twitter

September 4, 2022

[1]:
```
#general packages for data manipulation
import os
import pandas as pd
import numpy as np
#visualizations
import matplotlib.pyplot as plt
import seaborn as sns
%matplotlib inline
#consistent sized plot
from pylab import rcParams
rcParams['figure.figsize']=12,5
rcParams['axes.labelsize']=12
rcParams['xtick.labelsize']=12
rcParams['ytick.labelsize']=12
#handle the warnings in the code
import warnings
warnings.filterwarnings(action='ignore',category=DeprecationWarning)
warnings.filterwarnings(action='ignore',category=FutureWarning)
#text preprocessing libraries
import nltk
from nltk.corpus import stopwords
from nltk.tokenize import word_tokenize
from nltk.tokenize import sent_tokenize
from nltk.tokenize import WordPunctTokenizer
from nltk.tokenize import TweetTokenizer
from nltk.stem import WordNetLemmatizer
from nltk.stem import PorterStemmer
#import texthero
#import texthero as hero
#regular expressions
import re
#display pandas dataframe columns
pd.options.display.max_columns = None
```

[2]:
```
#load the csv file as a pandas dataframe
#ISO-8859-1
tweet = pd.read_csv('TwitterHate.
 ↪csv',delimiter=',',engine='python',encoding='utf-8-sig')
```

```
tweet.head()
```

[2]:
```
   id  label                                              tweet
0   1      0   @user when a father is dysfunctional and is s…
1   2      0  @user @user thanks for #lyft credit i can't us…
2   3      0                                bihday your majesty
3   4      0  #model   i love u take with u all the time in …
4   5      0             factsguide: society now    #motivation
```

[3]:
```
#get rid of the identifier number of the tweet
tweet.drop('id',axis=1,inplace=True)
```

[4]:
```
#view one of the tweets randomly
random = np.random.randint(0,len(tweet))
print(random)
tweet.iloc[random]['tweet']
```

```
1167
```

[4]:
```
'happy feet #kid#color#withgranny
feet#baby#sweet#welcomechamp#canon#50mm#nepal#kathmandu '
```

[5]:
```
#create a copy of the original data to work with
df = tweet.copy()
```

## Text Cleaning

### Handle Diacritics using text normalization

[6]:
```
def simplify(text):
    '''Function to handle the diacritics in the text'''
    import unicodedata
    try:
        text = unicode(text, 'utf-8')
    except NameError:
        pass
    text = unicodedata.normalize('NFD', text).encode('ascii', 'ignore').
 ↪decode("utf-8")
    return str(text)
```

[7]:
```
df['tweet'] = df['tweet'].apply(simplify)
```

### Remove user handles

[8]:
```
#test on a sample string
sample = "and @user1 i would like you to discuss with @user2 and then with␣
 ↪@username3"
pattern = re.compile(r'@\w+')
re.findall(pattern,sample)
```

```
[8]: ['@user1', '@user2', '@username3']
```

```
[9]: #remove all the user handles --> strings starting with @
     df['tweet'].replace(r'@\w+','',regex=True,inplace=True)
```

### *Remove the urls*

```
[10]: #test on a sample
      sample = "https://www.machinelearing.com prakhar and https://www.simple.com"
      pattern = re.compile(r'http\S+')
      re.findall(pattern,sample)
```

```
[10]: ['https://www.machinelearing.com', 'https://www.simple.com']
```

```
[11]: df['tweet'].replace(r'http\S+','',regex=True,inplace=True)
```

### *Tokenize using tweet tokenizer*

```
[12]: #test on a sample text
      sample = 'wonderfl :-)  when are you coming for #party'
      tweet_tokenize = TweetTokenizer(preserve_case=True)
      tweet_tokenize.tokenize(sample)
```

```
[12]: ['wonderfl', ':-)', 'when', 'are', 'you', 'coming', 'for', '#party']
```

```
[13]: #tokenize the tweets in the dataframe using TweetTokenizer
      tokenizer = TweetTokenizer(preserve_case=True)
      df['tweet'] = df['tweet'].apply(tokenizer.tokenize)
```

```
[14]: #view the tokenized tweets
      df.head(3)
```

```
[14]:    label                                              tweet
      0      0  [when, a, father, is, dysfunctional, and, is, …
      1      0  [thanks, for, #lyft, credit, i, can't, use, ca…
      2      0                            [bihday, your, majesty]
```

