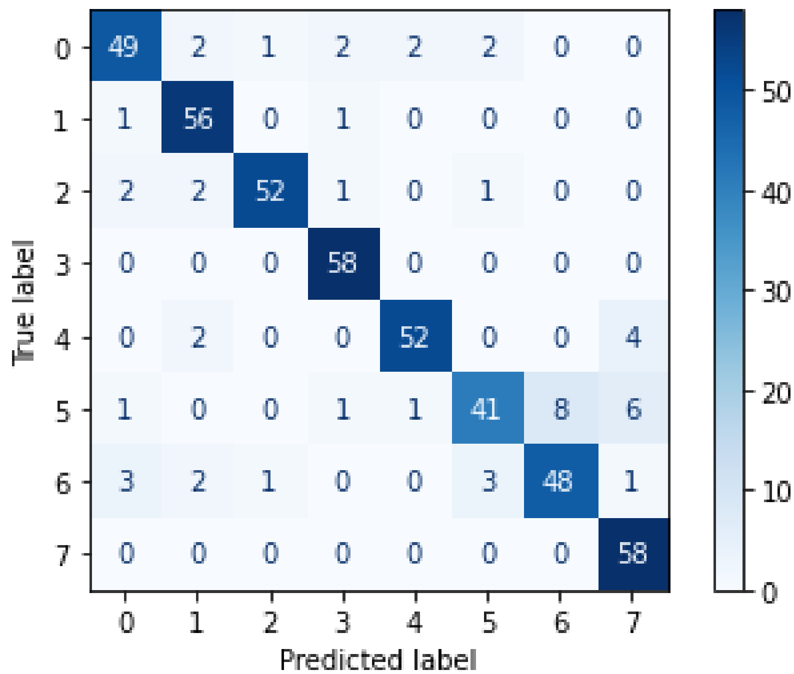
```
# class imbalance

from imblearn.over_sampling import SMOTE
sm = SMOTE(random_state=42)
train_bala, train_leaf_bala = sm.fit_resample(X_train_tfidf, train["leaf_label"].
 ↪tolist())
test_bala, test_leaf_bala = sm.fit_resample(X_test_tfidf, test["leaf_label"].
 ↪tolist())
```

[ ]:

```
# one vs one naive_bayes
#X_train_tfidf
from sklearn.multiclass import OneVsOneClassifier
clf = OneVsOneClassifier(MultinomialNB()).fit(train_bala, train_leaf_bala)
test_pred=clf.predict(test_bala)
score(test_leaf_bala, test_pred)
```

```
confusion matrix
[[49  2  1  2  2  2  0  0]
 [ 1 56  0  1  0  0  0  0]
 [ 2  2 52  1  0  1  0  0]
 [ 0  0  0 58  0  0  0  0]
 [ 0  2  0  0 52  0  0  4]
 [ 1  0  0  1  1 41  8  6]
 [ 3  2  1  0  0  3 48  1]
 [ 0  0  0  0  0  0  0 58]]
```

