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Project Deadline: 11/25/2021

Problem Description

The term hate speech is any form of expression (verbal, written, or behavioral communication) that attacks or uses derogatory or discriminatory language against a person or group. This hate could be towards religion, ethnicity, nationality, race, color, ancestry, sex, or other identity factors. In this problem, we need to build a machine learning model that predicts which tweets have hate speech in them.

Hate Speech Detection is generally a task of sentiment classification. To classify hate speech from a piece of text, we need to train the model on data used to classify sentiments. So for the task of the hate speech detection model, we will use Twitter tweets to identify tweets containing hate speech.

Business Understanding

Organizations need to consider customers' mentality and what type of audience they are offering their products to, but dealing with the immediacy of user feedback is not an easy task, especially when the speech turns offensive. Our goal is to build a machine learning model with an f1-score higher than or equal to 0.95 to help organizations automatically detect hate speech within tweets.

Project Lifecycle



Figure 1: Project Lifecycle

Data Intake Report

Name: Hate Speech Detection
Report date: 11/25/2021
Internship Batch: NLP02
Version:1.0
Data intake by: Alaa Eddine Osta
Data intake reviewer:
Data storage location: <https://github.com/Osta-Alaa/Hate-Speech-Detection>

Tabular data details: df

Total number of observations	31962
Total number of files	1
Total number of features	3
Base format of the file	.csv
Size of the data	749.2+ KB

Data Understanding

	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
...
31957	31958	0	ate @user isz that youuu?δ□□□δ□□□δ□□□δ□□□δ...
31958	31959	0	to see nina turner on the airwaves trying to...
31959	31960	0	listening to sad songs on a monday morning otw...
31960	31961	1	@user #sikh #temple vandalised in in #calgary,...
31961	31962	0	thank you @user for you follow

31962 rows × 3 columns

Figure 1: Data Frame of the Data

Observations from Figure 1:

- There is a lot of noise in the data ()
- There are three total columns in the dataset
- The number of observations is equal to 31962

```
RangeIndex: 31962 entries, 0 to 31961
Data columns (total 3 columns):
#   Column  Non-Null Count  Dtype
---  -
0   id      31962 non-null  int64
1   label   31962 non-null  int64
2   tweet   31962 non-null  object
dtypes: int64(2), object(1)
memory usage: 749.2+ KB
```

Figure 2: Data Frame Information

Observations from Figure 2:

- There are no null values in the dataset
- The data type of the tweet column is String object
- The data type of both id and label columns is int64
- The size of the data is 749.2+ KB

	label	count	percentage
0	0	29720	92.98542
1	1	2242	7.01458

Figure 3: The number of examples each class has

Observations from Figure 3:

- The data given is unbalanced where the number of data samples labeled 0 is about 13 times higher than the samples labeled 1, which causes an overfitting problem for models, as they mostly predict zeros.

To overcome the data set problems we observed we can consider the following approaches:

- Cleaning data (removing noise from data)
- Transforming data (transforming data into numerical values)
- Using pre-trained vectorizers for data transformation
- Using a pre-trained Transformer and fine-tuning it to the given data

EDA

0.1 Importing Modules

```
%%capture  
!pip install 'transformers == 4.6.0'
```

```
import zipfile  
import pandas as pd  
import numpy as np  
import re  
import random  
import matplotlib.pyplot as plt  
from wordcloud import WordCloud  
import seaborn as sns  
from sklearn.feature_extraction import text  
from sklearn.model_selection import train_test_split  
from sklearn.metrics import f1_score, accuracy_score  
import xgboost as xgb  
import numpy as np  
import tensorflow_hub as hub  
import tensorflow as tf  
from sklearn.feature_extraction.text import TfidfVectorizer  
from sklearn.pipeline import Pipeline  
from sklearn.naive_bayes import MultinomialNB  
from sklearn.ensemble import RandomForestClassifier  
from sklearn.linear_model import LogisticRegression  
from sklearn.linear_model import SGDClassifier  
from tensorflow.keras import layers  
from sklearn.metrics import accuracy_score, precision_recall_fscore_support  
from sklearn.metrics import confusion_matrix  
from transformers import DistilBertTokenizerFast  
from transformers import TFDistilBertForSequenceClassification, TFTrainer,  
↳ TFTrainingArguments
```

