47uvtidub

March 26, 2024

1 Importing neccessary libraries and dataset

[7]:
```
!pip install contractions
!pip install autocorrect
```

```
Collecting contractions
  Downloading contractions-0.1.73-py2.py3-none-any.whl.metadata (1.2 kB)
Collecting textsearch>=0.0.21 (from contractions)
  Downloading textsearch-0.0.24-py2.py3-none-any.whl.metadata (1.2 kB)
Collecting anyascii (from textsearch>=0.0.21->contractions)
  Downloading anyascii-0.3.2-py3-none-any.whl.metadata (1.5 kB)
Collecting pyahocorasick (from textsearch>=0.0.21->contractions)
  Downloading pyahocorasick-2.1.0-cp310-cp310-manylinux_2_5_x86_64.manylinux1_x8
6_64.manylinux_2_12_x86_64.manylinux2010_x86_64.whl.metadata (13 kB)
Downloading contractions-0.1.73-py2.py3-none-any.whl (8.7 kB)
Downloading textsearch-0.0.24-py2.py3-none-any.whl (7.6 kB)
Downloading anyascii-0.3.2-py3-none-any.whl (289 kB)
                         289.9/289.9 kB
2.1 MB/s eta 0:00:00a 0:00:01m
Downloading pyahocorasick-2.1.0-cp310-cp310-manylinux_2_5_x86_64.manylinux
1_x86_64.manylinux_2_12_x86_64.manylinux2010_x86_64.whl (110 kB)
                         110.7/110.7 kB
6.0 MB/s eta 0:00:00
Installing collected packages: pyahocorasick, anyascii, textsearch,
contractions
Successfully installed anyascii-0.3.2 contractions-0.1.73 pyahocorasick-2.1.0
textsearch-0.0.24
Collecting autocorrect
  Downloading autocorrect-2.6.1.tar.gz (622 kB)
                          622.8/622.8

kB 3.3 MB/s eta 0:00:0000:0100:01
  Preparing metadata (setup.py) … done
Building wheels for collected packages: autocorrect
  Building wheel for autocorrect (setup.py) … done
  Created wheel for autocorrect: filename=autocorrect-2.6.1-py3-none-
any.whl size=622364
sha256=e1b110641c8b5f4fcf61dfb01d138f70c2d986974dcfd19d1310d3c4b3754aab
```

```
  Stored in directory: /root/.cache/pip/wheels/b5/7b/6d/b76b29ce11ff8e2521c8c7dd
0e5bfee4fb1789d76193124343
Successfully built autocorrect
Installing collected packages: autocorrect
Successfully installed autocorrect-2.6.1
```

[8]:

```
import string # from some string manipulation tasks
import nltk # natural language toolkit
import re # regex
from string import punctuation # solving punctuation problems
from nltk.corpus import stopwords # stop words in sentences
from nltk.stem import WordNetLemmatizer # For stemming the sentence
from nltk.stem import SnowballStemmer # For stemming the sentence
from contractions import contractions_dict # to solve contractions
from autocorrect import Speller #correcting the spellings

#Libraries for general purpose
import matplotlib.pyplot as plt
import seaborn as sns

#Data preprocessing
from sklearn import preprocessing
```

[9]:

```
import numpy as np
import pandas as pd

url="https://raw.githubusercontent.com/AvantikaJalote/Final-Year-Project/main/
 ↪cyberbullying_tweets_changes.csv"
df=pd.read_csv(url)
df.head()
```

[9]:

```
                                          tweet_text cyberbullying_type
0  In other words #katandandre, your food was cra…  not_cyberbullying
1  Why is #aussietv so white? #MKR #theblock #ImA…  not_cyberbullying
2  @XochitlSuckkks a classy whore? Or more red ve…  not_cyberbullying
3  @Jason_Gio meh. :P  thanks for the heads up, b…  not_cyberbullying
4  @RudhoeEnglish This is an ISIS account pretend…  not_cyberbullying
```

There is not much imbalance between different cyberbulling type. other__cyberbulling will be removed since it may cause a confusion for the models with other cyberbullying class.

[10]:

```
df['cyberbullying_type'].value_counts()
```

[10]:

```
cyberbullying_type
cyberbullying        39749
not_cyberbullying    13496
Name: count, dtype: int64
```

2 Dataset Preprocessing

```
[11]: # Renaming Categories
      df = df.rename(columns={'tweet_text': 'text', 'cyberbullying_type':␣
       ↪'sentiment'})
```

```
[12]: # Checking 10 samples
      df.sample(10)
```

```
[12]:                                                     text          sentiment
      7181   Rebecca Black Pulled From School Due to Bullyi…  not_cyberbullying
      10317  Gay Rapist Reynhard Sinaga, Gets Life Sentence…      cyberbullying
      22687  How any Hindus or Muslims can ever Vote 4 this…      cyberbullying
      12141  You're a horrible parent. @jrdrury13 Call me s…      cyberbullying
      43760  @rickstayslick fuck off you dumb ass NIGGER yo…      cyberbullying
      30988               @DanaSheehan What right do you lack?      cyberbullying
      30086  Hey, you big bully. why don't you pick on some…      cyberbullying
      47341  poc tell y'all constantly that there's a racis…      cyberbullying
      48888  Noooo - damn  that site is brilliant aswell - …  not_cyberbullying
      12909  Things that are not okay & I will never stand …      cyberbullying
```

Converting categories into numbers

```
[13]: df["sentiment"].replace({"not_cyberbullying": 0, "cyberbullying": 1},␣
       ↪inplace=True)
```

```
/tmp/ipykernel_33/217867185.py:1: FutureWarning: A value is trying to be set on
a copy of a DataFrame or Series through chained assignment using an inplace
method.
The behavior will change in pandas 3.0. This inplace method will never work
because the intermediate object on which we are setting values always behaves as
a copy.

For example, when doing 'df[col].method(value, inplace=True)', try using
'df.method({col: value}, inplace=True)' or df[col] = df[col].method(value)
instead, to perform the operation inplace on the original object.


  df["sentiment"].replace({"not_cyberbullying": 0, "cyberbullying": 1},
inplace=True)
/tmp/ipykernel_33/217867185.py:1: FutureWarning: Downcasting behavior in
`replace` is deprecated and will be removed in a future version. To retain the
old behavior, explicitly call `result.infer_objects(copy=False)`. To opt-in to
the future behavior, set `pd.set_option('future.no_silent_downcasting', True)`
  df["sentiment"].replace({"not_cyberbullying": 0, "cyberbullying": 1},
inplace=True)
```

```
[14]: sentiments = ["cyberbullying","not bullying"]
```

Preprocessing

Predefined functions for text cleaning

[15]:

```
#Text cleaning
import re, string
import emoji
import nltk
from nltk.stem import WordNetLemmatizer,PorterStemmer
from nltk.corpus import stopwords
stop_words = set(stopwords.words('english'))

#Clean emojis from text
#def strip_emoji(text):
    #return re.sub(emoji.get_emoji_regexp(), r"", text) #remove emoji
def strip_emoji(text):
    return emoji.replace_emoji(text, "")

# Remove punctuations, links, mentions and \r\n new line characters
def strip_all_entities(text):
    text = text.replace('\r', '').replace('\n', ' ').lower()  # remove \n and␣
 ↪\r and lowercase
    text = re.sub(r"(?:\@|https?\://)\S+", "", text)  # remove links and␣
 ↪mentions
    text = re.sub(r'[^\x00-\x7f]', r'', text)  # remove non utf8/ascii␣
 ↪characters such as '\x9a\x91\x97\x9a\x97'
    banned_list = string.punctuation
    table = str.maketrans('', '', banned_list)
    text = text.translate(table)
    words = [word for word in text.split() if len(word) < 14]  # remove words␣
 ↪longer than 14 characters
    return ' '.join(words)

#remove contractions
def decontract(text):
    text = re.sub(r"can\'t", "can not", text)
    text = re.sub(r"n\'t", " not", text)
    text = re.sub(r"\'re", " are", text)
    text = re.sub(r"\'s", " is", text)
    text = re.sub(r"\'d", " would", text)
    text = re.sub(r"\'ll", " will", text)
    text = re.sub(r"\'t", " not", text)
    text = re.sub(r"\'ve", " have", text)
    text = re.sub(r"\'m", " am", text)
    return text

#clean hashtags at the end of the sentence, and keep those in the middle of the␣
 ↪sentence by removing just the "#" symbol
```

```
def clean_hashtags(tweet):
    new_tweet = " ".join(word.strip() for word in re.split('#(?!(?:
 ↪hashtag)\b)[\w-]+(?=(?:\s+#[\w-]+)*\s*$)', tweet)) #remove last hashtags
    new_tweet2 = " ".join(word.strip() for word in re.split('#|_', new_tweet))␣
 ↪#remove hashtags symbol from words in the middle of the sentence
    return new_tweet2

#Filter special characters such as "&" and "$" present in some words
def filter_chars(a):
    sent = []
    for word in a.split(' '):
        if ('$' in word) | ('&' in word):
            sent.append('')
        else:
            sent.append(word)
    return ' '.join(sent)

#Remove multiple sequential spaces
def remove_mult_spaces(text):
    return re.sub("\s\s+" , " ", text)

#Stemming
def stemmer(text):
    tokenized = nltk.word_tokenize(text)
    ps = PorterStemmer()
    return ' '.join([ps.stem(words) for words in tokenized])

#Then we apply all the defined functions in the following order
def preprocess(text):
    text = strip_emoji(text)
    text = decontract(text)
    text = strip_all_entities(text)
    text = clean_hashtags(text)
    text = filter_chars(text)
    text = remove_mult_spaces(text)
    text = stemmer(text)
    return text
```

[16]:

```
texts_cleaned = []
for t in df.text:
    texts_cleaned.append(preprocess(t))
```

[17]:

```
df['text_clean'] = texts_cleaned
```

Clean text

[18]:

```
df.head()
```

```
[18]:                                                 text  sentiment  \
      0  In other words #katandandre, your food was cra…          0
      1  Why is #aussietv so white? #MKR #theblock #ImA…          0
      2  @XochitlSuckkks a classy whore? Or more red ve…          0
      3  @Jason_Gio meh. :P  thanks for the heads up, b…          0
      4  @RudhoeEnglish This is an ISIS account pretend…          0

                                        text_clean
      0  in other word katandandr your food wa crapilic…
      1  whi is aussietv so white mkr theblock today su…
      2           a classi whore or more red velvet cupcak
      3  meh p thank for the head up but not too concer…
      4  thi is an isi account pretend to be a kurdish …
```

Checking tweet duplicates

```
[19]: df["text_clean"].duplicated().sum()
```

```
[19]: 2820
```

There are around 1000 duplicates. We will remove them at the next cell.

```
[20]: df.drop_duplicates("text_clean", inplace=True)
```

```
[21]: df.sentiment.value_counts()
```

```
[21]: sentiment
      1    37223
      0    13202
      Name: count, dtype: int64
```

3 Checking tweet length

```
[22]: text_len = []
      for text in df.text_clean:
          tweet_len = len(text.split())
          text_len.append(tweet_len)
```

```
[23]: df['text_len'] = text_len
```

```
[24]: # checking long tweets
      df.sort_values(by=['text_len'], ascending=False)
```

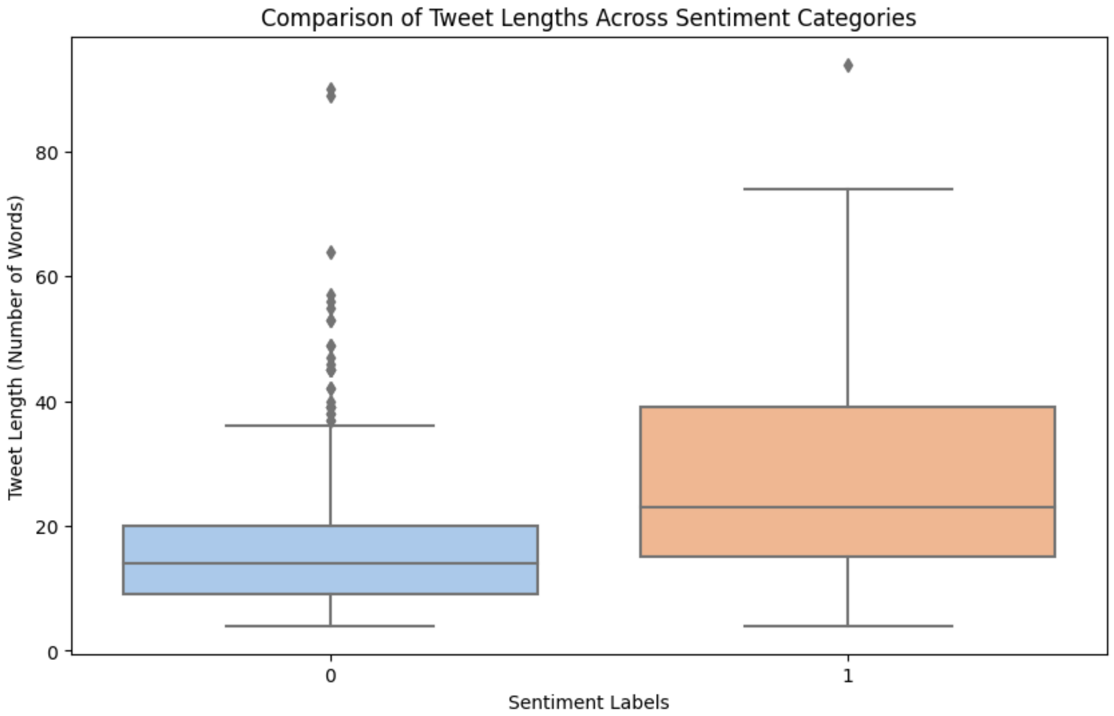
```
[24]:                                                     text  sentiment  \
      29205  is feminazi an actual word with a denot…\n@Nas…          1
      24516  @NICKIMINAJ: #WutKinda\nAt this rate the MKR f…          1
      30752  I don't retreat.\nyesssssssss http://t.co/Td90k…          1
```

```
52919    So I say goodbye to a town that has ears and…         0
44035  You so black and white trying to live like a n…         1
…                                                  …        …
31423                                    @dylanw random.          1
2448                                  @haniff_azman yes.          0
28843                                       @mummey omfg          1
51932                                               Jet.          0
10                      @Jord_Is_Dead http://t.co/UsQInYW5Gn          0

                                              text_clean  text_len
29205  is feminazi an actual word with a denot my job…       745
24516  wutkinda at thi rate the mkr final will be in …       662
30752  i do not retreat yesssssssss uh whi do they not…       480
52919  so i say goodby to a town that ha ear and eye …       362
44035  you so black and white tri to live like a nigg…       319
…                                                  …       …
31423                                             random         1
2448                                                  ye         1
28843                                               omfg         1
51932                                                jet         1
10                                                               0

[50425 rows x 4 columns]
```

Removing tweets with less than 4 words and more than 100 words as they can be outliers