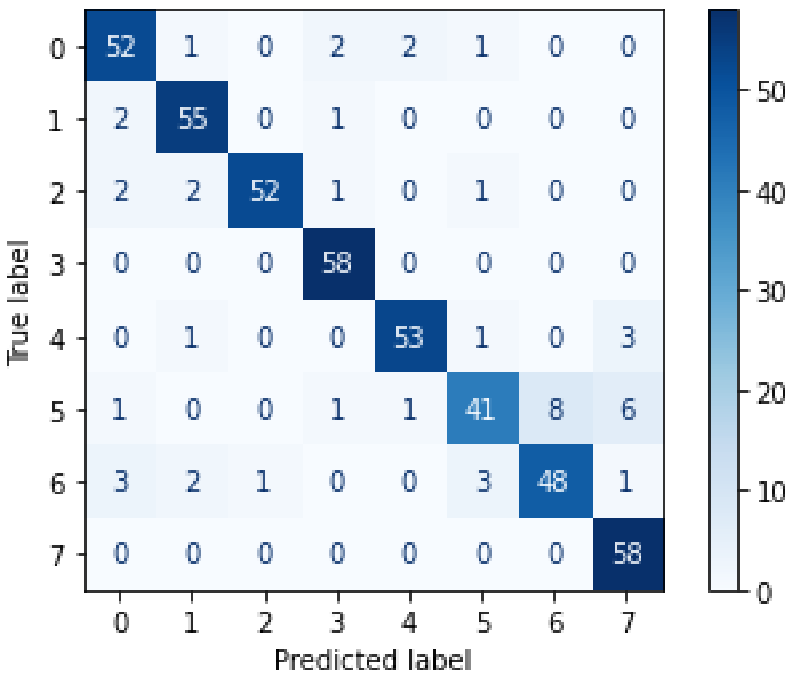
```
accuracy
0.8922413793103449
recall
0.8922413793103449
precision
0.8936394277340161
f1 score
0.890216059674615
```



[ ]:
```
# one vs rest naive_bayes
#X_train_tfidf
from sklearn.multiclass import OneVsOneClassifier
clf = OneVsRestClassifier(MultinomialNB()).fit(train_bala, train_leaf_bala)
test_pred=clf.predict(test_bala)
score(test_leaf_bala, test_pred)
```

```
confusion matrix
[[52  1  0  2  2  1  0  0]
 [ 2 55  0  1  0  0  0  0]
 [ 2  2 52  1  0  1  0  0]
 [ 0  0  0 58  0  0  0  0]
 [ 0  1  0  0 53  1  0  3]
 [ 1  0  0  1  1 41  8  6]
 [ 3  2  1  0  0  3 48  1]
 [ 0  0  0  0  0  0  0 58]]
```

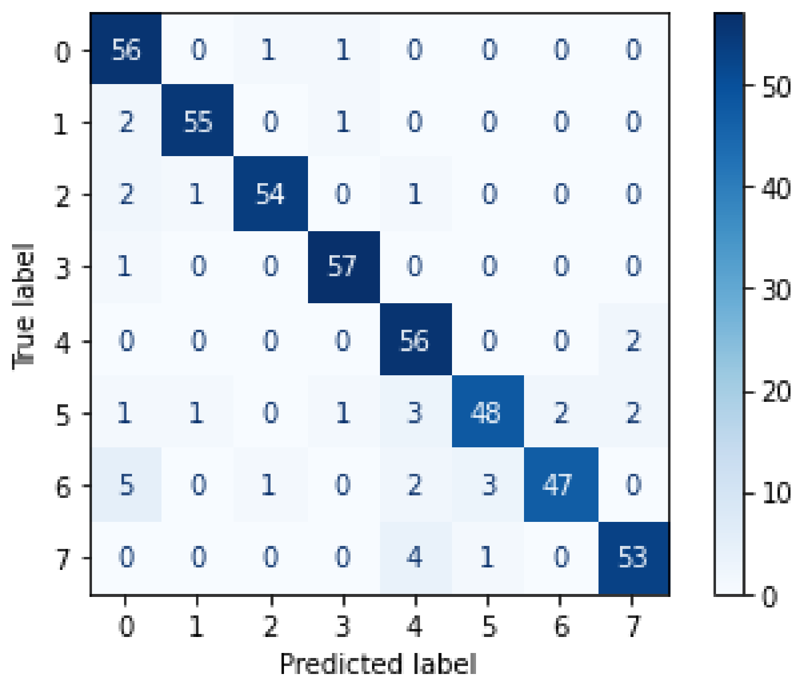
```
accuracy
0.8987068965517241
recall
0.8987068965517241
precision
0.899865754701189
f1 score
0.8968571786423256
```




```
[ ]: # one vs one svm
from sklearn.multiclass import OneVsOneClassifier
params = {'estimator__C':[0.001,0.01,0.1,1,10,100,1000,10000]}
sm_im = OneVsOneClassifier(svm.SVC(random_state=42,class_weight='balanced')).
 ↪fit(train_bala, train_leaf_bala)
search = GridSearchCV(sm_im,params,cv=5,scoring='accuracy')
clf = search.fit(train_bala, train_leaf_bala)
test_pred=clf.best_estimator_.predict(test_bala)
score(test_leaf_bala, test_pred)
```

```
confusion matrix
[[56  0  1  1  0  0  0  0]
 [ 2 55  0  1  0  0  0  0]
 [ 2  1 54  0  1  0  0  0]
 [ 1  0  0 57  0  0  0  0]
 [ 0  0  0  0 56  0  0  2]
```