### *Remove Stopwords Append more words to be removed from the text - example rt and amp which occur very frequently*

```
[15]: stop_words = stopwords.words('english')

      #add additional stop words to be removed from the text
      additional_list = ['amp','rt','u',"can't",'ur']

      for words in additional_list:
          stop_words.append(words)
```

```
[16]: stop_words[-10:]
```

```
[16]: ["weren't",
       'won',
       "won't",
       'wouldn',
       "wouldn't",
       'amp',
       'rt',
       'u',
       "can't",
       'ur']
```

```
[17]: #remove stop words
      def remove_stopwords(text):
          '''Function to remove the stop words from the text corpus'''
          clean_text = [word for word in text if not word in stop_words]
          return clean_text
```

```
[18]: #remove the stop words from the tweets
      df['tweet'] = df['tweet'].apply(remove_stopwords)
```

```
[19]: df['tweet'].head()
```

```
[19]: 0    [father, dysfunctional, selfish, drags, kids, …
      1    [thanks, #lyft, credit, use, cause, offer, whe…
      2                                  [bihday, majesty]
      3                 [#model, love, take, time, !, !, !]
      4               [factsguide, :, society, #motivation]
      Name: tweet, dtype: object
```

### Spelling corrections

```
[20]: #apply spelling correction on a sample text
      from textblob import TextBlob
      sample = 'amazng man you did it finallyy'
      txtblob = TextBlob(sample)
      corrected_text = txtblob.correct()
      print(corrected_text)
```

```
amazing man you did it finally
```

```
[21]: #textblob expect a string to be passed and not a list of strings
      from textblob import TextBlob

      def spell_check(text):
          '''Function to do spelling correction using '''
          txtblob = TextBlob(text)
          corrected_text = txtblob.correct()
          return corrected_text
```

```
```

### Remove # symbols while retaining the text

```
[22]: #try tremoving # symbols from a sample text
      sample = '#winner #machine i am learning'
      pattern = re.compile(r'#')
      re.sub(pattern,'',sample)

[22]: 'winner machine i am learning'

[23]: def remove_hashsymbols(text):
          '''Function to remove the hashtag symbol from the text'''
          pattern = re.compile(r'#')
          text = ' '.join(text)
          clean_text = re.sub(pattern,'',text)
          return tokenizer.tokenize(clean_text)

[24]: df['tweet'] = df['tweet'].apply(remove_hashsymbols)

[25]: df.head(3)

[25]:    label                                             tweet
      0      0  [father, dysfunctional, selfish, drags, kids, …
      1      0  [thanks, lyft, credit, use, cause, offer, whee…
      2      0                               [bihday, majesty]
```

### Remove single and double length characters

```
[26]: def rem_shortwords(text):
          '''Function to remove the short words of length 1 and 2 characters'''
          '''Arguments:
             text: string
             returns: string without containing words of length 1 and 2'''
          lengths = [1,2]
          new_text = ' '.join(text)
          for word in text:
              text = [word for word in tokenizer.tokenize(new_text) if not len(word)␣
       ↪in lengths]

          return new_text

[27]: df['tweet'] = df['tweet'].apply(rem_shortwords)

[28]: df.head(2)
```

[28]:
```
   label                                              tweet
0      0  father dysfunctional selfish drags kids dysfun…
1      0  thanks lyft credit use cause offer wheelchair …
```

[29]:
```
df['tweet'] = df['tweet'].apply(tokenizer.tokenize)
```

[30]:
```
df.head(3)
```

[30]:
```
   label                                              tweet
0      0  [father, dysfunctional, selfish, drags, kids, …
1      0  [thanks, lyft, credit, use, cause, offer, whee…
2      0                                [bihday, majesty]
```

### Remove digits

[31]:
```
def rem_digits(text):
    '''Function to remove the digits from the list of strings'''
    no_digits = []
    for word in text:
        no_digits.append(re.sub(r'\d','',word))
    return ' '.join(no_digits)
```

[32]:
```
df['tweet'] = df['tweet'].apply(rem_digits)
```

[33]:
```
df['tweet'] = df['tweet'].apply(tokenizer.tokenize)
```

[34]:
```
df.head()
```

[34]:
```
   label                                              tweet
0      0  [father, dysfunctional, selfish, drags, kids, …
1      0  [thanks, lyft, credit, use, cause, offer, whee…
2      0                                [bihday, majesty]
3      0                 [model, love, take, time, !, !, !]
4      0               [factsguide, :, society, motivation]
```