[25]:
```
df = df[df['text_len'] > 3]
df = df[df['text_len'] < 100]
```

[26]:
```
# Box plot for comparing tweet lengths across different sentiment categories
plt.figure(figsize=(10, 6))
sns.boxplot(x='sentiment', y=df['text_clean'].apply(lambda x: len(x.split())),␣
 ↪data=df, palette='pastel')
plt.title('Comparison of Tweet Lengths Across Sentiment Categories')
plt.xlabel('Sentiment Labels')
plt.ylabel('Tweet Length (Number of Words)')
plt.show()
```



```
[27]: df
```

```
[27]:                                                   text  sentiment  \
      0      In other words #katandandre, your food was cra…          0
      1      Why is #aussietv so white? #MKR #theblock #ImA…          0
      2      @XochitlSuckkks a classy whore? Or more red ve…          0
      3      @Jason_Gio meh. :P  thanks for the heads up, b…          0
      4      @RudhoeEnglish This is an ISIS account pretend…          0
      …                                                    …        …
      53234                          encore! encore! suree hahaha          0
      53237   thumbs up!r i just realize our sig pic is thu…          0
      53240             Umm made love to my boyfriend. :] r hahah          0
      53242   Is there ever a day that mattresses are not o…          0
      53244                               What Color Are Your Eyes?          0

                                                  text_clean  text_len
      0      in other word katandandr your food wa crapilic…         9
      1      whi is aussietv so white mkr theblock today su…        13
      2                  a classi whore or more red velvet cupcak          8
      3      meh p thank for the head up but not too concer…        17
      4      thi is an isi account pretend to be a kurdish …        17
      …                                                    …       …
      53234                               encor encor sure hahaha          4
      53237  thumb upr i just realiz our sig pic is thumb u…        15
```

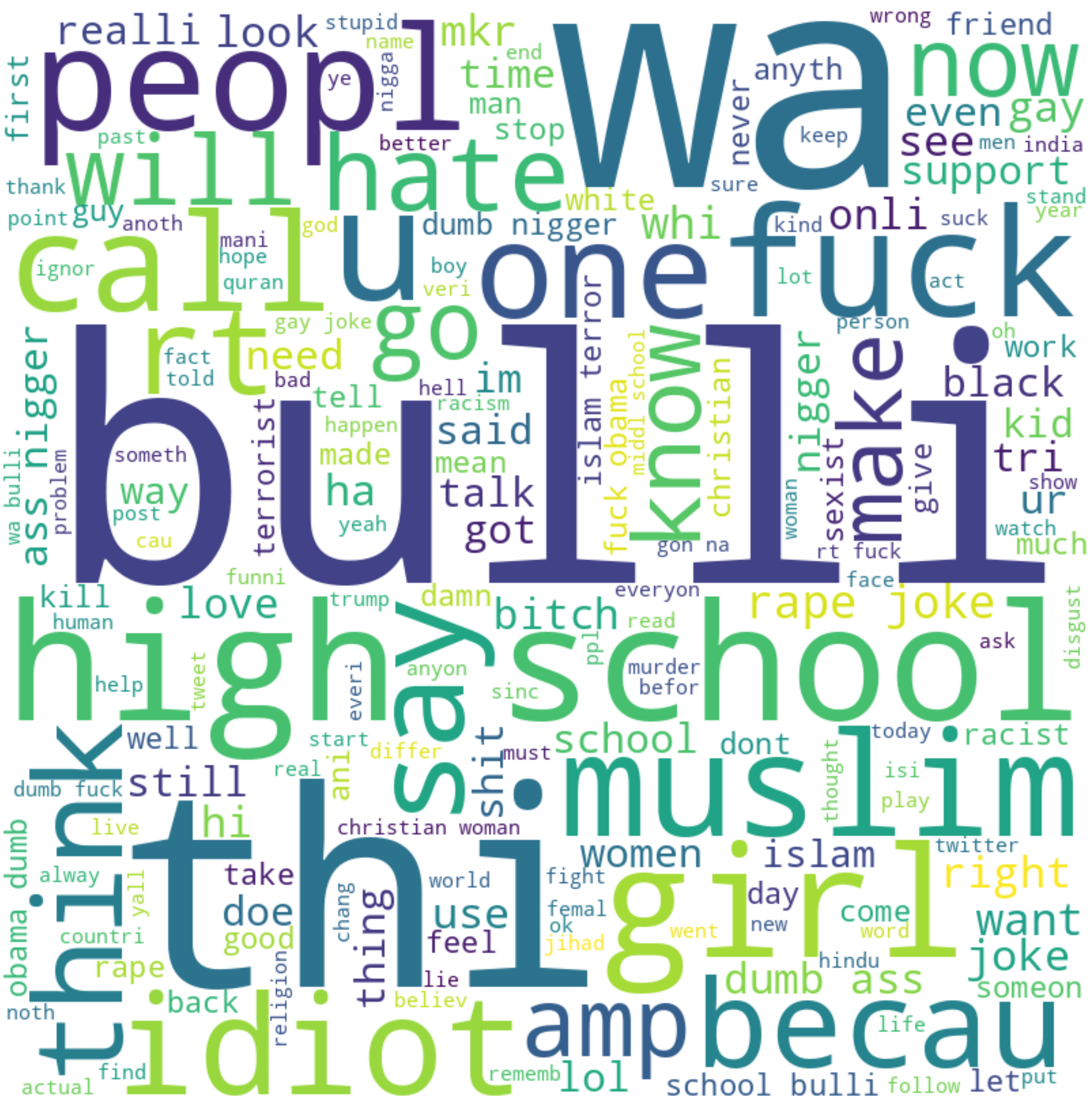
```
53240                umm made love to my boyfriend r hahah         8
53242  is there ever a day that mattress are not on sale          11
53244                              what color are your eye         5

[48872 rows x 4 columns]
```

Wordcloud

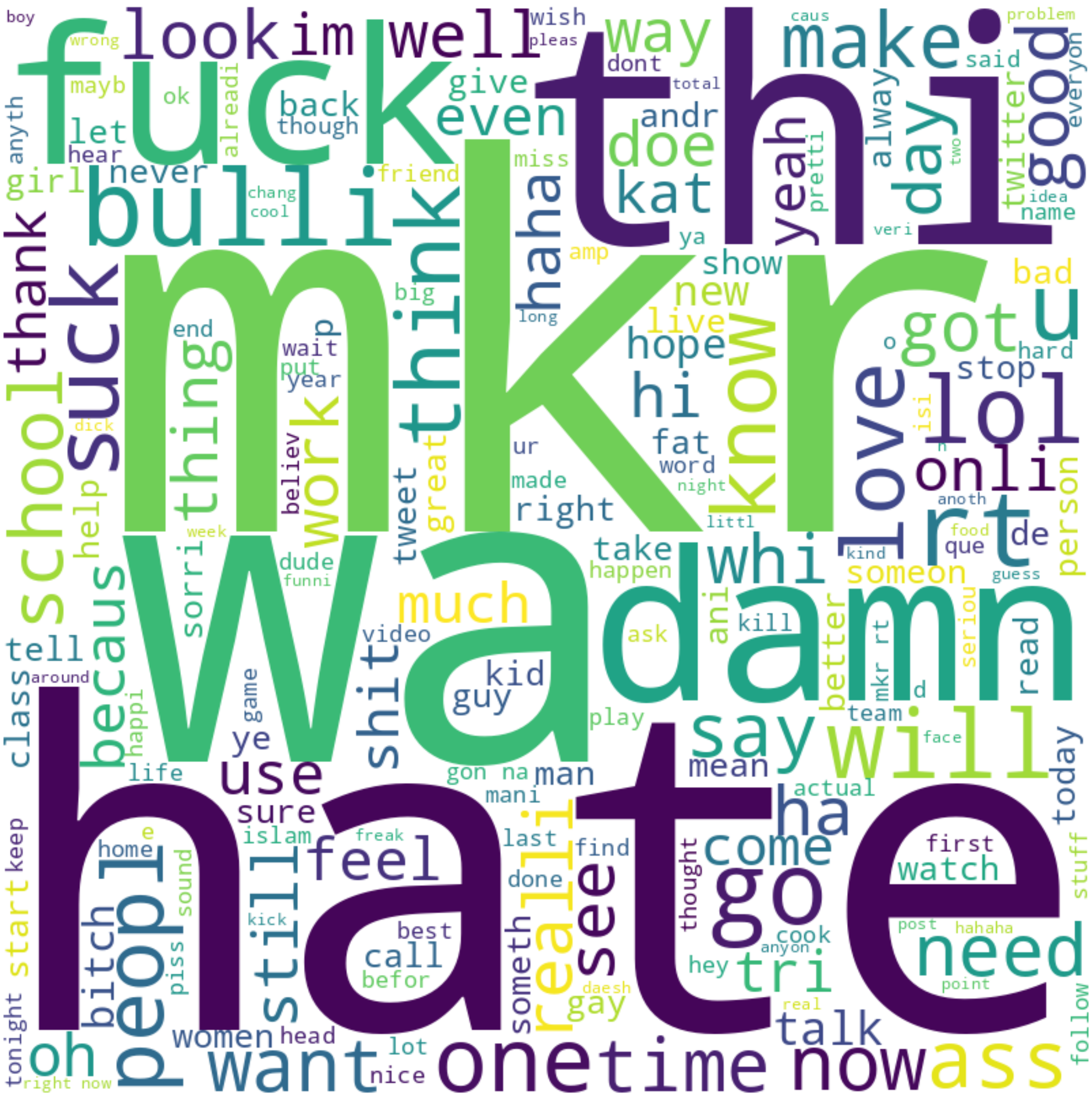
[28]:

```
from wordcloud import WordCloud, STOPWORDS

# Function to generate word cloud
def generate_wordcloud(text):
    wordcloud = WordCloud(width = 800, height = 800,
                background_color ='white',
                stopwords = STOPWORDS,
                min_font_size = 10).generate(text)
    plt.figure(figsize = (8, 8), facecolor = None)
    plt.imshow(wordcloud)
    plt.axis("off")
    plt.tight_layout(pad = 0)
    plt.show()

# Overall sentiment word cloud
overall_text = " ".join(text for text in df.text_clean)
print("Overall Sentiment Word Cloud:")
generate_wordcloud(overall_text)

# Individual sentiment word clouds
sentiments = {
    0: "not_cyberbullying",
    1: "cyberbullying"
}

for sentiment_code, sentiment_name in sentiments.items():
    sentiment_text = " ".join(text for text in df[df['sentiment'] ==␣
 ↪sentiment_code].text_clean)
    print(f"\nWord Cloud for {sentiment_name} :")
    generate_wordcloud(sentiment_text)
```

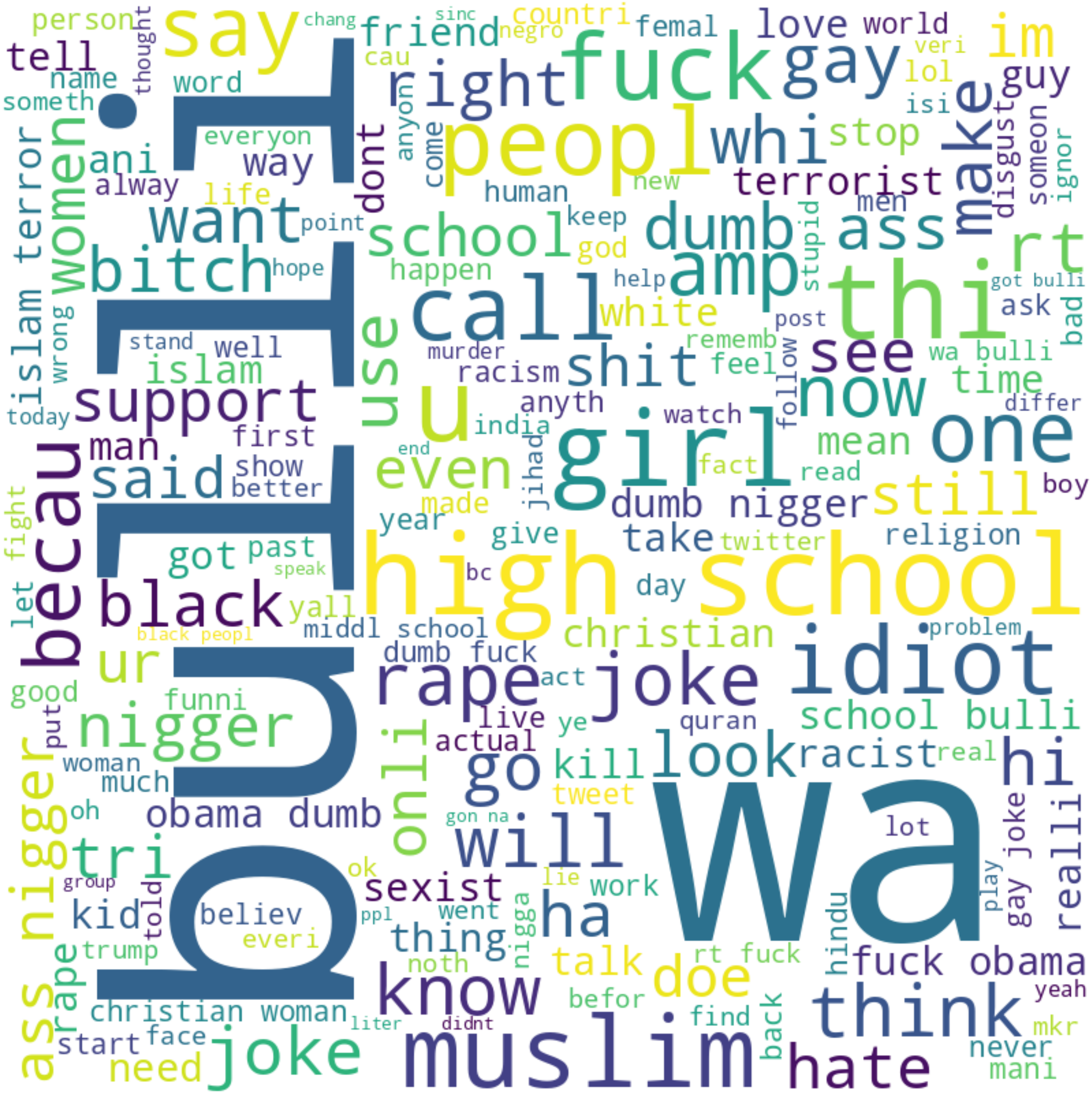
```
Overall Sentiment Word Cloud:
```



Word Cloud for not_cyberbullying :



Word Cloud for cyberbullying :



3.0.1 Balancing the data using SMOTE

[29]:
```
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import classification_report, accuracy_score
from sklearn.metrics import precision_score, recall_score, f1_score,␣
 ↪confusion_matrix
from sklearn.metrics import roc_curve, auc
import matplotlib.pyplot as plt
```

[34]:

```
#SMOTE and Count Vectorizer
from sklearn.feature_extraction.text import CountVectorizer
from imblearn.over_sampling import SMOTE
from sklearn.model_selection import train_test_split

# Split data into features (X) and labels (y)
X_cv = df['text_clean']  # Renamed X to X_cv
y_cv = df['sentiment']   # Renamed y to y_cv

# Initialize CountVectorizer
count_vectorizer_cv = CountVectorizer()  # Renamed count_vectorizer to␣
 ↪count_vectorizer_cv

# Convert text data into numerical vectors using CountVectorizer
X_count_cv = count_vectorizer_cv.fit_transform(X_cv)  # Renamed X_count to␣
 ↪X_count_cv

# Initialize SMOTE
smote_cv = SMOTE(random_state=42)

# Resample the data using SMOTE
X_resampled_cv, y_resampled_cv = smote_cv.fit_resample(X_count_cv, y_cv)  #␣
 ↪Renamed X_resampled, y_resampled to X_resampled_cv, y_resampled_cv

# Split the resampled data into train and test sets
X_train_cv, X_test_cv, y_train_cv, y_test_cv = train_test_split(X_resampled_cv,␣
 ↪y_resampled_cv, test_size=0.2, random_state=42)  # Renamed variables with␣
 ↪_cv suffix
```