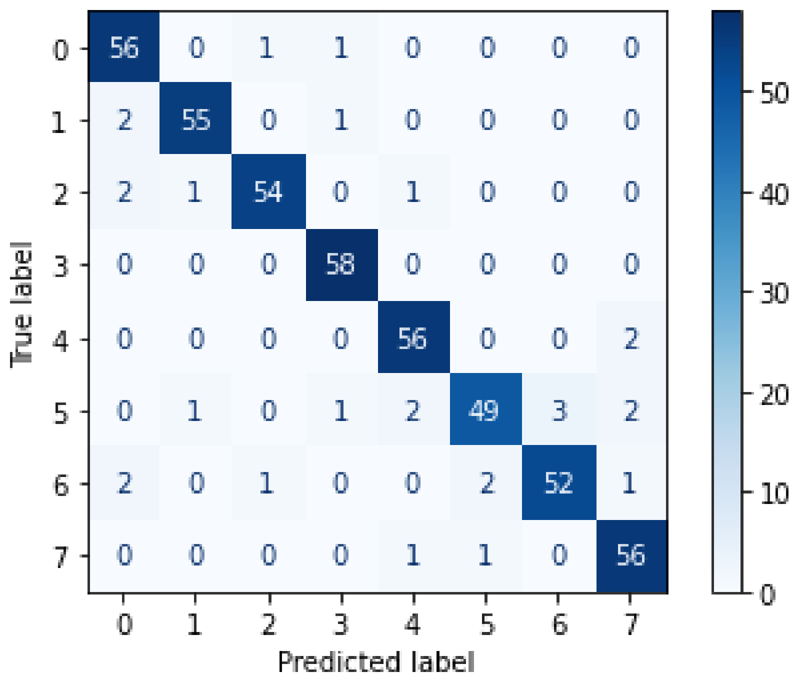
```
 [ 1  1  0  1  3 48  2  2]
 [ 5  0  1  0  2  3 47  0]
 [ 0  0  0  0  4  1  0 53]]
accuracy
0.9181034482758621
recall
0.9181034482758621
precision
0.9219486121180656
f1 score
0.9177735922011482
```



[ ]:
```
# one vs rest svm
params = {'estimator__C':[0.001,0.01,0.1,1,10,100,1000,10000]}
sm_im = OneVsRestClassifier(svm.SVC(random_state=42,class_weight='balanced')).
 ↪fit(train_bala, train_leaf_bala)
search = GridSearchCV(sm_im,params,cv=5,scoring='accuracy')
clf = search.fit(train_bala, train_leaf_bala)
test_pred=clf.best_estimator_.predict(test_bala)
score(test_leaf_bala, test_pred)
```

```
confusion matrix
[[56  0  1  1  0  0  0  0]
 [ 2 55  0  1  0  0  0  0]
 [ 2  1 54  0  1  0  0  0]
```

```
 [ 0  0  0 58  0  0  0  0]
 [ 0  0  0  0 56  0  0  2]
 [ 0  1  0  1  2 49  3  2]
 [ 2  0  1  0  0  2 52  1]
 [ 0  0  0  0  1  1  0 56]]
accuracy
0.9396551724137931
recall
0.9396551724137931
precision
0.9402964789438807
f1 score
0.9392006869567349
```