### Remove special characters

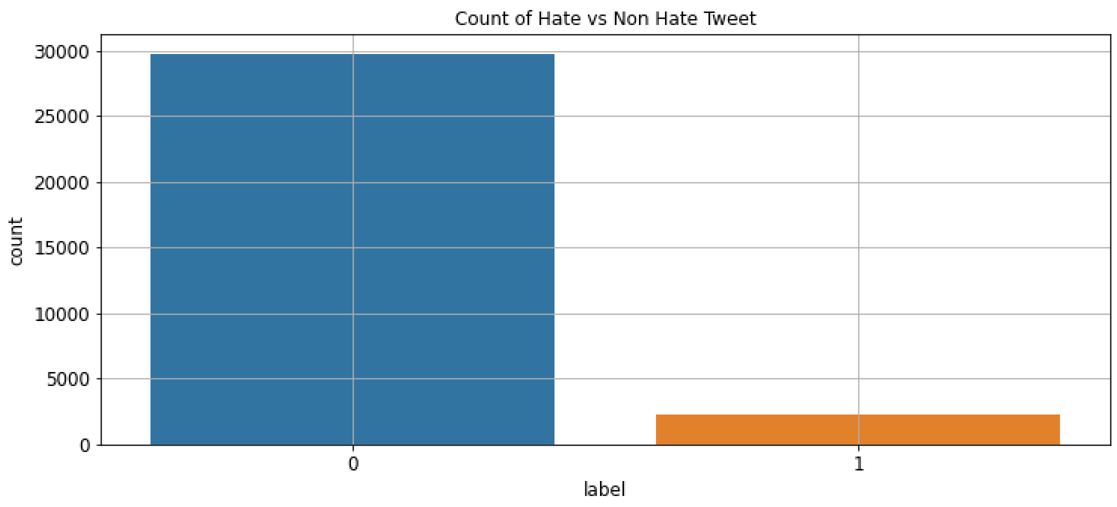
[35]:
```
def rem_nonalpha(text):
    '''Function to remove the non-alphanumeric characters from the text'''
    text = [word for word in text if word.isalpha()]
    return text
```

[36]:
```
#remove the non alpha numeric characters from the tweet tokens
df['tweet'] = df['tweet'].apply(rem_nonalpha)
```

## Exploratory Data Analysis - Broad Approach

### Check for data balance

[37]:
```
#plot of the count of hate and non hate tweet
sns.countplot(df['label'])
plt.title('Count of Hate vs Non Hate Tweet')
plt.grid()
plt.show()
```



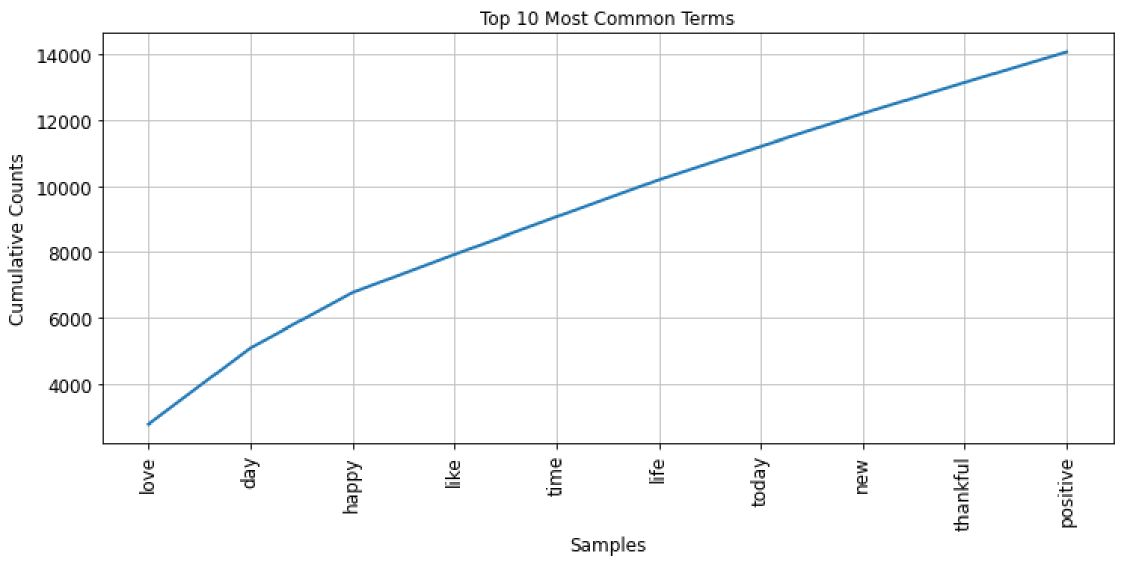
There are more non hatespeeches than the hatespeech in the dataset