0.2 Loading Data

```
zip_path= "/content/drive/MyDrive/Hate Speech Detection Data/train_E6oV3lV.csv.  
→zip"
```

```
# Create function to unzip a zipfile into current working directory  
def unzip_data(filename):  
    """  
    Unzips filename into the current working directory.  
  
    Args:  
        filename (str): a filepath to a target zip folder to be unzipped.  
    """  
    zip_ref = zipfile.ZipFile(filename, "r")  
    zip_ref.extractall()  
    zip_ref.close()  
unzip_data(zip_path)
```

```
# Read csv file  
df = pd.read_csv("/content/train_E6oV3lV.csv")
```

0.3 Exploring Data

```
# Check data  
df
```

	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
...
31957	31958	0	ate @user isz that youuu?ð ð ð ð ð ð...
31958	31959	0	to see nina turner on the airwaves trying to...
31959	31960	0	listening to sad songs on a monday morning otw...
31960	31961	1	@user #sikh #temple vandalised in in #calgary,...
31961	31962	0	thank you @user for you follow

[31962 rows x 3 columns]

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>  
RangeIndex: 31962 entries, 0 to 31961  
Data columns (total 3 columns):  
#   Column  Non-Null Count  Dtype  
---  ---      -
```

```

0    id      31962 non-null  int64
1    label   31962 non-null  int64
2    tweet   31962 non-null  object
dtypes: int64(2), object(1)
memory usage: 749.2+ KB

```

```

# Drop the id column
df = df.drop('id',axis=1)
df.head()

```

```

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

```

```

# Check how many examples each class has
df.label.value_counts()

```

```

0    29720
1     2242
Name: label, dtype: int64

```

```

df_Stat=df[['label','tweet']].groupby('label').count().reset_index()
df_Stat.columns=['label','count']
df_Stat['percentage']=(df_Stat['count']/df_Stat['count'].sum())*100
df_Stat

```

```

      label  count  percentage
0         0  29720    92.98542
1         1   2242     7.01458

```

```

# Shuffle the data
df_shuffled = df.sample(frac=1, random_state=42)
df_shuffled.head()

```

```

      label      tweet
12227     0  @user â my mom says my smile is captivatingâ...
14709     0  in 3 days i will be meeting my sis-n-law, coun...
19319     0  hating the conservative homophobes using this ...
4308      0  awee if this doesn't  #scream  #friday #acewe...
24055     0  fathersday  #fatherÃÃÃ s #day #god! #ÃÃÃ #...

```

```

# Remove symbols from tweets and lower case all characters
def process_tweet(tweet):
    return " ".join(re.sub("(@[A-Za-z0-9]+)|([^0-9A-Za-z \t])", "",tweet.
    .lower()).split())

```

```
df_shuffled['processed_tweets'] = df_shuffled['tweet'].apply(process_tweet)
df_shuffled.head()
```

	label	...	processed_tweets
12227	0	...	my mom says my smile is captivating i says hap...
14709	0	...	in 3 days i will be meeting my sis n law coune...
19319	0	...	hating the conservative homophobes using this ...
4308	0	...	awee if this doesn t scream friday acwellstuc...
24055	0	...	fathersday father s day god tony a smith buy t...

[5 rows x 3 columns]