Question 9: * A good classifier should have a confusion matrix with large values on the main diagonal corresponding to high TPRs and TNRs and small values off the main diagonal corresponding to low FPRs and FNRs. The OVO and OVR Naive Bayes classifiers show this performance, but the OVO and OVR SVM classifiers have smaller values on the main diagonal and even some large values off the main diagonal, so it performs poorly at classifying most classes. * "flood" and "earthquake" classes were merged together, since the confusion matrices show that the classifiers sometimes confused these two classes, since the values just off the main diagonal are larger for these classes. Merging improved the accuracy in the OVO Naive Bayes classification but decreased the accuracy in the other cases. * Class imbalance negatively affected the performance of classifiers, and has more impact on svm than naive bayes. Therefore, before smote, svm has a smaller accuarcy than naive bayes. For example, for One VS One svm, classifier is more inclined

to predict labels as drought due to class imbalance. * Using smote and class_weight='balanced' could help solving the class imbalance problem. For instance, after smote, the accuracy of One Vs Rest svm effectively improved from 0.2 to 0.94.

3 Word Embedding

[ ]:
```
embeddings_dict = {50: {}, 100: {}, 200: {}, 300: {}}
dimension_of_glove_list = [50, 100, 200, 300]
for dimension_of_glove in dimension_of_glove_list:
    with open(f"glove/glove.6B.{dimension_of_glove}d.txt", 'r') as f:
        for line in f:
            values = line.split()
            word = values[0]
            vector = np.asarray(values[1:], "float32")
            embeddings_dict[dimension_of_glove][word] = vector
```

[ ]:
```
print(np.linalg.
 ↪norm(embeddings_dict[50]["queen"]-embeddings_dict[50]["king"]-embeddings_dict[50]["wife"]+emb
print(np.linalg.norm(embeddings_dict[50]["queen"]-embeddings_dict[50]["king"]))
print(np.linalg.norm(embeddings_dict[50]["wife"]-embeddings_dict[50]["husband"]))
v1 = embeddings_dict[50]["queen"]-embeddings_dict[50]["king"]
v2 = embeddings_dict[50]["wife"]-embeddings_dict[50]["husband"]
print(np.dot(v1,v2)/np.linalg.norm(v1)/np.linalg.norm(v2))
```

```
3.290033
3.4777563
1.7672977
0.35743952
```

Question 10: - (a) Compared to the raw probabilities, the ratio is better able to distinguish relevant words from irrelevant words and it is also better able to discriminate between the two relevant words. For example, we take i = *ice* and j = *steam*. For words k related to ice but not steam, say k = *solid*, we expect the ratio Pik/Pjk will be large. For words k like water or fashion, that are either related to both ice and steam, or to neither, the ratio should be close to one.

- (b) GLoVE embeddings will return the same vector for the word **running** in both cases. The reason is that GLoVE embeddings only give each word one vector representation which is trained on the ratio of co-occurrence probabilities.
- (c) We expect that ||GLoVE["queen"] - GLoVE["king"] - GLoVE["wife"] + GLoVE["husband"]||2 is close to 0 and ||GLoVE["queen"] - GLoVE["king"]||2 is close to ||GLoVE["wife"] - GLoVE["husband"]||2. In the above code, we print the norms of the differences of these vectors. Furthermore, we compute the cosine of the angle between GLoVE["queen"] - GLoVE["king"] and GLoVE["wife"] - GLoVE["husband"], which shows the similarity of these two vectors.
- (d) We would rather not stem or lemmatize the work before mapping it to its GLoVE embedding. The reason is that GLoVE embeddings give different vector representations for the different forms of the same word.