### *Check out the top terms in the tweets*

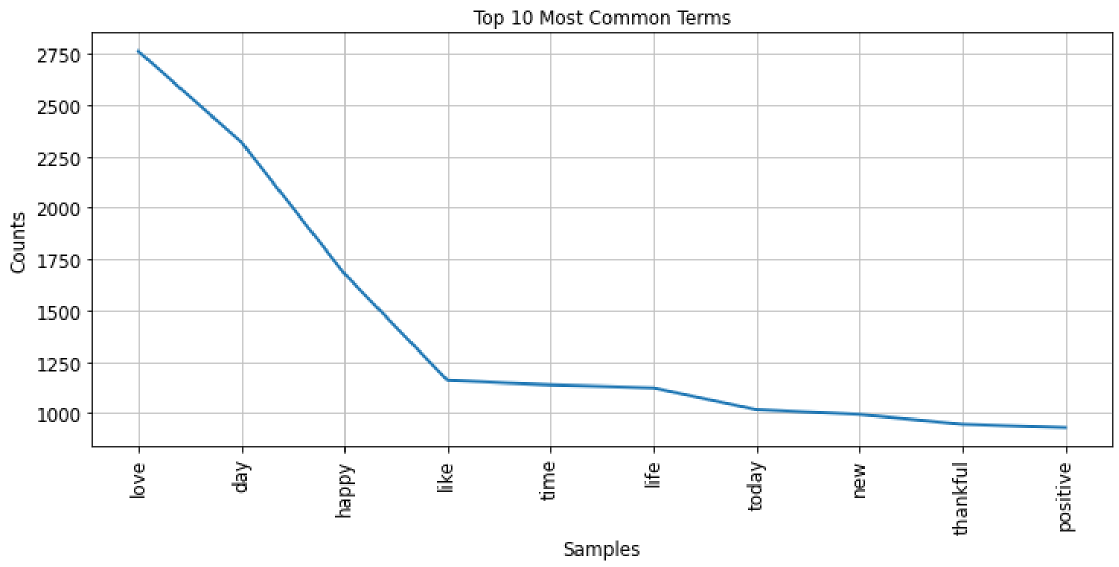
[38]:
```
from collections import Counter
results = Counter()
df['tweet'].apply(results.update)
#print the top 10 most common terms in the tweet
print(results.most_common(10))
```

```
[('love', 2762), ('day', 2319), ('happy', 1679), ('like', 1160), ('time', 1138),
('life', 1124), ('today', 1017), ('new', 994), ('thankful', 947), ('positive',
931)]
```

[39]:
```
#plot the cumulative frequency of the top 10 most common tokens
frequency = nltk.FreqDist(results)
plt.title('Top 10 Most Common Terms')
frequency.plot(10,cumulative=True)
plt.show()
```



[40]:
```
#plot the frequency of the top 10 most common tokens
frequency = nltk.FreqDist(results)
plt.title('Top 10 Most Common Terms')
frequency.plot(10,cumulative=False)
plt.show()
```



Love is the most frequently used word followed by day, happy etc. This is expected as there are more non hate tweets than hate tweets in the dataset

## Predictive Modeling

0.0.1 *Data Formatting for Predictive Modeling*

[41]:
```
df.head()
```

[41]:
```
   label                                              tweet
0      0  [father, dysfunctional, selfish, drags, kids, …
1      0  [thanks, lyft, credit, use, cause, offer, whee…
2      0                                  [bihday, majesty]
3      0                         [model, love, take, time]
4      0                [factsguide, society, motivation]
```

[42]:
```
#check for the null values
df.isnull().sum()
```

[42]:
```
label    0
tweet    0
dtype: int64
```

[43]:
```
#join the tokens back to form the string
df['tweet'] = df['tweet'].apply(lambda x: ' '.join(x))
```

[44]:
```
#check the top rows
df.head(3)
```

[44]:
```
   label                                              tweet
0      0  father dysfunctional selfish drags kids dysfun…
1      0  thanks lyft credit use cause offer wheelchair …
2      0                                    bihday majesty
```

[45]:
```
#split the data into input X and output y
X = df['tweet']
y = df['label']
```

[46]:
```
#split the data
from sklearn.model_selection import train_test_split
seed = 51
test_size = 0.2 #20% of the data in the
X_train,X_test,y_train,y_test = train_test_split(X,y,test_size=0.
 ↪2,random_state=seed,stratify=df['label'])
print(X_train.shape,X_test.shape,y_train.shape,y_test.shape)
```

```
(25569,) (6393,) (25569,) (6393,)
```

### *Use tf-idf as a feature to get into the vector space model*

[47]:
```
#import tfidf vectorizer
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.feature_extraction.text import TfidfTransformer
```

[48]:
```
#instantiate the vectorizer
vectorizer = TfidfVectorizer(max_features=5000)
```