```
# Visualize some random examples
random_index = random.randint(0, len(df_shuffled)-10) # create random indexes
for row in df_shuffled[["processed_tweets", "label"]][random_index:
    random_index+10].itertuples():
    _, tweet, label = row
    print(f"Label: {label}", "(hate speech)" if label > 0 else "(normal speech)")
    print(f"Tweet:\n{tweet}\n")
    print("----\n")
```

Label: 0 (normal speech)

Tweet:

remember when used to lead on impoant social issues 29 years later they re
afraid to even talk abt cannabis whathappened

Label: 0 (normal speech)

Tweet:

i think everything in my life right now is a leapoffaith and i m not scared im
sta betting on yourself

Label: 1 (hate speech)

Tweet:

isn t it time we realized what we ve done hate exploitation read america s
history

Label: 0 (normal speech)

Tweet:

thanks kidsrehab

Label: 0 (normal speech)

Tweet:

is that a jet engine in your pocket or are you just to see me via

Label: 0 (normal speech)

Tweet:

cause we lost

Label: 0 (normal speech)

Tweet:

ramadan to all mussulmanic twitter friends blesseing month n happy

Label: 0 (normal speech)

Tweet:

absolutely disgusted with andover kfc disgusting service the food was cold and horrible and over cooked very

Label: 0 (normal speech)

Tweet:

being ignored confused disappointed after so many years i can t see a change sadly i tried to trust

Label: 0 (normal speech)

Tweet:

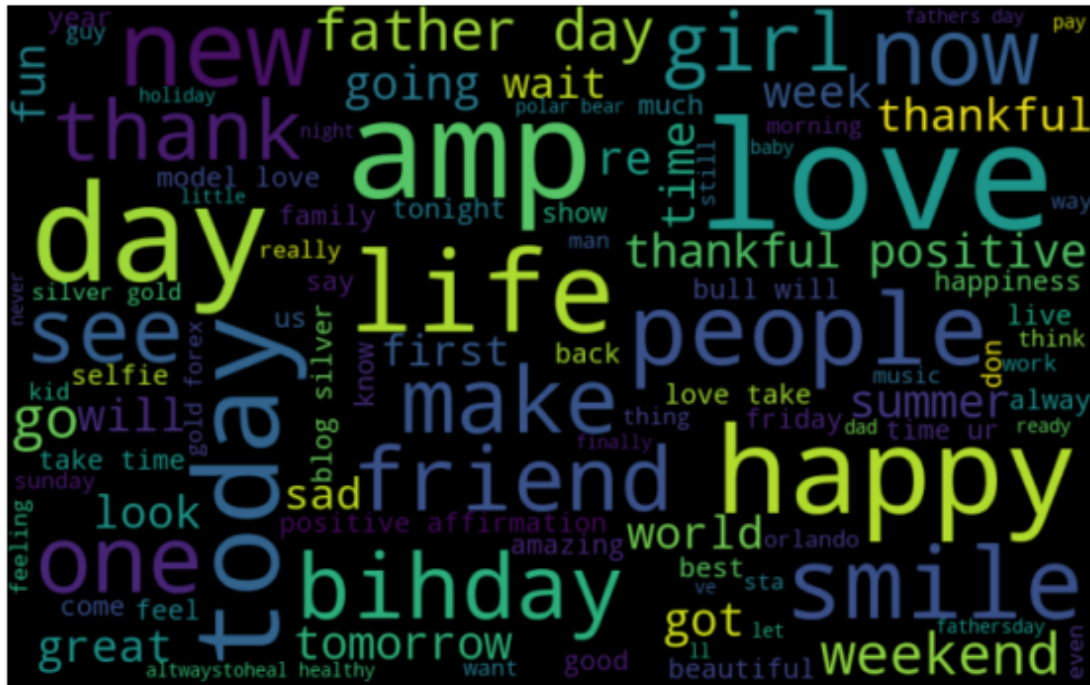
luth nurses begin indefinite strike

```
# Visualize the most frequent words in normal tweets
normal_words = ' '.join([word for word in
    ↪df_shuffled['processed_tweets'][df_shuffled['label'] == 0]])
wordcloud = WordCloud(width = 800, height = 500, max_font_size = 110,max_words_
    ↪= 100).generate(normal_words)
print('Normal speech words')
plt.figure(figsize= (12,8))
plt.imshow(wordcloud, interpolation = 'bilinear',cmap='viridis')
```



```
plt.axis('off');
```

Normal speech words



```
# Visualize the most frequent words in hate tweets
normal_words = ' '.join([word for word in
    df_shuffled['processed_tweets'][df_shuffled['label'] == 1]])
wordcloud = WordCloud(width = 800, height = 500, max_font_size = 110,max_words
    = 100).generate(normal_words)
print('Hate speech words')
plt.figure(figsize= (12,8))
plt.imshow(wordcloud, interpolation = 'bilinear',cmap='viridis')
plt.axis('off');
```

Hate speech words

people	792
smile	745
father	650
want	626
don	616
fun	614
healthy	609
weekend	604
work	604
summer	571
family	536
make	532
friday	530
beautiful	523
friends	517
best	513

dtype: int64