[ ]:
```python
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.model_selection import train_test_split

train, test = train_test_split(df, test_size=0.2)

analyzer = CountVectorizer().build_analyzer()

def text2vec(text, dimension_of_glove=50):
    count = 0
    sum = np.zeros(dimension_of_glove)
    for word in analyzer(text):
        if word in embeddings_dict[dimension_of_glove]:
            count += 1
            sum += embeddings_dict[dimension_of_glove][word]
    # return sum/count
    return sum/np.linalg.norm(sum)

train["clean_text"] = train["full_text"].apply(clean)
test["clean_text"] = test["full_text"].apply(clean)

train["text_vec"] = train["clean_text"].apply(text2vec)
test["text_vec"] = test["clean_text"].apply(text2vec)
```

[ ]:
```python
from sklearn.svm import SVC
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import accuracy_score
# clf = SVC(gamma=2.3)
# clf.fit(train["text_vec"].tolist(), train["root_label"].tolist())
# predicted = clf.predict(test["text_vec"].tolist())
parameters = {'gamma':np.arange(1,3,0.1), 'C':[2.5, 5, 10, 20]}
svc = SVC()
clf = GridSearchCV(svc, parameters)
clf.fit(train["text_vec"].tolist(), train["root_label"].tolist())
predicted = clf.predict(test["text_vec"].tolist())
print(accuracy_score(np.array(test["root_label"]), predicted))
print(clf.get_params())
```

```
0.9662650602409638
{'cv': None, 'error_score': nan, 'estimator__C': 1.0, 'estimator__break_ties':
False, 'estimator__cache_size': 200, 'estimator__class_weight': None,
'estimator__coef0': 0.0, 'estimator__decision_function_shape': 'ovr',
'estimator__degree': 3, 'estimator__gamma': 'scale', 'estimator__kernel': 'rbf',
'estimator__max_iter': -1, 'estimator__probability': False,
'estimator__random_state': None, 'estimator__shrinking': True, 'estimator__tol':
0.001, 'estimator__verbose': False, 'estimator': SVC(), 'n_jobs': None,
'param_grid': {'gamma': array([1. , 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9,
2. , 2.1, 2.2,
       2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9]), 'C': [2.5, 5, 10, 20]},
```

```
'pre_dispatch': '2*n_jobs', 'refit': True, 'return_train_score': False,
'scoring': None, 'verbose': 0}
```

[ ]:
```
print(clf.best_params_)
```

```
{'C': 20, 'gamma': 2.9000000000000017}
```

Question 11: - (a) The feature of the document is computed as follows: First, we clean the document without lemmatization. Second, we get the GLoVE word embeddings of all the words in the document. Third we compute the sum of all the word embeddings and normalize the sum into a unit vector, which is the our computed feature of the document. - (b) The above code uses SVM classifer and the accuracy is 96.63%. Here the dimension of the word embeddings is 50.

[ ]:
```
dimension_of_glove_list = [50, 100, 200, 300]
acc_list = []
for dimension_of_glove in dimension_of_glove_list:
    train["text_vec"] = train["clean_text"].apply(text2vec,␣
 ↪dimension_of_glove=dimension_of_glove)
    test["text_vec"] = test["clean_text"].apply(text2vec,␣
 ↪dimension_of_glove=dimension_of_glove)
    parameters = {'gamma':np.arange(1,3,0.1), 'C':[2.5, 5, 10, 20]}
    svc = SVC()
    clf = GridSearchCV(svc, parameters)
    clf.fit(train["text_vec"].tolist(), train["root_label"].tolist())
    predicted = clf.predict(test["text_vec"].tolist())
    acc_list.append(accuracy_score(np.array(test["root_label"]), predicted))
    print(clf.best_params_)
```