[49]:
```
print(X_train.head())
print(X_test.head())
```

```
2732        kicks today check full list guests see weekend
9850     looking forward another great day tomorrow w t…
25413    wedding planning got like engaged somuch stressed
1527       thankful honest conversations thankful positive
1700     billy goat trail outdoor education flashbacks …
Name: tweet, dtype: object
16773    debut album released tomorrow good parentmcr g…
23570    good morning saturday exercise energy producti…
901      rest peace christinagrimmie loss rip missed fa…
30077                       great seats waiting boston comedya
13876    trying two days tuckoninstagram juneinstaspank…
Name: tweet, dtype: object
```

[50]:
```
#fit on the training data
X_train = vectorizer.fit_transform(X_train)
#transform the test data
X_test = vectorizer.transform(X_test)
```

[51]:
```
#check the shape
X_train.shape, X_test.shape
```

[51]:
```
((25569, 5000), (6393, 5000))
```

### *Model building: Ordinary Logistic Regression*

[52]:
```
#import the models
from sklearn.linear_model import LogisticRegression
from sklearn.naive_bayes import MultinomialNB
```

[53]:
```
#instantiate the models with default hyper-parameters
clf = LogisticRegression()
clf.fit(X_train,y_train)
train_predictions = clf.predict(X_train)
test_predictions = clf.predict(X_test)
```

### *Model evaluation*

[54]:
```
#import the metrics
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix
```

[55]:
```
#get the model accuracy on the training and the test set
print('Accuracy Score on training set %.5f'␣
 ↪%accuracy_score(y_train,train_predictions))
print('Accuracy Score on test set %.5f'␣
 ↪%accuracy_score(y_test,test_predictions))
```

```
Accuracy Score on training set 0.95569
Accuracy Score on test set 0.94791
```

Accuracy is never a good metric for an imbalanced dataset as in this case. This can be highighted using the f1 score. A low f1-score for a label indicate poor performance of the model.

[56]:
```
print('Classification Report Training set')
print('\n')
print(classification_report(y_train,train_predictions))
```

```
Classification Report Training set


              precision    recall  f1-score   support

           0       0.96      1.00      0.98     23775
           1       0.95      0.39      0.55      1794

    accuracy                           0.96     25569
   macro avg       0.95      0.69      0.76     25569
weighted avg       0.96      0.96      0.95     25569
```

[57]:
```
print('Classification Report Testing set')
print('\n')
print(classification_report(y_test,test_predictions))
```

```
Classification Report Testing set


              precision    recall  f1-score   support

           0       0.95      1.00      0.97      5945
           1       0.90      0.29      0.44       448

    accuracy                           0.95      6393
   macro avg       0.93      0.64      0.70      6393
weighted avg       0.95      0.95      0.94      6393
```

The model's f1-score is low for label 1 which indicates the hate text in the twitter

### Weighted Logistic Regression Or Cost Sensitive Logistic Regression

```
[58]: df['label'].value_counts()
```

```
[58]: 0    29720
      1     2242
      Name: label, dtype: int64
```

The minority to majority class ratio is 1:13

```
[59]: #define the weight of the class labels using inverse ratio
      weights = {0:1.0,1:13.0}

      #instantiate the logistic regression model and account for the weights to be␣
       ↪applied for model coefficients update magnitude
      clf = LogisticRegression(solver='lbfgs',class_weight=weights)

      #fit and predict
      clf.fit(X_train,y_train)
      train_predictions = clf.predict(X_train)
      test_predictions = clf.predict(X_test)

      #classification report
      print('Classification Report Training set')
      print('------------------------------------')
      print('\n')
      print(classification_report(y_train,train_predictions))
      print('\n')

      print('Classification Report Testing set')
      print('------------------------------------')
      print('\n')
      print(classification_report(y_test,test_predictions))
```

```
Classification Report Training set
------------------------------------


              precision    recall  f1-score   support

           0       1.00      0.95      0.97     23775
           1       0.60      0.98      0.74      1794

    accuracy                           0.95     25569
   macro avg       0.80      0.96      0.86     25569
weighted avg       0.97      0.95      0.96     25569



Classification Report Testing set
```

```
------------------------------------

              precision    recall  f1-score   support

           0       0.98      0.94      0.96      5945
           1       0.48      0.75      0.58       448

    accuracy                           0.92      6393
   macro avg       0.73      0.84      0.77      6393
weighted avg       0.94      0.92      0.93      6393
```

The f1 score of both the training and testing set has improved compared to the plain vanilla Logistic Regression model. There is still more opportunity to improve the score using better models or even handling the data imbalance by adding synthetic data