[30]:

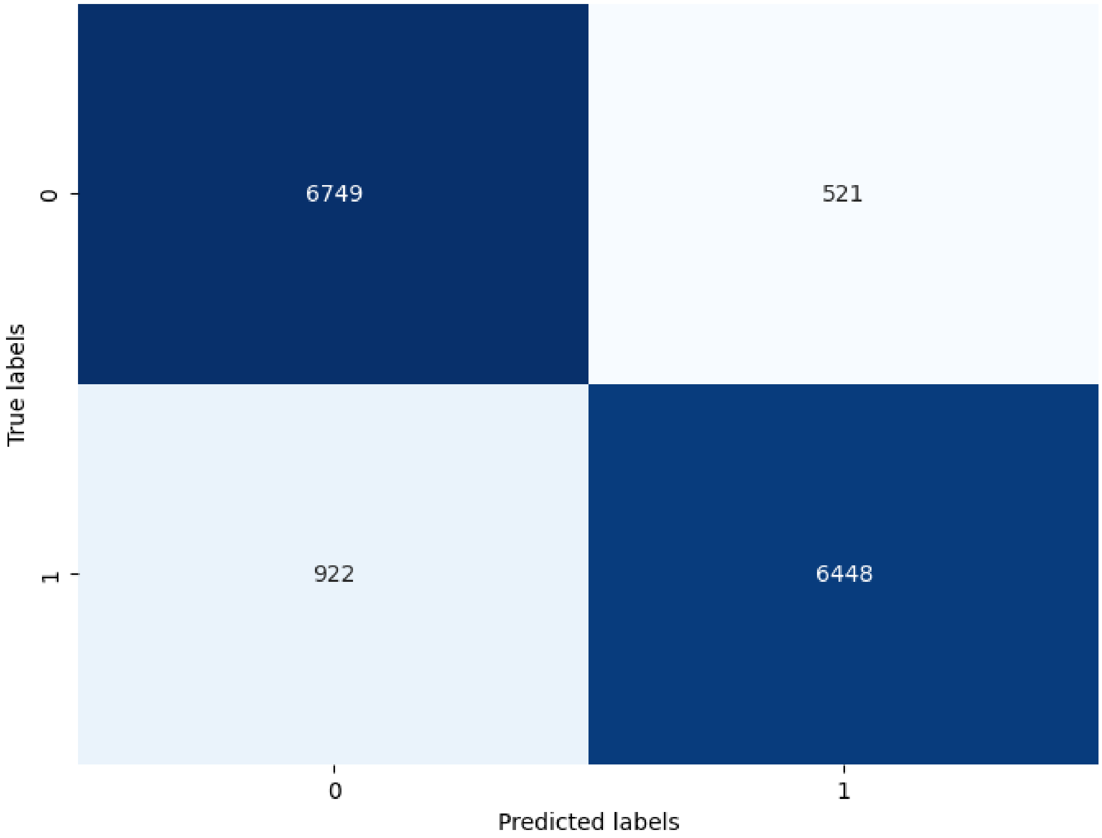
```
import joblib
```

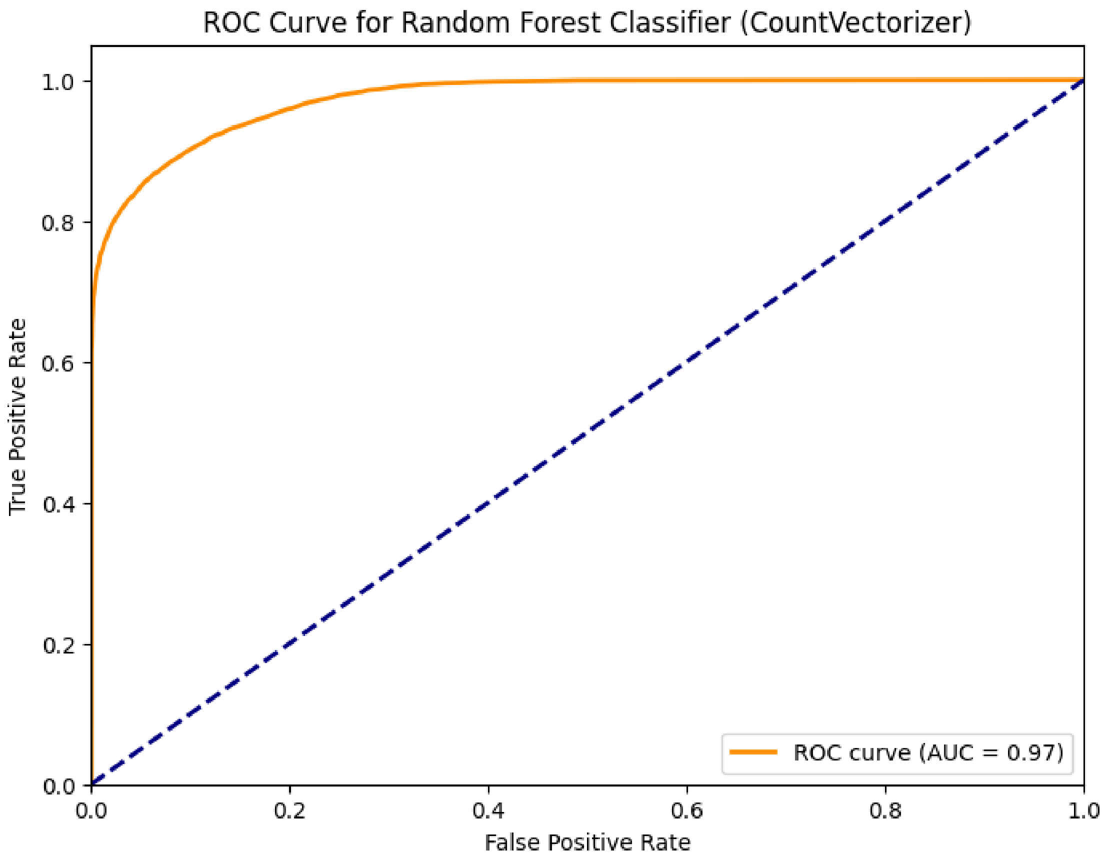
[35]:

```
#CV and RF

# Train Random Forest classifier
rf_classifier_cv = RandomForestClassifier()
rf_classifier_cv.fit(X_train_cv, y_train_cv)

# Make predictions using Random Forest classifier
rf_predictions_cv = rf_classifier_cv.predict(X_test_cv)
# Calculate accuracy for Random Forest classifier
rf_accuracy_cv = accuracy_score(y_test_cv, rf_predictions_cv)

joblib.dump(rf_classifier_cv, 'rf_classifier_cv.joblib')

# Calculate precision, recall, and F1-score for Random Forest classifier
precision_rf = precision_score(y_test_cv, rf_predictions_cv, average='weighted')
recall_rf = recall_score(y_test_cv, rf_predictions_cv, average='weighted')
```

```
f1_rf = f1_score(y_test_cv, rf_predictions_cv, average='weighted')

# Generate classification reports
print("Random Forest Classification Report:")
print(classification_report(y_test_cv, rf_predictions_cv))
print(f"Accuracy Score for Random Forest Classifier: {rf_accuracy_cv:.4f}")

print("Precision Score for Random Forest Classifier:", precision_rf)
print("Recall Score for Random Forest Classifier:", recall_rf)
print("F1 Score for Random Forest Classifier:", f1_rf)

# Generate confusion matrix for Random Forest classifier
conf_matrix_rf = confusion_matrix(y_test_cv, rf_predictions_cv)
print("Confusion Matrix for Random Forest Classifier:")
# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix_rf, annot=True, fmt='d', cmap='Blues', cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.savefig('confusion_matrix_rf.png')  # Save the plot as an image
plt.show()

# Get predicted probabilities for each class
rf_probs_cv = rf_classifier_cv.predict_proba(X_test_cv)

# Compute ROC curve and AUC
fpr, tpr, _ = roc_curve(y_test_cv, rf_probs_cv[:, 1])  # Use probabilities for␣
 ↪the positive class
roc_auc = auc(fpr, tpr)

# Plot ROC curve
plt.figure(figsize=(8, 6))
plt.plot(fpr, tpr, color='darkorange', lw=2, label=f'ROC curve (AUC = {roc_auc:.
 ↪2f})')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Random Forest Classifier (CountVectorizer)')
plt.legend(loc='lower right')
plt.show()
```

```
Random Forest Classification Report:
              precision    recall  f1-score   support

           0       0.88      0.93      0.90      7270
           1       0.93      0.87      0.90      7370

    accuracy                           0.90     14640
   macro avg       0.90      0.90      0.90     14640
weighted avg       0.90      0.90      0.90     14640

Accuracy Score for Random Forest Classifier: 0.9014
Precision Score for Random Forest Classifier: 0.9026788761683529
Recall Score for Random Forest Classifier: 0.9014344262295082
F1 Score for Random Forest Classifier: 0.9013788949612742
Confusion Matrix for Random Forest Classifier:
```