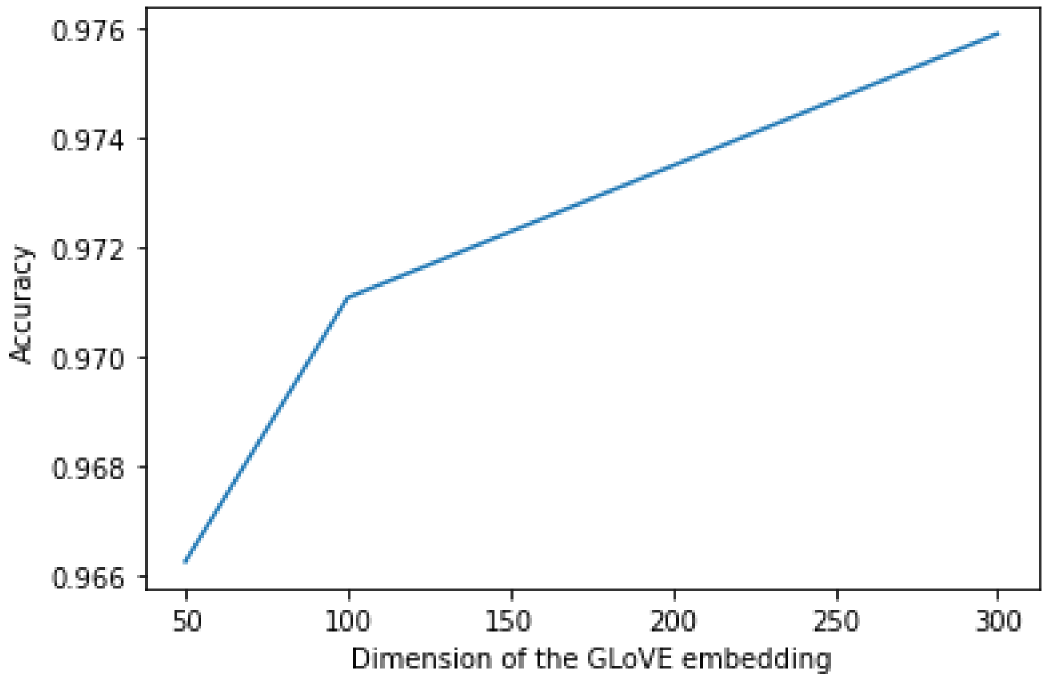
```
{'C': 20, 'gamma': 2.9000000000000017}
{'C': 20, 'gamma': 2.7000000000000015}
{'C': 10, 'gamma': 2.8000000000000016}
{'C': 10, 'gamma': 2.8000000000000016}
```

[ ]:
```
acc_list
```

[ ]:
```
[0.9662650602409638,
 0.9710843373493976,
 0.9734939759036144,
 0.9759036144578314]
```

[ ]:
```
from matplotlib import pyplot as plt
plt.plot(dimension_of_glove_list, acc_list)
plt.xlabel("Dimension of the GLoVE embedding")
plt.ylabel("Accuracy")
```

[ ]:
```
Text(0, 0.5, 'Accuracy')
```



Question 12

- The plot is shown above. We can see that as the dimension of the GLoVE embedding increases, the accuracy also increases. It is expected because higher dimension gives more representation power to the word embeddings and the computed feature of the document.

[ ]:
```
pip install umap-learn
```

```
Collecting umap-learn
  Downloading umap-learn-0.5.2.tar.gz (86 kB)
     || 86 kB 2.3 MB/s
Requirement already satisfied: numpy>=1.17 in
/usr/local/lib/python3.7/dist-packages (from umap-learn) (1.19.5)
Requirement already satisfied: scikit-learn>=0.22 in
/usr/local/lib/python3.7/dist-packages (from umap-learn) (1.0.2)
Requirement already satisfied: scipy>=1.0 in /usr/local/lib/python3.7/dist-
packages (from umap-learn) (1.4.1)
Requirement already satisfied: numba>=0.49 in /usr/local/lib/python3.7/dist-
packages (from umap-learn) (0.51.2)
Collecting pynndescent>=0.5
  Downloading pynndescent-0.5.6.tar.gz (1.1 MB)
     || 1.1 MB 29.4 MB/s
Requirement already satisfied: tqdm in /usr/local/lib/python3.7/dist-
packages (from umap-learn) (4.62.3)
Requirement already satisfied: setuptools in /usr/local/lib/python3.7/dist-
packages (from numba>=0.49->umap-learn) (57.4.0)
```