### Regularization and Hyperparameter tuning:

[60]:
```
#import the required libraries for grid search
from sklearn.model_selection import RandomizedSearchCV
from sklearn.model_selection import StratifiedKFold
from sklearn.model_selection import cross_val_score
```

[61]:
```
# define search space
from scipy.stats import loguniform
space = dict()
space['solver'] = ['newton-cg', 'lbfgs', 'liblinear']
space['penalty'] = ['l1', 'l2', 'elasticnet']
space['C'] = loguniform(1e-5, 100)
```

[62]:
```
#check the search space
print(space)
```

```
{'solver': ['newton-cg', 'lbfgs', 'liblinear'], 'penalty': ['l1', 'l2',
'elasticnet'], 'C': <scipy.stats._distn_infrastructure.rv_frozen object at
0x13cccaa60>}
```

### Fine tuned Model with Balanced Class Weights

[63]:
```
#define the model with balanced class weights
weights = {0:1.0,1:1.0}
clf = LogisticRegression(class_weight=weights, random_state=seed)
#define the number of folds
folds = StratifiedKFold(n_splits=4)
# define search
grid_search = RandomizedSearchCV(estimator=clf,param_distributions=space,␣
 ↪n_iter=100, scoring='recall',
                            n_jobs=-1, cv=folds, random_state=seed)
```

```python
#fit grid search on the train data
grid_result = grid_search.fit(X_train,y_train)
```

```
/usr/local/lib/python3.9/site-packages/sklearn/linear_model/_logistic.py:814:
ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/usr/local/lib/python3.9/site-packages/sklearn/svm/_base.py:1206:
ConvergenceWarning: Liblinear failed to converge, increase the number of
iterations.
  warnings.warn(
/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py:372: FitFailedWarning:
248 fits failed out of a total of 400.
The score on these train-test partitions for these parameters will be set to
nan.
If these failures are not expected, you can try to debug them by setting
error_score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------------
52 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 447, in _check_solver
    raise ValueError(
ValueError: Solver lbfgs supports only 'l2' or 'none' penalties, got l1 penalty.

--------------------------------------------------------------------------------
80 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
```

```
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 447, in _check_solver
    raise ValueError(
ValueError: Solver newton-cg supports only 'l2' or 'none' penalties, got l1
penalty.

--------------------------------------------------------------------------------
40 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 447, in _check_solver
    raise ValueError(
ValueError: Solver newton-cg supports only 'l2' or 'none' penalties, got
elasticnet penalty.

--------------------------------------------------------------------------------
32 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 457, in _check_solver
    raise ValueError(
ValueError: Only 'saga' solver supports elasticnet penalty, got
solver=liblinear.

--------------------------------------------------------------------------------
44 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 447, in _check_solver
```

```
    raise ValueError(
ValueError: Solver lbfgs supports only 'l2' or 'none' penalties, got elasticnet
penalty.

  warnings.warn(some_fits_failed_message, FitFailedWarning)
/usr/local/lib/python3.9/site-packages/sklearn/model_selection/_search.py:969:
UserWarning: One or more of the test scores are non-finite: [0.19733336
nan 0.          0.                 nan        nan
        nan 0.                 nan        nan        nan 0.
 0.51894463 0.                 nan 0.         0.37571091        nan
 0.57468357 0.56018707         nan 0.58749975 0.18729866        nan
        nan 0.                 nan        nan 0.         0.
        nan 0.51058404         nan        nan        nan        nan
        nan        nan 0.         0.         0.                 nan
 0.                nan        nan        nan        nan        nan
        nan        nan        nan        nan 0.1984544          nan
        nan        nan        nan 0.                  nan        nan
 0.52952991        nan 0.         0.         0.                 nan
        nan        nan        nan        nan 0.59865425         nan
        nan        nan        nan 0.         0.00334697 0.
        nan 0.29990629         nan 0.29544325        nan        nan
        nan        nan        nan 0.04013259        nan        nan
        nan 0.47881577 0.                 nan        nan        nan
        nan        nan 0.59809994 0.55070792]
  warnings.warn(
```

[64]:
```
#retrieve the best model
grid_result.best_estimator_
```

[64]:
```
LogisticRegression(C=23.871926754399514, class_weight={0: 1.0, 1: 1.0},
                   penalty='l1', random_state=51, solver='liblinear')
```

[65]:
```
#instantiate the best model
clf = LogisticRegression(C=23.
↪871926754399514,penalty='l1',solver='liblinear',class_weight=weights)
```