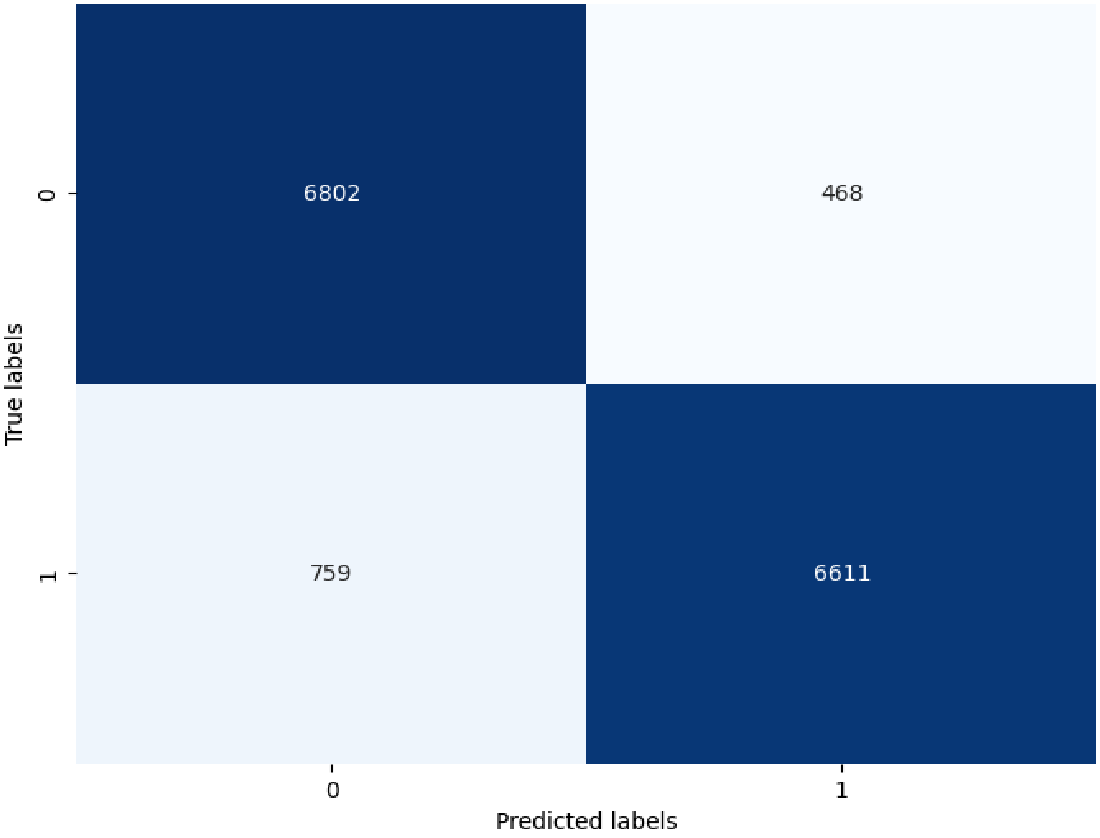


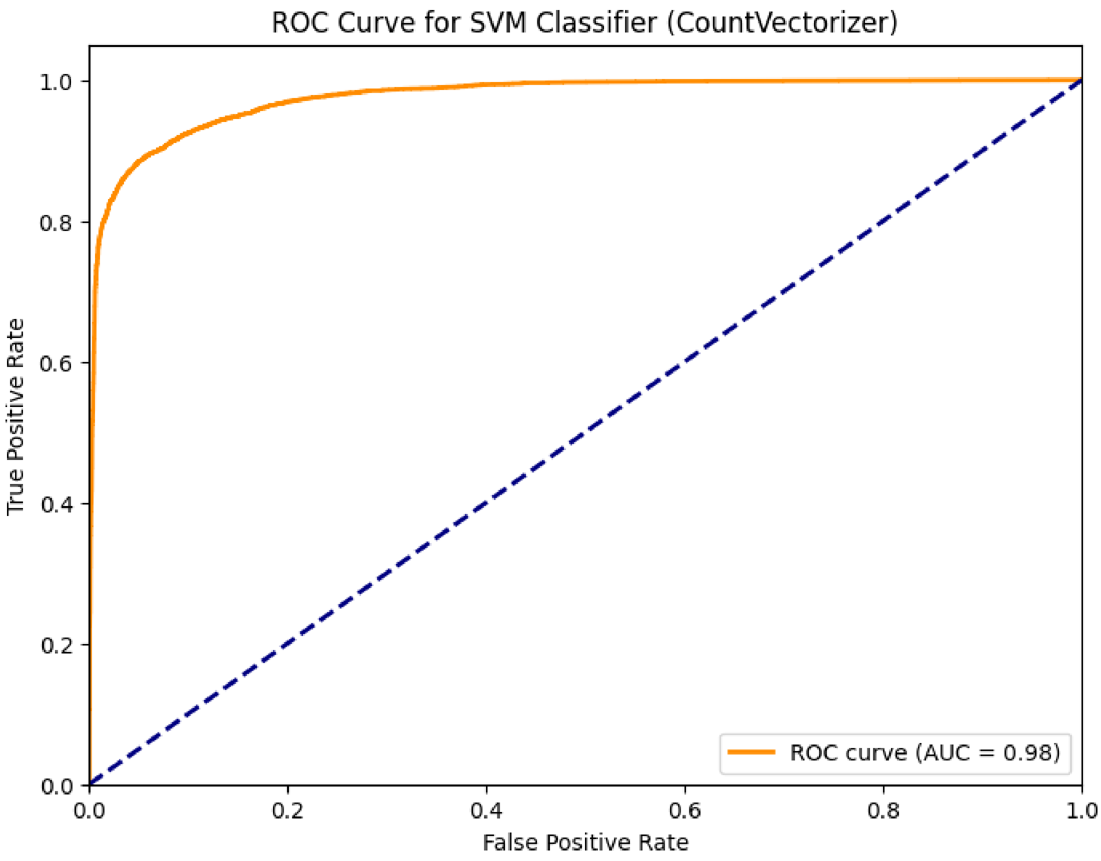
[27]:

```
#CV AND SVM

# Train SVM classifier
svm_classifier_cv = SVC()
svm_classifier_cv.fit(X_train_cv, y_train_cv)

# Make predictions using SVM classifier
svm_predictions_cv = svm_classifier_cv.predict(X_test_cv)
# Calculate accuracy for SVM classifier
svm_accuracy_cv = accuracy_score(y_test_cv, svm_predictions_cv)

joblib.dump(svm_classifier_cv, 'svm_classifier_cv.joblib')

# Calculate precision, recall, and F1-score for SVM classifier
precision_svm = precision_score(y_test_cv, svm_predictions_cv,␣
  ↪average='weighted')
recall_svm = recall_score(y_test_cv, svm_predictions_cv, average='weighted')
f1_svm = f1_score(y_test_cv, svm_predictions_cv, average='weighted')

print("SVM Classification Report:")
print(classification_report(y_test_cv, svm_predictions_cv))
print(f"Accuracy Score for SVM Classifier: {svm_accuracy_cv:.4f}\n")

print("Precision Score for SVM Classifier:", precision_svm)
print("Recall Score for SVM Classifier:", recall_svm)
print("F1 Score for SVM Classifier:", f1_svm)

# Generate confusion matrix for SVM classifier
conf_matrix_cv_svm = confusion_matrix(y_test_cv, svm_predictions_cv)
print("Confusion Matrix for SVM Classifier:")
# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix_cv_svm, annot=True, fmt='d', cmap='Blues', cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.savefig('confusion_matrix_rf.png')  # Save the plot as an image
plt.show()

# Get predicted probabilities for each class
svm_probs_cv = svm_classifier_cv.decision_function(X_test_cv)

# Compute ROC curve and AUC
fpr, tpr, _ = roc_curve(y_test_cv, svm_probs_cv)
roc_auc = auc(fpr, tpr)

# Plot ROC curve
plt.figure(figsize=(8, 6))
plt.plot(fpr, tpr, color='darkorange', lw=2, label=f'ROC curve (AUC = {roc_auc:.
 ↪2f})')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for SVM Classifier (CountVectorizer)')
plt.legend(loc='lower right')
plt.show()
```

```
SVM Classification Report:
              precision    recall  f1-score   support

           0       0.90      0.94      0.92      7270
           1       0.93      0.90      0.92      7370

    accuracy                           0.92     14640
   macro avg       0.92      0.92      0.92     14640
weighted avg       0.92      0.92      0.92     14640
```

```
Accuracy Score for SVM Classifier: 0.9162

Precision Score for SVM Classifier: 0.9168697610467742
Recall Score for SVM Classifier: 0.916188524590164
F1 Score for SVM Classifier: 0.9161667864884624
Confusion Matrix for SVM Classifier:
```





[ ]:

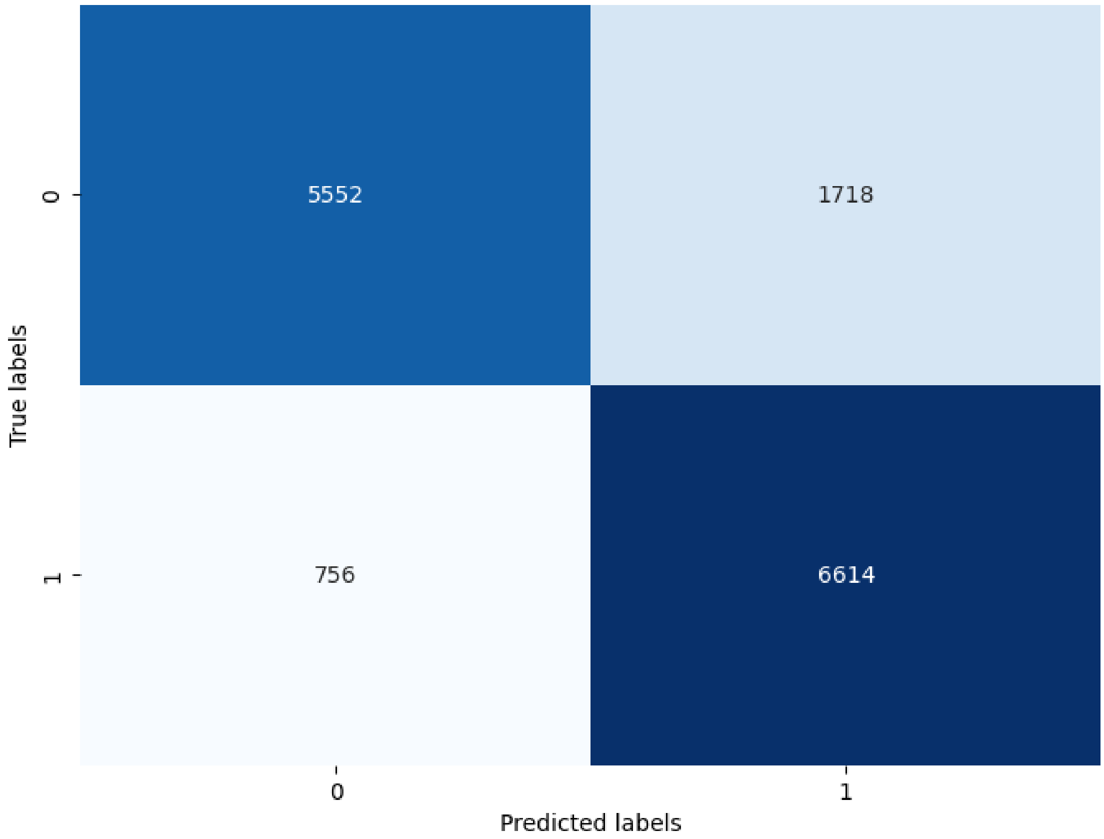
```
from sklearn.model_selection import cross_val_score

# Define the SVM classifier
svm_classifier_cv = SVC()

# Perform cross-validation
cv_scores = cross_val_score(svm_classifier_cv, X_train_cv, y_train_cv, cv=100) ␣
  ↪# cv=5 means 5-fold cross-validation

# Print the cross-validation scores
print("Cross-validation scores:", cv_scores)

# Calculate and print the mean accuracy score
mean_cv_score = cv_scores.mean()
print("Mean cross-validation score:", mean_cv_score)
```

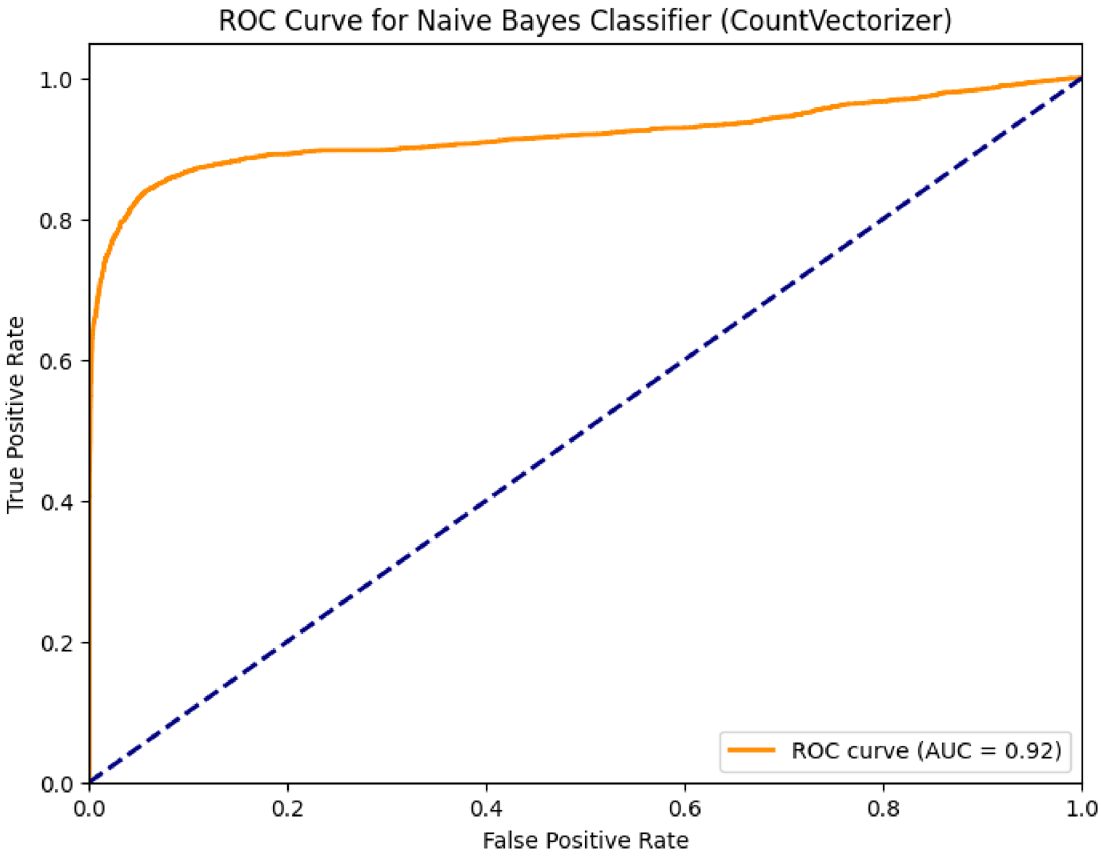
[36]:

```
#CV and NB

# Train Naive Bayes classifier
nb_classifier_cv = MultinomialNB()
```

```python
nb_classifier_cv.fit(X_train_cv, y_train_cv)

# Make predictions using Naive Bayes classifier
nb_predictions_cv = nb_classifier_cv.predict(X_test_cv)
# Calculate accuracy for Naive Bayes classifier
nb_accuracy_cv = accuracy_score(y_test_cv, nb_predictions_cv)

joblib.dump(nb_classifier_cv, 'nb_classifier_cv.joblib')

# Calculate precision, recall, and F1-score for Naive Bayes classifier
precision_nb = precision_score(y_test_cv, nb_predictions_cv, average='weighted')
recall_nb = recall_score(y_test_cv, nb_predictions_cv, average='weighted')
f1_nb = f1_score(y_test_cv, nb_predictions_cv, average='weighted')

print("Naive Bayes Classification Report:")
print(classification_report(y_test_cv, nb_predictions_cv))
print(f"Accuracy Score for Naive Bayes Classifier: {nb_accuracy_cv:.4f}")

print("Precision Score for Naive Bayes Classifier:", precision_nb)
print("Recall Score for Naive Bayes Classifier:", recall_nb)
print("F1 Score for Naive Bayes Classifier:", f1_nb)

# Generate confusion matrix for Naive Bayes classifier
conf_matrix_cv_nb = confusion_matrix(y_test_cv, nb_predictions_cv)
print("\nConfusion Matrix for Naive Bayes Classifier and Count Vectorizer:")
# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix_cv_nb, annot=True, fmt='d', cmap='Blues', cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.savefig('confusion_matrix_rf.png')  # Save the plot as an image
plt.show()

# Get predicted probabilities for each class
nb_probs_cv = nb_classifier_cv.predict_proba(X_test_cv)[:, 1]

# Compute ROC curve and AUC
fpr, tpr, _ = roc_curve(y_test_cv, nb_probs_cv)
roc_auc = auc(fpr, tpr)

# Plot ROC curve
plt.figure(figsize=(8, 6))
plt.plot(fpr, tpr, color='darkorange', lw=2, label=f'ROC curve (AUC = {roc_auc:.
 ↪2f})')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Naive Bayes Classifier (CountVectorizer)')
plt.legend(loc='lower right')
plt.show()
```

```
Naive Bayes Classification Report:
              precision    recall  f1-score   support

           0       0.88      0.76      0.82      7270
           1       0.79      0.90      0.84      7370

    accuracy                           0.83     14640
   macro avg       0.84      0.83      0.83     14640
weighted avg       0.84      0.83      0.83     14640

Accuracy Score for Naive Bayes Classifier: 0.8310
Precision Score for Naive Bayes Classifier: 0.8366847036742341
Recall Score for Naive Bayes Classifier: 0.8310109289617487
F1 Score for Naive Bayes Classifier: 0.8302011482463786

Confusion Matrix for Naive Bayes Classifier and Count Vectorizer:
```





3.1 SMOTE & TF-IDF

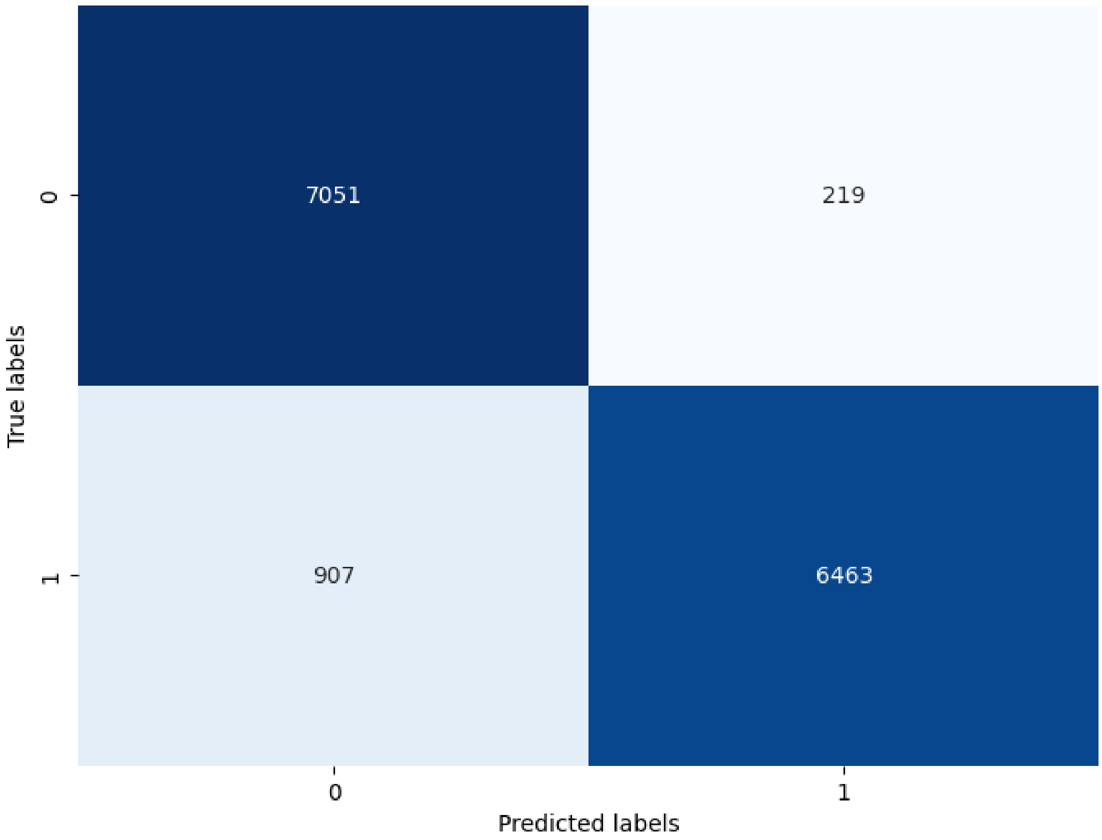
[31]:
```
#SMOTE TF-IDF
from sklearn.feature_extraction.text import TfidfVectorizer
from imblearn.over_sampling import SMOTE
from sklearn.model_selection import train_test_split

# Split data into features (X) and labels (y)
X_tfidf = df['text_clean']
y_tfidf = df['sentiment']

# Initialize TfidfVectorizer
tfidf_vectorizer = TfidfVectorizer()

# Convert text data into numerical vectors using TF-IDF vectorization
X_tfidf_vectors = tfidf_vectorizer.fit_transform(X_tfidf)
```