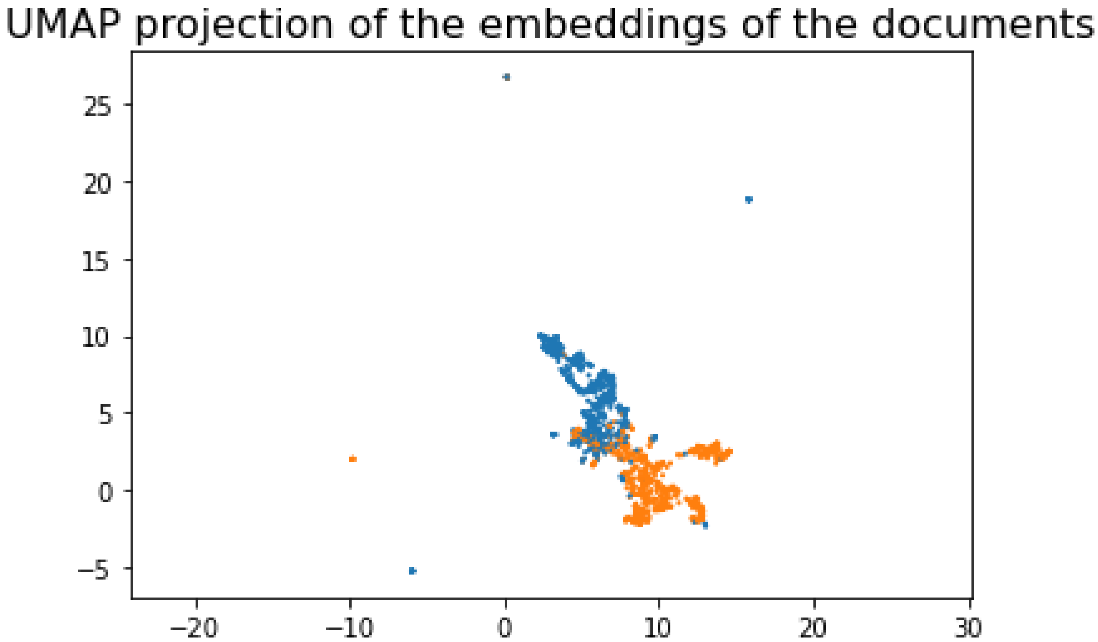
```
Requirement already satisfied: llvmlite<0.35,>=0.34.0.dev0 in
/usr/local/lib/python3.7/dist-packages (from numba>=0.49->umap-learn) (0.34.0)
Requirement already satisfied: joblib>=0.11 in /usr/local/lib/python3.7/dist-
packages (from pynndescent>=0.5->umap-learn) (1.1.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in
/usr/local/lib/python3.7/dist-packages (from scikit-learn>=0.22->umap-learn)
(3.0.0)
Building wheels for collected packages: umap-learn, pynndescent
  Building wheel for umap-learn (setup.py) ... done
  Created wheel for umap-learn: filename=umap_learn-0.5.2-py3-none-any.whl
size=82708
sha256=fe2fa333f4c7ff30c8ab5bc97dc7ac15f795907642903b8a3a10b9d706cd4872
  Stored in directory: /root/.cache/pip/wheels/84/1b/c6/aaf68a748122632967cef4df
fef68224eb16798b6793257d82
  Building wheel for pynndescent (setup.py) ... done
  Created wheel for pynndescent: filename=pynndescent-0.5.6-py3-none-any.whl
size=53943
sha256=bc9cecd3f0eec1e594e47b547fa88be189d96e6082c35b1ca7ce544f83e2f490
  Stored in directory: /root/.cache/pip/wheels/03/f1/56/f80d72741e400345b5a5b50e
c3d929aca581bf45e0225d5c50
Successfully built umap-learn pynndescent
Installing collected packages: pynndescent, umap-learn
Successfully installed pynndescent-0.5.6 umap-learn-0.5.2
```