[66]:
```
#fit and predict
clf.fit(X_train,y_train)
train_predictions = clf.predict(X_train)
test_predictions = clf.predict(X_test)

#classification report
print('Classification Report Training set')
print('-------------------------------------')
print('\n')
print(classification_report(y_train,train_predictions))
print('\n')
print('Classification Report Testing set')
print('------------------------------------')
print('\n')
print(classification_report(y_test,test_predictions))
```

```
Classification Report Training set
------------------------------------


              precision    recall  f1-score   support

           0       0.99      1.00      1.00     23775
           1       0.98      0.93      0.95      1794

    accuracy                           0.99     25569
   macro avg       0.99      0.96      0.97     25569
weighted avg       0.99      0.99      0.99     25569



Classification Report Testing set
------------------------------------


              precision    recall  f1-score   support

           0       0.97      0.97      0.97      5945
           1       0.62      0.56      0.59       448

    accuracy                           0.94      6393
   macro avg       0.79      0.77      0.78      6393
weighted avg       0.94      0.94      0.94      6393
```

### Fine tuned model with class weights proportional to the class imbalance

[67]:
```
#use the class weights to handle the imbalance in the labels
weights = {0:1.0,1:13}

clf = LogisticRegression(class_weight=weights, random_state=seed)
#define the number of folds
folds = StratifiedKFold(n_splits=4)#,random_state=seed)
# define search
grid_search = RandomizedSearchCV(estimator=clf,param_distributions=space,␣
↪n_iter=100, scoring='recall',
                            n_jobs=-1, cv=folds, random_state=seed)
#fit grid search on the train data
grid_result = grid_search.fit(X_train,y_train)
```

```python
#retrieve the best model
grid_result.best_estimator_
```

```
/usr/local/lib/python3.9/site-packages/sklearn/linear_model/_logistic.py:814:
ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/usr/local/lib/python3.9/site-packages/sklearn/linear_model/_logistic.py:814:
ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/usr/local/lib/python3.9/site-packages/sklearn/linear_model/_logistic.py:814:
ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/usr/local/lib/python3.9/site-packages/sklearn/linear_model/_logistic.py:814:
ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py:372: FitFailedWarning:
248 fits failed out of a total of 400.
The score on these train-test partitions for these parameters will be set to
```

```
nan.
If these failures are not expected, you can try to debug them by setting
error_score='raise'.

Below are more details about the failures:
--------------------------------------------------------------------------------
52 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 447, in _check_solver
    raise ValueError(
ValueError: Solver lbfgs supports only 'l2' or 'none' penalties, got l1 penalty.

--------------------------------------------------------------------------------
80 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 447, in _check_solver
    raise ValueError(
ValueError: Solver newton-cg supports only 'l2' or 'none' penalties, got l1
penalty.

--------------------------------------------------------------------------------
40 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 447, in _check_solver
    raise ValueError(
ValueError: Solver newton-cg supports only 'l2' or 'none' penalties, got
elasticnet penalty.
```

```
--------------------------------------------------------------------------------
32 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 457, in _check_solver
    raise ValueError(
ValueError: Only 'saga' solver supports elasticnet penalty, got
solver=liblinear.

--------------------------------------------------------------------------------
44 fits failed with the following error:
Traceback (most recent call last):
  File "/usr/local/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 680, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 1461, in fit
    solver = _check_solver(self.solver, self.penalty, self.dual)
  File "/usr/local/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py", line 447, in _check_solver
    raise ValueError(
ValueError: Solver lbfgs supports only 'l2' or 'none' penalties, got elasticnet
penalty.

  warnings.warn(some_fits_failed_message, FitFailedWarning)
/usr/local/lib/python3.9/site-packages/sklearn/model_selection/_search.py:969:
UserWarning: One or more of the test scores are non-finite: [0.759202
nan 0.47771834 0.05129081        nan        nan
        nan 0.68172452        nan        nan        nan 0.20234822
 0.7062321  0.5379079         nan 0.         0.7469364         nan
 0.68728375 0.68895412        nan 0.68839236 0.76087238        nan
        nan 0.49722474        nan        nan 0.19677532 0.08472946
        nan 0.71125194        nan        nan        nan        nan
        nan        nan 0.49833956 0.38407647 0.734114          nan
 0.44428343        nan        nan        nan        nan        nan
        nan        nan        nan        nan 0.73187565        nan
        nan        nan        nan 0.                nan        nan
 0.69953816        nan 0.33168201 0.11261384 0.                nan
        nan        nan        nan        nan 0.67613422        nan
        nan        nan        nan 0.         0.59196404 0.67782075
        nan 0.75306982        nan 0.75306982        nan        nan
        nan        nan        nan 0.76476993        nan        nan
        nan 0.72630896 0.18057986        nan        nan        nan
        nan        nan 0.67948119 0.69118502]
  warnings.warn(
```