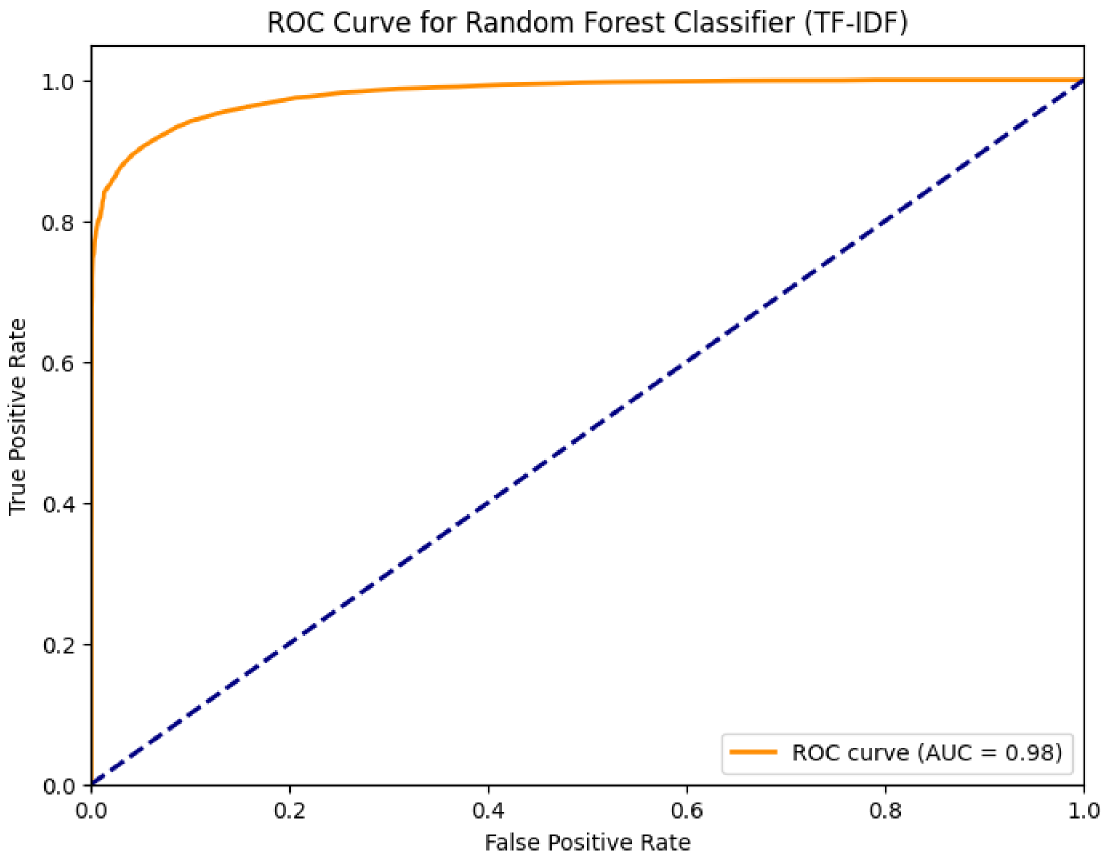
```
# Initialize SMOTE
smote_tfidf = SMOTE(random_state=42)

# Resample the data using SMOTE
X_resampled_tfidf, y_resampled_tfidf = smote_tfidf.
 ↪fit_resample(X_tfidf_vectors, y_tfidf)

# Split the resampled data into train and test sets
X_train_tfidf, X_test_tfidf, y_train_tfidf, y_test_tfidf =␣
 ↪train_test_split(X_resampled_tfidf, y_resampled_tfidf, test_size=0.2,␣
 ↪random_state=42)
```

[37]:

```
#TF-IDF & RF
# Train Random Forest classifier
rf_classifier_tfidf = RandomForestClassifier()
rf_classifier_tfidf.fit(X_train_tfidf, y_train_tfidf)

# Make predictions using Random Forest classifier
rf_predictions_tfidf = rf_classifier_tfidf.predict(X_test_tfidf)
# Calculate accuracy for Random Forest classifier
rf_accuracy_tfidf = accuracy_score(y_test_tfidf, rf_predictions_tfidf)

joblib.dump(rf_classifier_tfidf, 'rf_classifier_tfidf.joblib')

# Calculate precision, recall, and F1-score for Random Forest classifier
precision_rf_tfidf = precision_score(y_test_tfidf, rf_predictions_tfidf,␣
 ↪average='weighted')
recall_rf_tfidf = recall_score(y_test_tfidf, rf_predictions_tfidf,␣
 ↪average='weighted')
f1_rf_tfidf = f1_score(y_test_tfidf, rf_predictions_tfidf, average='weighted')

# Generate classification report
print("Random Forest Classification Report:")
print(classification_report(y_test_tfidf, rf_predictions_tfidf))
print(f"Accuracy Score for Random Forest Classifier: {rf_accuracy_tfidf:.4f}")
print("Precision Score for Random Forest Classifier:", precision_rf_tfidf)
print("Recall Score for Random Forest Classifier:", recall_rf_tfidf)
print("F1 Score for Random Forest Classifier:", f1_rf_tfidf)

# Generate confusion matrix for Random Forest classifier
conf_matrix_rf_tfidf = confusion_matrix(y_test_tfidf, rf_predictions_tfidf)
print("\nConfusion Matrix for Random Forest Classifier:")
# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix_rf_tfidf, annot=True, fmt='d', cmap='Blues', cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.show()

# Get predicted probabilities for each class
rf_probs_tfidf = rf_classifier_tfidf.predict_proba(X_test_tfidf)

# Compute ROC curve and AUC
fpr, tpr, _ = roc_curve(y_test_tfidf, rf_probs_tfidf[:, 1])  # Use␣
 ↪probabilities for the positive class
roc_auc = auc(fpr, tpr)

# Plot ROC curve
plt.figure(figsize=(8, 6))
plt.plot(fpr, tpr, color='darkorange', lw=2, label=f'ROC curve (AUC = {roc_auc:.
 ↪2f})')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Random Forest Classifier (TF-IDF)')
plt.legend(loc='lower right')
plt.show()
```

```
Random Forest Classification Report:
              precision    recall  f1-score   support

           0       0.89      0.97      0.93      7270
           1       0.97      0.88      0.92      7370

    accuracy                           0.92     14640
   macro avg       0.93      0.92      0.92     14640
weighted avg       0.93      0.92      0.92     14640

Accuracy Score for Random Forest Classifier: 0.9231
Precision Score for Random Forest Classifier: 0.926903328847879
Recall Score for Random Forest Classifier: 0.9230874316939891
F1 Score for Random Forest Classifier: 0.9229420257805973

Confusion Matrix for Random Forest Classifier:
```


7051
219
907
6463
0
1
True labels
0
1
Predicted labels

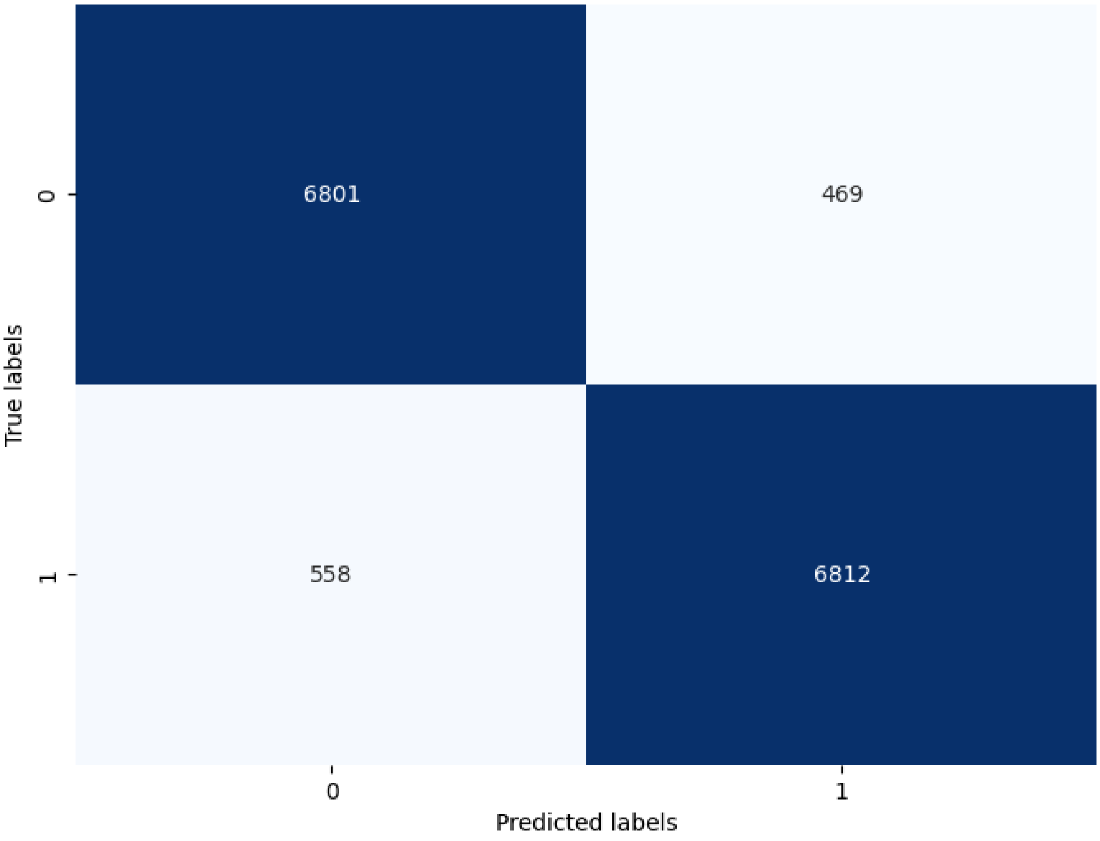


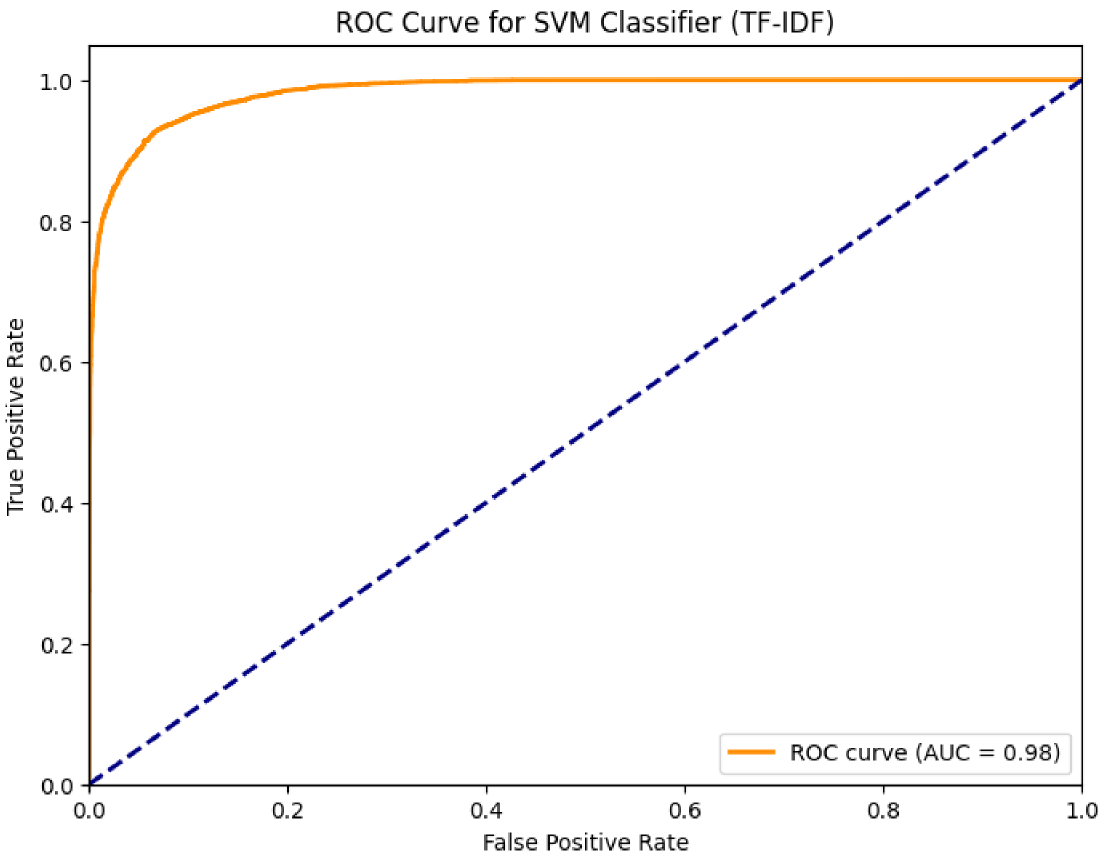
[32]:

```
#TF-IDF & SVM
# Train SVM classifier
svm_classifier_tfidf = SVC()
svm_classifier_tfidf.fit(X_train_tfidf, y_train_tfidf)

# Predictions using SVM classifier
svm_predictions_tfidf = svm_classifier_tfidf.predict(X_test_tfidf)
# Calculate accuracy for SVM classifier
svm_accuracy_tfidf = accuracy_score(y_test_tfidf, svm_predictions_tfidf)

joblib.dump(svm_classifier_tfidf, 'svm_classifier_tfidf.joblib')

# Calculate precision, recall, and F1-score for SVM classifier
precision_svm_tfidf = precision_score(y_test_tfidf, svm_predictions_tfidf,␣
  ↪average='weighted')
recall_svm_tfidf = recall_score(y_test_tfidf, svm_predictions_tfidf,␣
  ↪average='weighted')
f1_svm_tfidf = f1_score(y_test_tfidf, svm_predictions_tfidf, average='weighted')

print("SVM Classification Report:")
print(classification_report(y_test_tfidf, svm_predictions_tfidf))
print(f"Accuracy Score for SVM Classifier: {svm_accuracy_tfidf:.4f}")
print("Precision Score for SVM Classifier:", precision_svm_tfidf)
print("Recall Score for SVM Classifier:", recall_svm_tfidf)
print("F1 Score for SVM Classifier:", f1_svm_tfidf)

# Generate confusion matrix for SVM classifier
conf_matrix_svm_tfidf = confusion_matrix(y_test_tfidf, svm_predictions_tfidf)
print("\nConfusion Matrix for SVM Classifier:")
# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix_svm_tfidf, annot=True, fmt='d', cmap='Blues',␣
 ↪cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.show()

# Get predicted probabilities for each class
svm_probs_tfidf = svm_classifier_tfidf.decision_function(X_test_tfidf)

# Compute ROC curve and AUC
fpr, tpr, _ = roc_curve(y_test_tfidf, svm_probs_tfidf)
roc_auc = auc(fpr, tpr)

# Plot ROC curve
plt.figure(figsize=(8, 6))
plt.plot(fpr, tpr, color='darkorange', lw=2, label=f'ROC curve (AUC = {roc_auc:.
 ↪2f})')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for SVM Classifier (TF-IDF)')
plt.legend(loc='lower right')
plt.show()
```

```
SVM Classification Report:
              precision    recall  f1-score   support

           0       0.92      0.94      0.93      7270
           1       0.94      0.92      0.93      7370

    accuracy                           0.93     14640
   macro avg       0.93      0.93      0.93     14640
weighted avg       0.93      0.93      0.93     14640
```

```
Accuracy Score for SVM Classifier: 0.9298
Precision Score for SVM Classifier: 0.9299190986950254
Recall Score for SVM Classifier: 0.9298497267759562
F1 Score for SVM Classifier: 0.9298500472037285

Confusion Matrix for SVM Classifier:
```