```
# Get the top used words from hate tweets excluding stopwords, numbers, and
↳ strings with length of one character
hate_words = pd.Series(' '.
↳ join(df_shuffled['processed_tweets'][df_shuffled['label'] == 1].apply(lambda
↳ x: ' '.join(item for item in str(x).split() if item not in stopwords and not
↳ item.isdigit() and len(item)>1))).split()).value_counts()[:30]
hate_words
```

amp	300
trump	213
libtard	149
white	140
like	139
black	134
racist	108
politics	97
people	95
allahsoil	92
liberal	82
just	79
women	78
sjw	74
new	72
obama	72
hate	72
retweet	67
racism	66
don	63
feel	59

```
listen      57
america     54
stomping    48
right       48
race        47
men         46
miami       46
woman       43
comments    39
dtype: int64
```

```
# Creating a dataframe to represent top 30 normal and hate used words
d1 = pd.DataFrame(normal_words.index, columns = ['Normal_Words'])
d2 = pd.DataFrame(normal_words.values, columns = ['Normal_Count'])
d3 = pd.DataFrame(hate_words.index, columns = ['Hate_Words'])
d4 = pd.DataFrame(hate_words.values, columns = ['Hate_Count'])
word_freq_df = pd.concat([d1,d2,d3,d4], axis = 1)
word_freq_df
```

	Normal_Words	Normal_Count	Hate_Words	Hate_Count
0	love	2796	amp	300
1	day	2346	trump	213
2	happy	1694	libtard	149
3	amp	1476	white	140
4	just	1288	like	139
5	life	1163	black	134
6	time	1127	racist	108
7	today	1080	politics	97
8	thankful	952	people	95
9	positive	934	allahsoil	92
10	new	931	liberal	82
11	like	920	just	79
12	bihday	872	women	78
13	good	841	sjw	74
14	people	792	new	72
15	smile	745	obama	72
16	father	650	hate	72
17	want	626	retweet	67
18	don	616	racism	66
19	fun	614	don	63
20	healthy	609	feel	59
21	weekend	604	listen	57
22	work	604	america	54
23	summer	571	stomping	48
24	family	536	right	48

25	make	532	race	47
26	friday	530	men	46

0.4 Splitting Data into Training and Validation Sets

```
# Use train_test_split to split training data into training and validation sets
train_sentences, val_sentences, train_labels, val_labels = \
    ↪train_test_split(list(df_shuffled["processed_tweets"]),
                    ↪list(df_shuffled["label"]),
                    ↪test_size=0.2, # use 10% of training data for validation
                    ↪random_state=42)
```

```
# Find the average number of tokens (words) in the training and validation
↪tweets
round (sum([len(i.split()) for i in train_sentences])/len(train_sentences)),
↪round (sum([len(i.split()) for i in val_sentences])/len(val_sentences))
```

(13, 13)

0.5 Running a Series of Modeling Experiments

```
# Create tokenization and modeling pipeline

# XGBClassifier
pipeline_xgb = Pipeline([
    ('tfidf', TfidfVectorizer()),
    ('model', xgb.XGBClassifier(use_label =False)),])

model_0 = pipeline_xgb.fit(train_sentences, train_labels)

model_0_score = model_0.score(val_sentences, val_labels)

print(f"Our model_0 (XGBClassifier) achieves an accuracy of:{model_0_score*100:.
↪2f}%")

# MultinomialNB
model_1 = Pipeline([
    ↪("tfidf", TfidfVectorizer()), # Convert words to numbers
    ↪using tfidf
    ↪("clf", MultinomialNB()) # model the text
])
```

```

model_1.fit(train_sentences, train_labels)
score_1 = model_1.score(val_sentences, val_labels)
print(f"Our model_1 (MultinomialNB) achieves an accuracy of:{score_1*100:.2f}%")

# RandomForestClassifier
model_2 = Pipeline([
    ("tfidf", TfidfVectorizer()), # Convert words to numbers
    →using tfidf
    ("clf", RandomForestClassifier()) # model the text
])

model_2.fit(train_sentences, train_labels)
score_2 = model_2.score(val_sentences, val_labels)
print(f"Our model_2 (RandomForestClassifier) achieves an accuracy of:
    →{score_2*100:.2f}%")