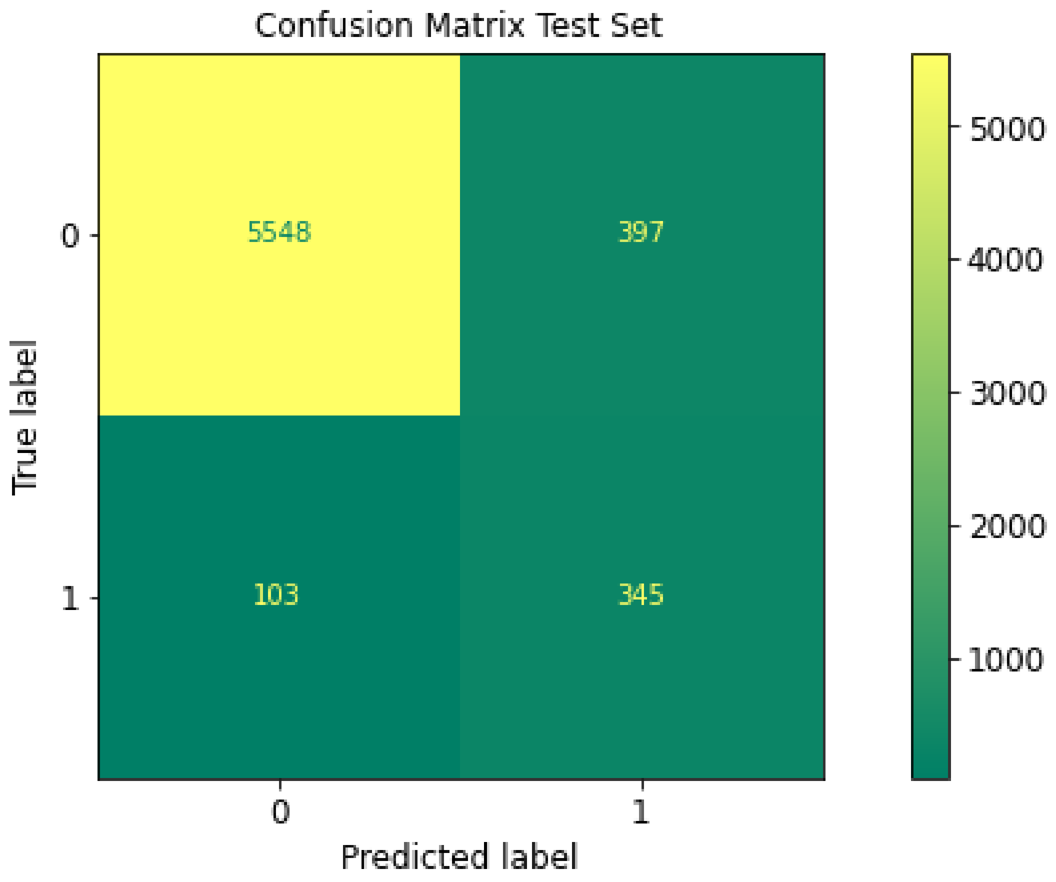
[67]:
```
LogisticRegression(C=0.16731783677034165, class_weight={0: 1.0, 1: 13},
                   random_state=51, solver='liblinear')
```

[68]:
```
#instantiate the best model
clf = LogisticRegression(C=0.
 ↪16731783677034165,penalty='l2',solver='liblinear',class_weight=weights)

#fit and predict
clf.fit(X_train,y_train)
train_predictions = clf.predict(X_train)
test_predictions = clf.predict(X_test)

#classification report
print('Classification Report Training set')
print('------------------------------------')
print('\n')
print(classification_report(y_train,train_predictions))
print('\n')

print('Classification Report Testing set')
print('------------------------------------')
print('\n')
print(classification_report(y_test,test_predictions))
```

```
Classification Report Training set
------------------------------------


              precision    recall  f1-score   support

           0       0.99      0.94      0.97     23775
           1       0.53      0.93      0.68      1794

    accuracy                           0.94     25569
   macro avg       0.76      0.93      0.82     25569
weighted avg       0.96      0.94      0.95     25569



Classification Report Testing set
------------------------------------
```

```
              precision    recall  f1-score   support

           0       0.98      0.93      0.96      5945
           1       0.46      0.77      0.58       448

    accuracy                           0.92      6393
   macro avg       0.72      0.85      0.77      6393
weighted avg       0.95      0.92      0.93      6393
```

[69]:
```python
from sklearn.metrics import plot_confusion_matrix
plot_confusion_matrix(clf,X_test,y_test,cmap='summer')
plt.title('Confusion Matrix Test Set')
plt.show()
```



[ ]:
```

```