[33]:
```
from sklearn.model_selection import cross_val_score

# Define the SVM classifier
svm_classifier_tfidf = SVC()

# Perform cross-validation
cv_scores_tfidf = cross_val_score(svm_classifier_tfidf, X_train_tfidf,␣
↪y_train_tfidf, cv=15)

# Print the cross-validation scores
print("Cross-validation scores:", cv_scores_tfidf)

# Calculate and print the mean accuracy score
mean_cv_score_tfidf = cv_scores_tfidf.mean()
print("Mean cross-validation score:", mean_cv_score_tfidf)
```

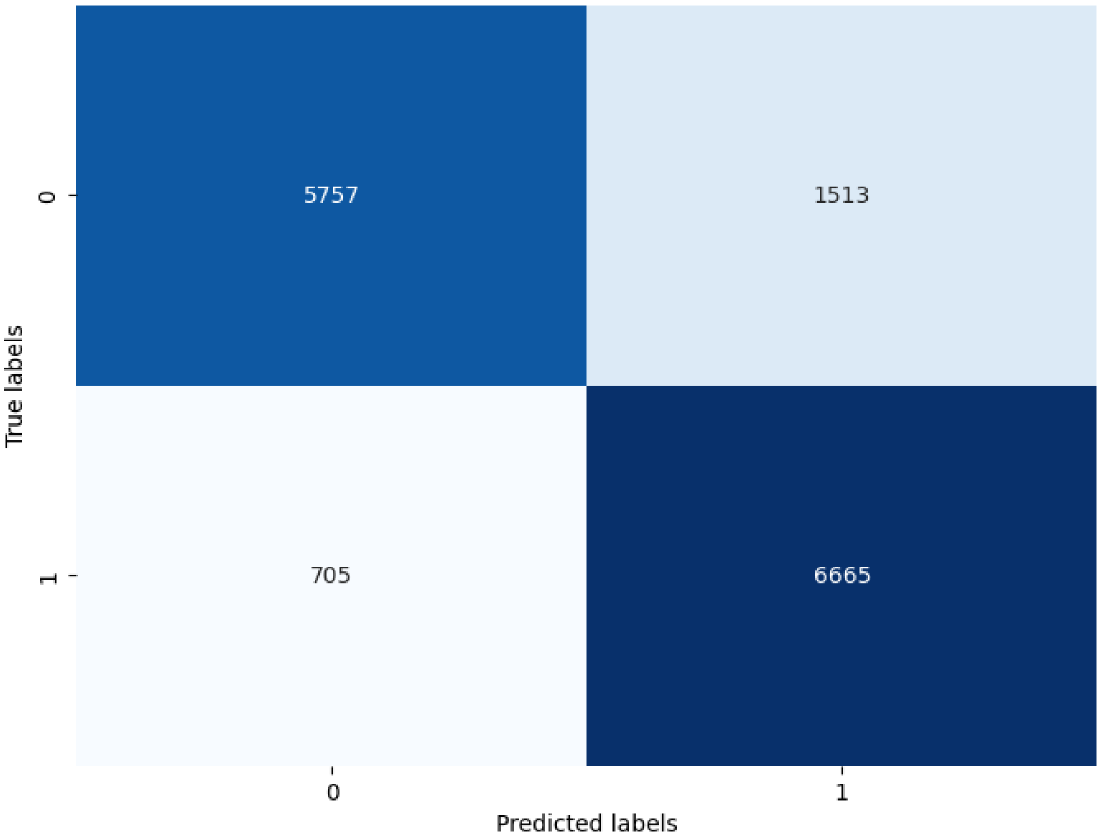
```
Cross-validation scores: [0.92418033 0.92597336 0.92648566 0.9213627  0.92085041
0.93084016
 0.92546107 0.93186475 0.92597336 0.93160861 0.92366803 0.91878043
 0.92339226 0.9318473  0.92159877]
```

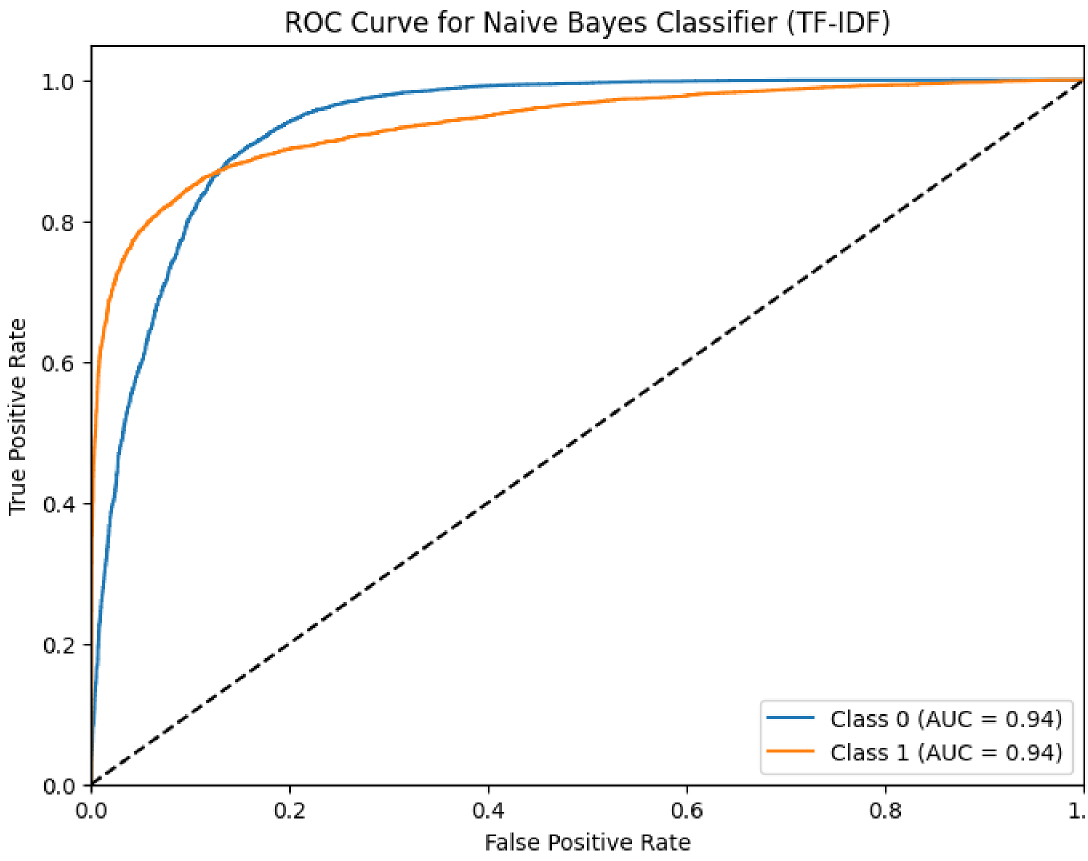
```
Mean cross-validation score: 0.9255924798284632
```

[38]:

```
#TF-IDF & NB
# Train Naive Bayes classifier
nb_classifier_tfidf = MultinomialNB()
nb_classifier_tfidf.fit(X_train_tfidf, y_train_tfidf)

# Predictions using Naive Bayes classifier
nb_predictions_tfidf = nb_classifier_tfidf.predict(X_test_tfidf)
# Calculate accuracy for Naive Bayes classifier
nb_accuracy_tfidf = accuracy_score(y_test_tfidf, nb_predictions_tfidf)

joblib.dump(nb_classifier_tfidf, 'nb_classifier_tfidf.joblib')

# Calculate precision, recall, and F1-score for Naive Bayes classifier
precision_nb_tfidf = precision_score(y_test_tfidf, nb_predictions_tfidf,␣
 ↪average='weighted')
recall_nb_tfidf = recall_score(y_test_tfidf, nb_predictions_tfidf,␣
 ↪average='weighted')
f1_nb_tfidf = f1_score(y_test_tfidf, nb_predictions_tfidf, average='weighted')

print("Naive Bayes Classification Report:")
print(classification_report(y_test_tfidf, nb_predictions_tfidf))
print(f"Accuracy Score for Naive Bayes Classifier: {nb_accuracy_tfidf:.4f}")
print("Precision Score for Naive Bayes Classifier:", precision_nb_tfidf)
print("Recall Score for Naive Bayes Classifier:", recall_nb_tfidf)
print("F1 Score for Naive Bayes Classifier:", f1_nb_tfidf)

# Generate confusion matrix for Naive Bayes classifier
conf_matrix_nb_tfidf = confusion_matrix(y_test_tfidf, nb_predictions_tfidf)
print("\nConfusion Matrix for Naive Bayes Classifier:")
# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix_nb_tfidf, annot=True, fmt='d', cmap='Blues', cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.show()

# Get predicted probabilities for each class
nb_probs_tfidf = nb_classifier_tfidf.predict_proba(X_test_tfidf)

# Compute ROC curve and AUC for each class
fpr = dict()
tpr = dict()
roc_auc = dict()
for i in range(len(nb_classifier_tfidf.classes_)):
    fpr[i], tpr[i], _ = roc_curve(y_test_tfidf == nb_classifier_tfidf.
 ↪classes_[i], nb_probs_tfidf[:, i])
    roc_auc[i] = auc(fpr[i], tpr[i])

# Plot ROC curve for each class
plt.figure(figsize=(8, 6))
for i in range(len(nb_classifier_tfidf.classes_)):
    plt.plot(fpr[i], tpr[i], label=f'Class {nb_classifier_tfidf.classes_[i]}␣
 ↪(AUC = {roc_auc[i]:.2f})')

plt.plot([0, 1], [0, 1], 'k--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Naive Bayes Classifier (TF-IDF)')
plt.legend(loc='lower right')
plt.show()
```

```
Naive Bayes Classification Report:
              precision    recall  f1-score   support

           0       0.89      0.79      0.84      7270
           1       0.81      0.90      0.86      7370

    accuracy                           0.85     14640
   macro avg       0.85      0.85      0.85     14640
weighted avg       0.85      0.85      0.85     14640

Accuracy Score for Naive Bayes Classifier: 0.8485
Precision Score for Naive Bayes Classifier: 0.8526867924370832
Recall Score for Naive Bayes Classifier: 0.8484972677595628
F1 Score for Naive Bayes Classifier: 0.8479766615454507

Confusion Matrix for Naive Bayes Classifier:
```


5757
1513
705
6665
0
1
True labels
0
1
Predicted labels



3.2 SMOTE & BoW

[39]:
```python
#SMOTE and BoW
from sklearn.feature_extraction.text import CountVectorizer
from imblearn.over_sampling import SMOTE
from sklearn.model_selection import train_test_split

# Split data into features (X) and labels (y)
X = df['text_clean']
y = df['sentiment']

# Initialize CountVectorizer with n-grams up to trigrams
count_vectorizer_ngrams = CountVectorizer(ngram_range=(1, 3))  # This specifies unigrams, bigrams, and trigrams

# Convert text data into numerical vectors using CountVectorizer with n-grams
X_count_ngrams = count_vectorizer_ngrams.fit_transform(X)

# Initialize SMOTE
```

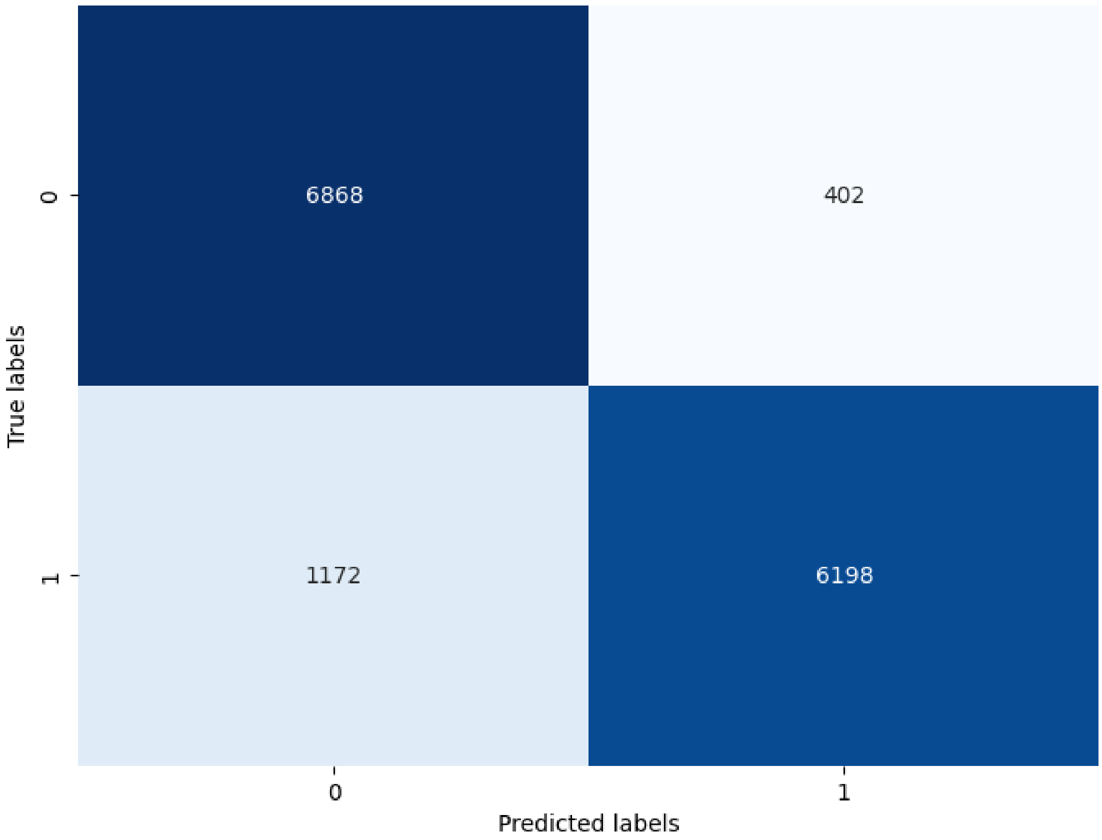
```
smote = SMOTE(random_state=42)

# Resample the data using SMOTE
X_resampled_ngrams, y_resampled_ngrams = smote.fit_resample(X_count_ngrams, y)

# Split the resampled data into train and test sets
X_train_ngrams, X_test_ngrams, y_train_ngrams, y_test_ngrams =␣
 ↪train_test_split(X_resampled_ngrams, y_resampled_ngrams, test_size=0.2,␣
 ↪random_state=42)
```