# LogisticRegression
model_3 = Pipeline([
    ("tfidf", TfidfVectorizer()), # Convert words to numbers
    →using tfidf
    ("clf", LogisticRegression()) # model the text
])

model_3.fit(train_sentences, train_labels)
score_3 = model_3.score(val_sentences, val_labels)
print(f"Our model_3 (LogisticRegression) achieves an accuracy of:{score_3*100:.
    →2f}%")

```

```

# SGDClassifier
model_4 = Pipeline([
    ("tfidf", TfidfVectorizer()), # Convert words to numbers
    →using tfidf
    ("clf", SGDClassifier()) # model the text
])

model_4.fit(train_sentences, train_labels)
score_4 = model_4.score(val_sentences, val_labels)
print(f"Our model_4 (SGDClassifier) achieves an accuracy of:{score_4*100:.2f}%")

```

Our model_0 (XGBClassifier) achieves an accuracy of:94.17%
 Our model_1 (MultinomialNB) achieves an accuracy of:93.52%
 Our model_2 (RandomForestClassifier) achieves an accuracy of:96.15%
 Our model_3 (LogisticRegression) achieves an accuracy of:94.81%

Our model_4 (SGDClassifier) achieves an accuracy of:95.10%

```
# Create a Keras Layer using the USE pretrained layer from tensorflow hub
sentence_encoder_layer = hub.KerasLayer("https://tfhub.dev/google/
↪universal-sentence-encoder/4",
                                         input_shape=[],
                                         dtype=tf.string,
                                         trainable=False,
                                         name="USE"
                                         )

# Create model using the Sequential API
model_5 = tf.keras.Sequential([
    sentence_encoder_layer,
    layers.Dense(64, activation="relu"),
    layers.Dense(1, activation="sigmoid")
], name = "model_5_USE")

# Compile
model_5.compile(loss="binary_crossentropy",
                optimizer=tf.keras.optimizers.Adam(),
                metrics=["accuracy"])
model_5.summary()
```

Model: "model_5_USE"

Layer (type)	Output Shape	Param #
USE (KerasLayer)	(None, 512)	256797824
dense_2 (Dense)	(None, 64)	32832
dense_3 (Dense)	(None, 1)	65

=====
Total params: 256,830,721
Trainable params: 32,897
Non-trainable params: 256,797,824
=====

```
# Train a classifier on top of USE pretrained embeddings
model_5_history = model_5.fit(train_sentences,
                              train_labels,
                              epochs=15,
                              validation_data=(val_sentences, val_labels)
                              )
```

Epoch 1/15

800/800 [=====] - 21s 23ms/step - loss: 0.1770 -
accuracy: 0.9437 - val_loss: 0.1368 - val_accuracy: 0.9487

Epoch 2/15

800/800 [=====] - 18s 22ms/step - loss: 0.1223 -
accuracy: 0.9565 - val_loss: 0.1302 - val_accuracy: 0.9504

Epoch 3/15

800/800 [=====] - 17s 22ms/step - loss: 0.1118 -
accuracy: 0.9594 - val_loss: 0.1246 - val_accuracy: 0.9529

Epoch 4/15

800/800 [=====] - 17s 22ms/step - loss: 0.1023 -
accuracy: 0.9623 - val_loss: 0.1192 - val_accuracy: 0.9564

Epoch 5/15

800/800 [=====] - 17s 22ms/step - loss: 0.0936 -
accuracy: 0.9659 - val_loss: 0.1152 - val_accuracy: 0.9570

Epoch 6/15

800/800 [=====] - 17s 22ms/step - loss: 0.0852 -
accuracy: 0.9689 - val_loss: 0.1137 - val_accuracy: 0.9587

Epoch 7/15

800/800 [=====] - 17s 21ms/step - loss: 0.0777 -
accuracy: 0.9719 - val_loss: 0.1118 - val_accuracy: 0.9592

Epoch 8/15

800/800 [=====] - 17s 22ms/step - loss: 0.0713 -
accuracy: 0.9741 - val_loss: 0.1102 - val_accuracy: 0.9598

Epoch 9/15

800/800 [=====] - 17s 22ms/step - loss: 0.0649 -
accuracy: 0.9777 - val_loss: 0.1108 - val_accuracy: 0.9592

Epoch 10/15

800/800 [=====] - 17s 21ms/step - loss: 0.0589 -
accuracy: 0.9804 - val_loss: 0.1123 - val_accuracy: 0.9598