[ ]:
```python
import umap
reducer = umap.UMAP()
embedding = reducer.fit_transform(train["text_vec"].tolist())
```

```
/usr/local/lib/python3.7/dist-packages/numba/np/ufunc/parallel.py:363:
NumbaWarning: The TBB threading layer requires TBB version 2019.5 or later i.e.,
TBB_INTERFACE_VERSION >= 11005. Found TBB_INTERFACE_VERSION = 9107. The TBB
threading layer is disabled.
  warnings.warn(problem)
```

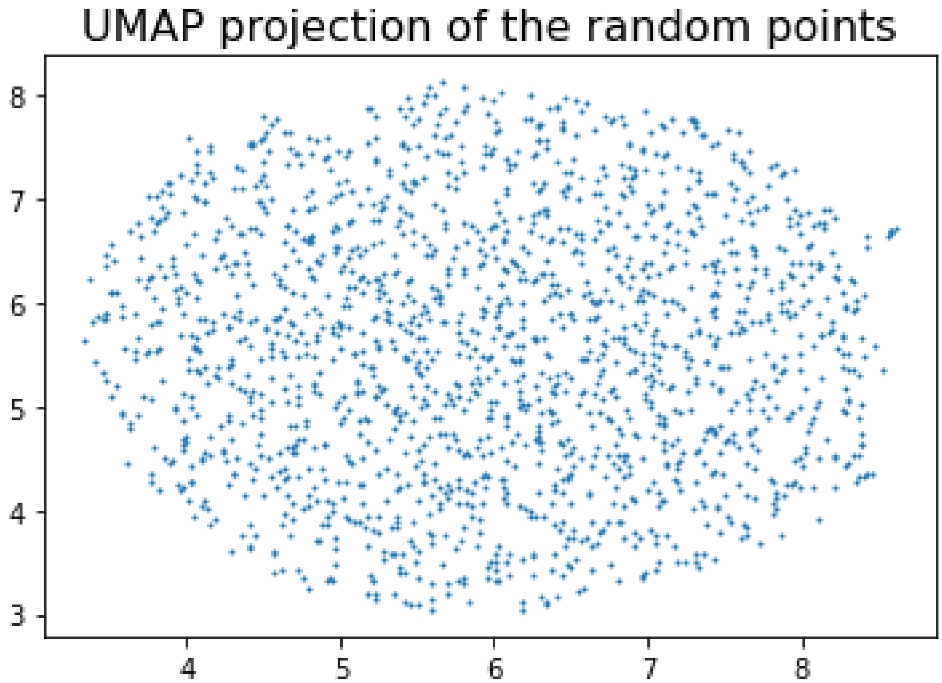
[ ]:
```python
import matplotlib.pyplot as plt
import seaborn as sns

plt.scatter(
    embedding[:, 0],
    embedding[:, 1],
    c=[sns.color_palette()[x] for x in train["root_label"].map({"sports":0,␣
 ↪"climate":1})],s=1)
plt.gca().set_aspect('equal', 'datalim')
plt.title('UMAP projection of the embeddings of the documents', fontsize=16)
```

[ ]: Text(0.5, 1.0, 'UMAP projection of the embeddings of the documents')




```
[ ]: random_points = np.random.randn(1657, 50)
     random_points = random_points/(np.linalg.norm(random_points,2, axis=1).
      ↪reshape(-1,1))
     reducer_1 = umap.UMAP()
     embedding_1 = reducer_1.fit_transform(random_points)
     plt.scatter(embedding_1[:, 0], embedding_1[:, 1], s=1)
     plt.title('UMAP projection of the random points', fontsize=16)
```

```
[ ]: Text(0.5, 1.0, 'UMAP projection of the random points')
```



Question 13

- In the visualization of the embeddings of the documents, we can see that two clusters are formed. In the visualization of the normalized random points, we can see that these points are scattered and no cluster is formed.