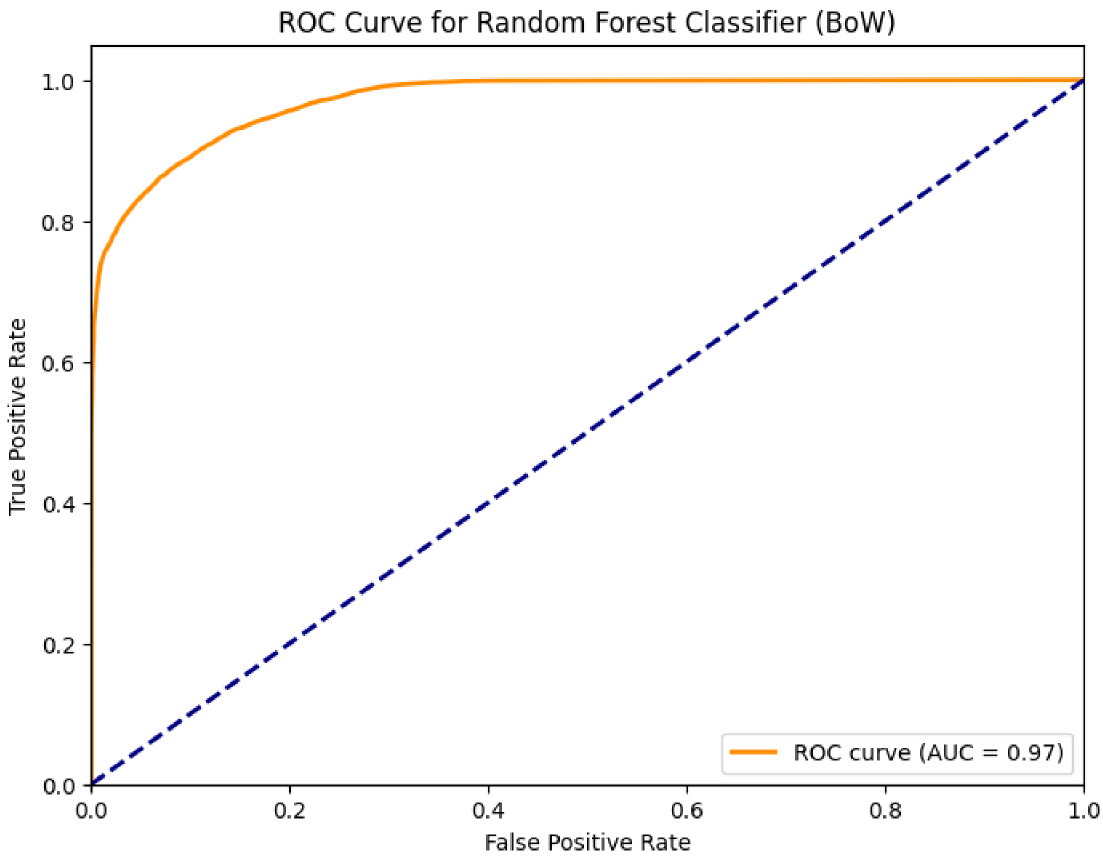
[40]:

```
#BoW & RF
# Train Random Forest classifier
rf_classifier_bow = RandomForestClassifier()
rf_classifier_bow.fit(X_train_ngrams, y_train_ngrams)

# Make predictions using Random Forest classifier
y_pred_rf = rf_classifier_bow.predict(X_test_ngrams)

# Calculate accuracy for Random Forest classifier
rf_accuracy = accuracy_score(y_test_ngrams, y_pred_rf)

joblib.dump(rf_classifier_bow, 'rf_classifier_bow.joblib')

# Calculate precision, recall, and F1-score for Random Forest classifier
precision_rf = precision_score(y_test_ngrams, y_pred_rf, average='weighted')
recall_rf = recall_score(y_test_ngrams, y_pred_rf, average='weighted')
f1_rf = f1_score(y_test_ngrams, y_pred_rf, average='weighted')

# Generate classification report for Random Forest classifier
print("Random Forest Classification Report:")
print(classification_report(y_test_ngrams, y_pred_rf))
print("Accuracy Score for Random Forest Classifier:", rf_accuracy)
print("Precision Score for Random Forest Classifier:", precision_rf)
print("Recall Score for Random Forest Classifier:", recall_rf)
print("F1 Score for Random Forest Classifier:", f1_rf)

# Generate confusion matrix for Random Forest classifier
conf_matrix_bow_rf = confusion_matrix(y_test_ngrams, y_pred_rf)
print("\nConfusion Matrix for Random Forest Classifier:")
# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix_bow_rf, annot=True, fmt='d', cmap='Blues', cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.show()

# Calculate predicted probabilities for each class
```

```python
rf_probs = rf_classifier_bow.predict_proba(X_test_ngrams)[:, 1]

# Compute ROC curve and AUC
fpr_rf, tpr_rf, _ = roc_curve(y_test_ngrams, rf_probs)
roc_auc_rf = auc(fpr_rf, tpr_rf)

# Plot ROC curve
plt.figure(figsize=(8, 6))
plt.plot(fpr_rf, tpr_rf, color='darkorange', lw=2, label=f'ROC curve (AUC = {roc_auc_rf:.2f})')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Random Forest Classifier (BoW)')
plt.legend(loc='lower right')
plt.show()
```

```
Random Forest Classification Report:
              precision    recall  f1-score   support

           0       0.85      0.94      0.90      7270
           1       0.94      0.84      0.89      7370

    accuracy                           0.89     14640
   macro avg       0.90      0.89      0.89     14640
weighted avg       0.90      0.89      0.89     14640

Accuracy Score for Random Forest Classifier: 0.8924863387978142
Precision Score for Random Forest Classifier: 0.8969497118233968
Recall Score for Random Forest Classifier: 0.8924863387978142
F1 Score for Random Forest Classifier: 0.8922270059182499

Confusion Matrix for Random Forest Classifier:
```


6868
402
1172
6198
True labels
0
1
0
1
Predicted labels



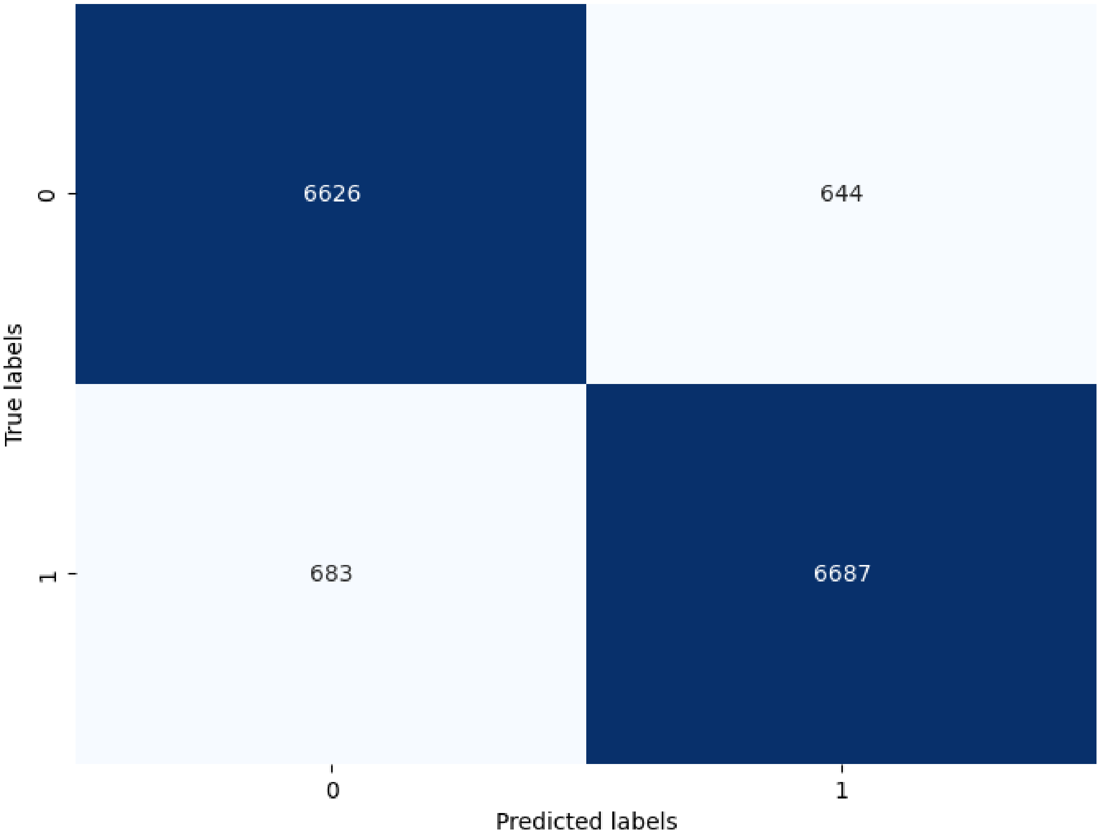
[41]:

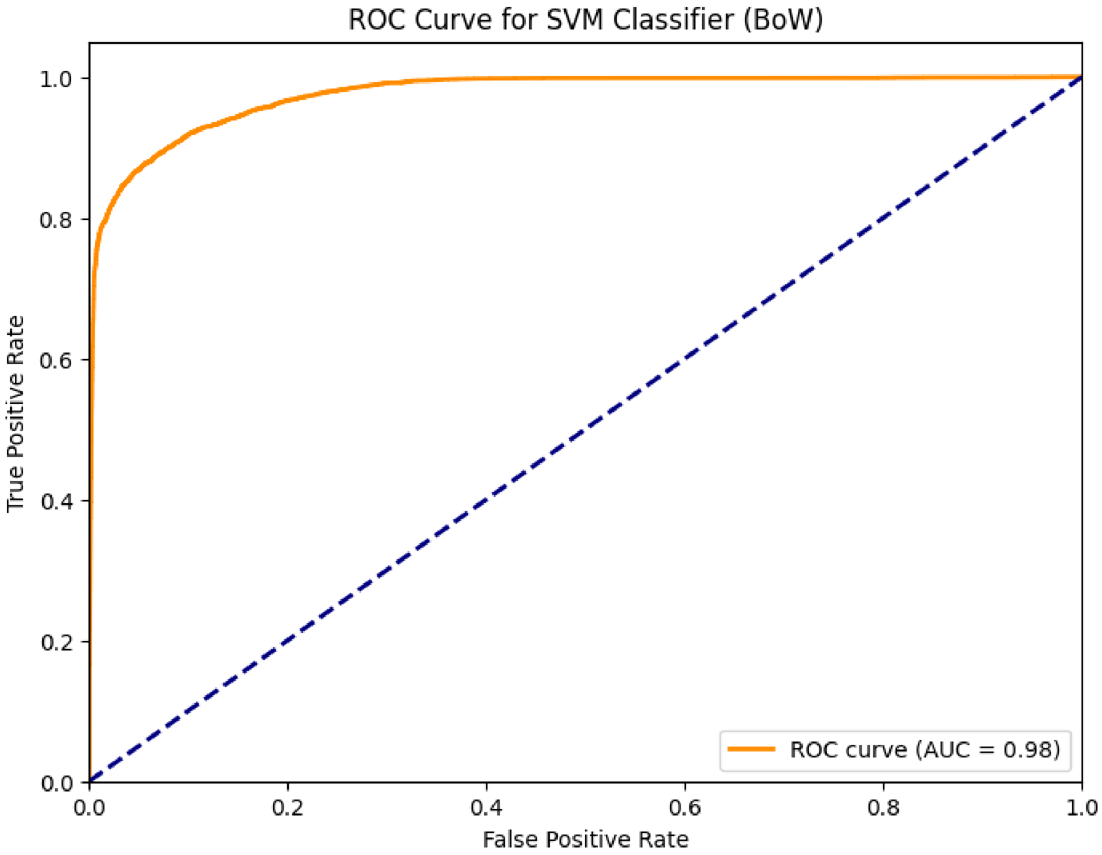
```
#BoW & SVM

# Train SVM classifier
svm_classifier_bow = SVC()
svm_classifier_bow.fit(X_train_ngrams, y_train_ngrams)

# Make predictions using SVM classifier
y_pred_svm = svm_classifier_bow.predict(X_test_ngrams)

# Calculate accuracy for SVM classifier
svm_accuracy = accuracy_score(y_test_ngrams, y_pred_svm)

joblib.dump(svm_classifier_bow, 'svm_classifier_bow.joblib')

# Calculate precision, recall, and F1-score for SVM classifier
precision_svm = precision_score(y_test_ngrams, y_pred_svm, average='weighted')
recall_svm = recall_score(y_test_ngrams, y_pred_svm, average='weighted')
f1_svm = f1_score(y_test_ngrams, y_pred_svm, average='weighted')

# Generate classification report for SVM classifier
```

```
print("SVM Classification Report:")
print(classification_report(y_test_ngrams, y_pred_svm))
print("Accuracy Score for SVM Classifier:", svm_accuracy)

print("Precision Score for SVM Classifier:", precision_svm)
print("Recall Score for SVM Classifier:", recall_svm)
print("F1 Score for SVM Classifier:", f1_svm)

# Generate confusion matrix for SVM classifier
conf_matrix_bow_svm = confusion_matrix(y_test_ngrams, y_pred_svm)
print("\nConfusion Matrix for SVM Classifier:")
# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix_bow_svm, annot=True, fmt='d', cmap='Blues', cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.show()

# Calculate predicted probabilities for each class
svm_probs = svm_classifier_bow.decision_function(X_test_ngrams)

# Compute ROC curve and AUC
fpr_svm, tpr_svm, _ = roc_curve(y_test_ngrams, svm_probs)
roc_auc_svm = auc(fpr_svm, tpr_svm)

# Plot ROC curve
plt.figure(figsize=(8, 6))
plt.plot(fpr_svm, tpr_svm, color='darkorange', lw=2, label=f'ROC curve (AUC =␣
 ↪{roc_auc_svm:.2f})')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for SVM Classifier (BoW)')
plt.legend(loc='lower right')
plt.show()
```

```
SVM Classification Report:
              precision    recall  f1-score   support

           0       0.91      0.91      0.91      7270
           1       0.91      0.91      0.91      7370

    accuracy                           0.91     14640
   macro avg       0.91      0.91      0.91     14640
weighted avg       0.91      0.91      0.91     14640
```

```
Accuracy Score for SVM Classifier: 0.9093579234972677
Precision Score for SVM Classifier: 0.9093728423373346
Recall Score for SVM Classifier: 0.9093579234972677
F1 Score for SVM Classifier: 0.9093589296170186

Confusion Matrix for SVM Classifier:
```





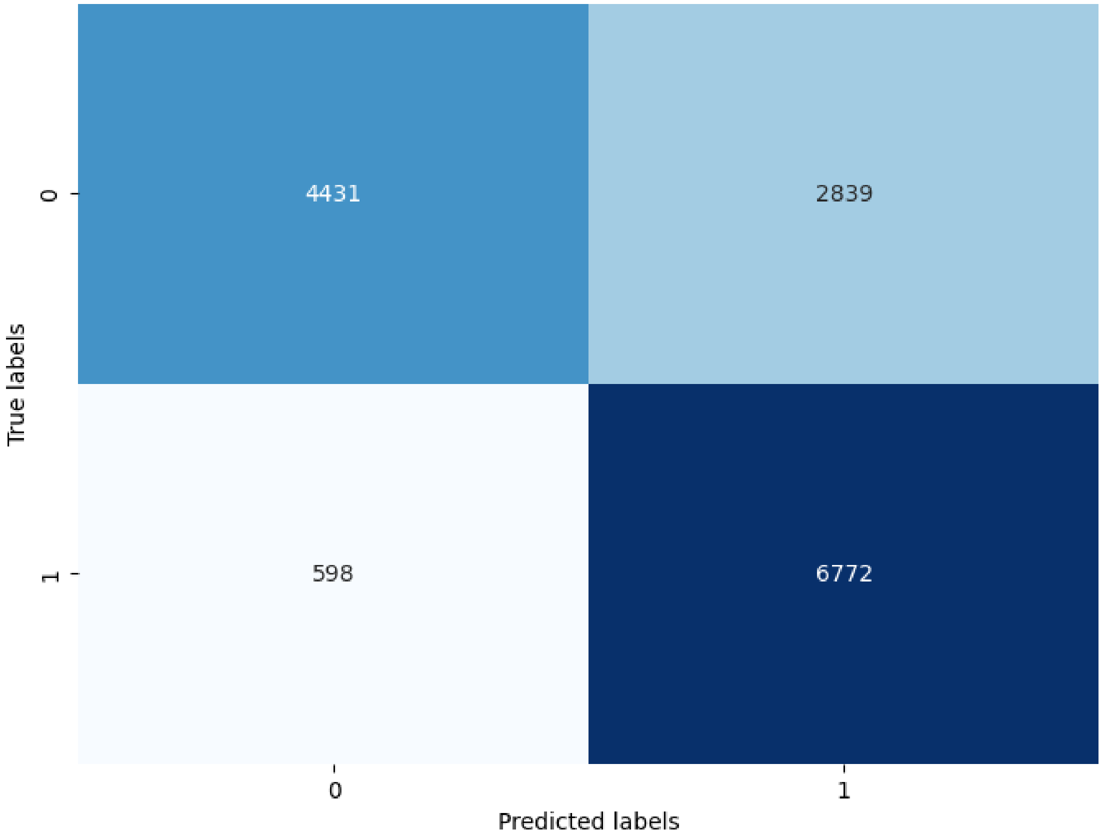
[42]:

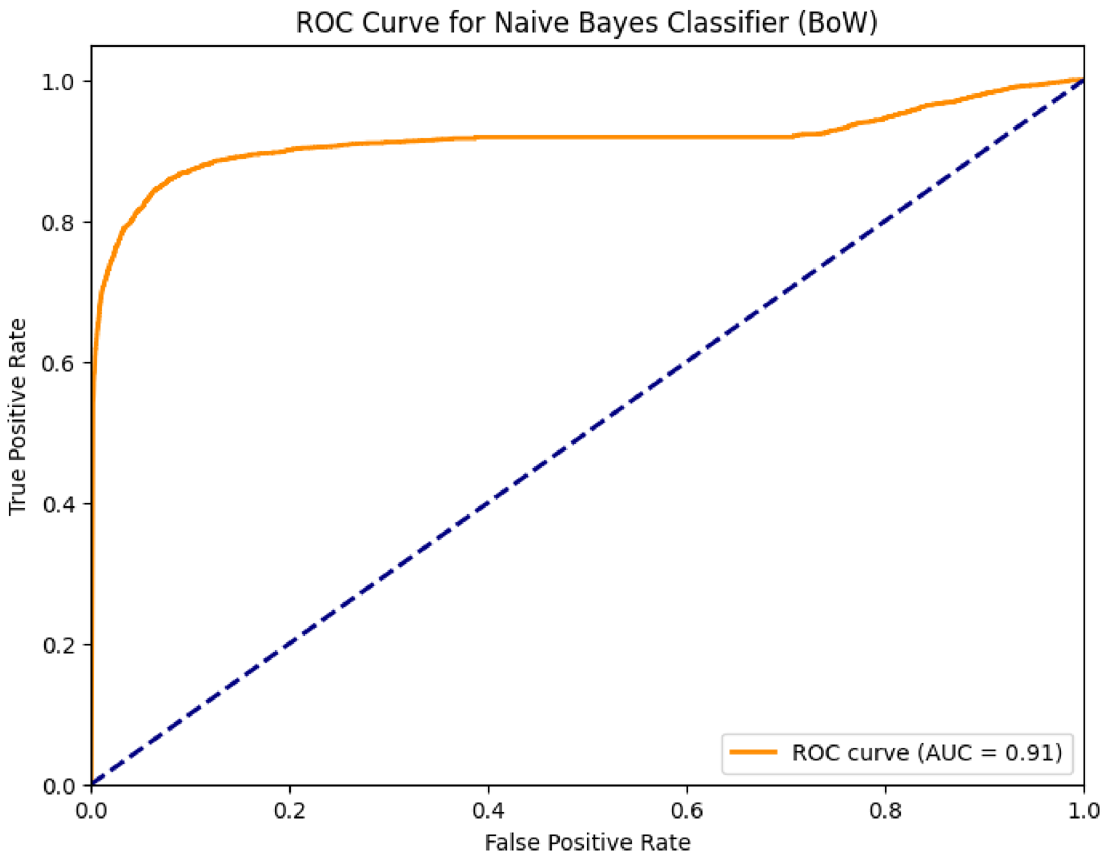
```
#BoW & NB

# Train Naive Bayes classifier
nb_classifier_bow = MultinomialNB()
nb_classifier_bow.fit(X_train_ngrams, y_train_ngrams)

# Make predictions using Naive Bayes classifier
y_pred_nb = nb_classifier_bow.predict(X_test_ngrams)

# Calculate accuracy for Naive Bayes classifier
nb_accuracy = accuracy_score(y_test_ngrams, y_pred_nb)

joblib.dump(nb_classifier_bow, 'nb_classifier_bow.joblib')

# Calculate precision, recall, and F1-score for Naive Bayes classifier
precision_nb = precision_score(y_test_ngrams, y_pred_nb, average='weighted')
recall_nb = recall_score(y_test_ngrams, y_pred_nb, average='weighted')
f1_nb = f1_score(y_test_ngrams, y_pred_nb, average='weighted')

# Generate classification report for Naive Bayes classifier
```

```python
print("Naive Bayes Classification Report:")
print(classification_report(y_test_ngrams, y_pred_nb))
print("Accuracy Score for Naive Bayes Classifier:", nb_accuracy)
print("Precision Score for Naive Bayes Classifier:", precision_nb)
print("Recall Score for Naive Bayes Classifier:", recall_nb)
print("F1 Score for Naive Bayes Classifier:", f1_nb)

# Generate confusion matrix for Naive Bayes classifier
conf_matrix_nb = confusion_matrix(y_test_ngrams, y_pred_nb)
print("\nConfusion Matrix for Naive Bayes Classifier:")
# Plot confusion matrix
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix_nb, annot=True, fmt='d', cmap='Blues', cbar=False)
plt.xlabel('Predicted labels')
plt.ylabel('True labels')
plt.show()

# Calculate predicted probabilities for each class
nb_probs = nb_classifier_bow.predict_proba(X_test_ngrams)[:, 1]  # Considering only the positive class

# Compute ROC curve and AUC
fpr_nb, tpr_nb, _ = roc_curve(y_test_ngrams, nb_probs)
roc_auc_nb = auc(fpr_nb, tpr_nb)

# Plot ROC curve
plt.figure(figsize=(8, 6))
plt.plot(fpr_nb, tpr_nb, color='darkorange', lw=2, label=f'ROC curve (AUC = {roc_auc_nb:.2f})')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Naive Bayes Classifier (BoW)')
plt.legend(loc='lower right')
plt.show()
```

```
Naive Bayes Classification Report:
              precision    recall  f1-score   support

           0       0.88      0.61      0.72      7270
           1       0.70      0.92      0.80      7370

    accuracy                           0.77     14640
   macro avg       0.79      0.76      0.76     14640
weighted avg       0.79      0.77      0.76     14640
```

```
Accuracy Score for Naive Bayes Classifier: 0.7652322404371584
Precision Score for Naive Bayes Classifier: 0.7922467573177625
Recall Score for Naive Bayes Classifier: 0.7652322404371584
F1 Score for Naive Bayes Classifier: 0.7593350023445067

Confusion Matrix for Naive Bayes Classifier:
```





[50]:

```
# Load the trained SVM classifier with TF-IDF vectorization
loaded_svm_classifier = joblib.load('svm_classifier_tfidf.joblib')

cyberbullying_types = {
    0: "not_cyberbullying",
    1: "cyberbullying"
}


# Take a dummy text as input
new_text = input("Enter your text: ")

# Preprocess the dummy text (apply the same preprocessing steps used during␣
 ↪training)
new_text_cleaned = preprocess(new_text)

# Convert the preprocessed text into numerical vectors using TF-IDF␣
 ↪vectorization
new_text_vectorized = tfidf_vectorizer.transform([new_text_cleaned])
```

```
# Make predictions using the loaded SVM classifier
predictions = loaded_svm_classifier.predict(new_text_vectorized)

# Map each numerical category to its corresponding actual type
predicted_types = [cyberbullying_types[prediction] for prediction in␣
  ↪predictions]

print(f"Predicted Category: {predicted_types}\n")
```

```
Enter your text:  You did a fantastic job on that project, keep up
the good work!

Predicted Category: ['not_cyberbullying']
```

[48]:

```
import joblib

# Load the trained SVM classifier with BoW vectorization
loaded_svm_classifier = joblib.load('svm_classifier_bow.joblib')

cyberbullying_types = {
    0: "not_cyberbullying",
    1: "cyberbullying"
}

# Take a dummy text as input
new_text = input("Enter your text: ")

# Preprocess the dummy text (apply the same preprocessing steps used during␣
  ↪training)
new_text_cleaned = preprocess(new_text)

# Convert the preprocessed text into numerical vectors using BoW vectorization
new_text_vectorized = count_vectorizer_ngrams.transform([new_text_cleaned])

# Make predictions using the loaded SVM classifier
predictions = loaded_svm_classifier.predict(new_text_vectorized)

# Map each numerical category to its corresponding actual type
predicted_types = [cyberbullying_types[prediction] for prediction in␣
  ↪predictions]

print(f"Predicted Category: {predicted_types}\n")
```

```
Enter your text:  You did a fantastic job on that project, keep up
the good work!

Predicted Category: ['not_cyberbullying']
```

[ ]:

```
# Load the trained SVM classifier with TF-IDF vectorization
loaded_svm_classifier = joblib.load('svm_classifier_tfidf.joblib')

cyberbullying_types = {
    0: "not_cyberbullying",
    1: "cyberbullying"
}



# Take a dummy text as input
new_text = input("Enter your text: ")

# Preprocess the dummy text (apply the same preprocessing steps used during␣
 ↪training)
new_text_cleaned = preprocess(new_text)

# Convert the preprocessed text into numerical vectors using TF-IDF␣
 ↪vectorization
new_text_vectorized = tfidf_vectorizer.transform([new_text_cleaned])

# Make predictions using the loaded SVM classifier
predictions = loaded_svm_classifier.predict(new_text_vectorized)

# Map each numerical category to its corresponding actual type
predicted_types = [cyberbullying_types[prediction] for prediction in␣
 ↪predictions]

print(f"Predicted Category: {predicted_types}\n")
```

4 Model Training and Evaluation

[ ]:

```
import joblib
```

[ ]:

```
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.model_selection import train_test_split
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import accuracy_score, classification_report,␣
 ↪precision_score, recall_score, f1_score
import joblib

# Define Count Vectorizer
count_vectorizer = CountVectorizer()

# Fit and transform the training data
```

```
X_train_count = count_vectorizer.fit_transform(X_train)

# Save the fitted Count Vectorizer to a file
joblib.dump(count_vectorizer, 'count_vectorizer.joblib')

# Initialize Random Forest model
random_forest = RandomForestClassifier()

# Train the Random Forest model
random_forest.fit(X_train_count, y_train)

# Save the trained model using joblib
joblib.dump(random_forest, 'random_forest_model.joblib')
```

[ ]:

```
# Load the saved Count Vectorizer
count_vectorizer = joblib.load('count_vectorizer.joblib')

# Transform the test data using the loaded Count Vectorizer
X_test_count = count_vectorizer.transform(X_test)

# Load the trained Random Forest model
random_forest = joblib.load('random_forest_model.joblib')

# Use the loaded Random Forest model to make predictions
y_pred = random_forest.predict(X_test_count)

# Generate the classification report
report = classification_report(y_test, y_pred)

print("Classification Report:")
print(report)
```

4.1 Hyper Parameter Tuning

[ ]:

```
from sklearn.ensemble import RandomForestClassifier
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import classification_report

# Define Count Vectorizer
count_vectorizer = CountVectorizer()

# Vectorize the training data
X_train_count = count_vectorizer.fit_transform(X_train)

# Define the Random Forest classifier
rf_classifier = RandomForestClassifier()
```

```
# Define the parameter grid for hyperparameter tuning
param_grid = {
    'n_estimators': [100, 200, 300],
    'max_depth': [None, 10, 20],
    'min_samples_split': [2, 5, 10],
    'min_samples_leaf': [1, 2, 4]
}

# Initialize GridSearchCV
grid_search = GridSearchCV(estimator=rf_classifier, param_grid=param_grid,␣
 ↪cv=5, scoring='accuracy', verbose=2, n_jobs=-1)

# Perform hyperparameter tuning
grid_search.fit(X_train_count, y_train)

# Print the best parameters and best score
print("Best Parameters:", grid_search.best_params_)
print("Best Score:", grid_search.best_score_)

# Vectorize the test data
X_test_count = count_vectorizer.transform(X_test)

# Make predictions using the best estimator
y_pred = grid_search.best_estimator_.predict(X_test_count)

# Evaluate the performance of the tuned model
print("Classification Report:")
print(classification_report(y_test, y_pred))
```

5

5.1 Prediction

[ ]:

```
import joblib

# Load the trained model
random_forest_model = joblib.load('random_forest_model.joblib')

# Load the Count Vectorizer
count_vectorizer = joblib.load('count_vectorizer.joblib')

# Define a mapping dictionary for numerical categories to actual types
cyberbullying_types = {
    0: "not_cyberbullying",
    1: "cyberbullying"
```

```python
}

# Define a function to predict the type of cyberbullying
def predict_cyberbullying_type(text):
    # Transform the input text using the Count Vectorizer
    processed_text_count = count_vectorizer.transform([text])

    # Use the trained Random Forest model to predict the type of cyberbullying
    predicted_type_code = random_forest_model.predict(processed_text_count)[0]

    # Map the numerical category to its corresponding actual type
    predicted_type = cyberbullying_types.get(predicted_type_code)

    return predicted_type

# Example usage:
input_text = input("Enter your text: ")

# Call the predict_cyberbullying_type function
predicted_type = predict_cyberbullying_type(input_text)
print("Predicted Type:", predicted_type)
```