```

Epoch 11/15
800/800 [=====] - 17s 22ms/step - loss: 0.0534 -
accuracy: 0.9824 - val_loss: 0.1144 - val_accuracy: 0.9606
Epoch 12/15
800/800 [=====] - 17s 21ms/step - loss: 0.0479 -
accuracy: 0.9850 - val_loss: 0.1143 - val_accuracy: 0.9601
Epoch 13/15
800/800 [=====] - 17s 21ms/step - loss: 0.0431 -
accuracy: 0.9863 - val_loss: 0.1151 - val_accuracy: 0.9592
Epoch 14/15
800/800 [=====] - 17s 21ms/step - loss: 0.0381 -
accuracy: 0.9893 - val_loss: 0.1171 - val_accuracy: 0.9612
Epoch 15/15
800/800 [=====] - 17s 21ms/step - loss: 0.0340 -
accuracy: 0.9906 - val_loss: 0.1214 - val_accuracy: 0.9615

```

```

# Make predictions with USE TF Hub Model
model_5_pred_probs = model_5.predict(val_sentences)

```

```

# Making predictions on validation data
y0_predict = model_0.predict(val_sentences)
y1_predict = model_1.predict(val_sentences)
y2_predict = model_2.predict(val_sentences)
y3_predict = model_3.predict(val_sentences)
y4_predict = model_4.predict(val_sentences)
y5_predict = tf.squeeze(tf.round(model_5_pred_probs))

```

0.6 Creating an Evaluation Function for Model Experiments

```

# Function to evaluate: accuracy, precision, recall, f1-score
def calculate_results(y_true,y_pred):
    """
    Calculates model accuracy, precision, recall and f1 score of a binary_
    ↪classification model
    """
    # Calculate model accuracy
    model_accuracy = accuracy_score(y_true, y_pred) * 100
    # Calculate model precision, recall and f1-score using "weighted" average
    model_precision, model_recall, model_f1, _ =_
    ↪precision_recall_fscore_support(y_true, y_pred, average="weighted")
    model_results = {"accuracy": model_accuracy,
                    "precision": model_precision,
                    "recall": model_recall,
                    "f1": model_f1}
    return model_results

```

```
# Get baseline results
```

```
model_0_results = calculate_results(y_true=val_labels,  
                                   y_pred= y0_predict)  
model_0_results
```

```
{'accuracy': 94.16549350852495,  
 'f1': 0.9240085458148133,  
 'precision': 0.9416924045330635,  
 'recall': 0.9416549350852494}
```

```
# Get model_1 results
```

```
model_1_results = calculate_results(y_true=val_labels,  
                                   y_pred= y1_predict)  
model_1_results
```

```
{'accuracy': 93.52416705771938,  
 'f1': 0.9103555383590493,  
 'precision': 0.9394690355064025,  
 'recall': 0.9352416705771938}
```

```
# Get model_2 results
```

```
model_2_results = calculate_results(y_true=val_labels,  
                                   y_pred= y2_predict)  
model_2_results
```

```
{'accuracy': 96.15204129516658,  
 'f1': 0.9560442219920248,  
 'precision': 0.9607553645482917,  
 'recall': 0.9615204129516659}
```

```
# Get model_3 results
```

```
model_3_results = calculate_results(y_true=val_labels,  
                                   y_pred= y3_predict)  
model_3_results
```

```
{'accuracy': 94.80681995933051,  
 'f1': 0.9359882323688977,  
 'precision': 0.9466040133565261,  
 'recall': 0.9480681995933051}
```

```
# Get model_4 results
model_4_results = calculate_results(y_true=val_labels,
                                   y_pred= y4_predict)
model_4_results
```

```
{'accuracy': 95.10402002189895,
 'f1': 0.9401526202494138,
 'precision': 0.9511041686353916,
 'recall': 0.9510402002189895}
```

```
# Get model_5 results
model_5_results = calculate_results(y_true = val_labels,
                                   y_pred = y5_predict)
model_5_results
```

```
{'accuracy': 96.15204129516658,
 'f1': 0.9595563153708081,
 'precision': 0.9589536629357007,
 'recall': 0.9615204129516659}
```

0.7 Comparing the Performance of the Models

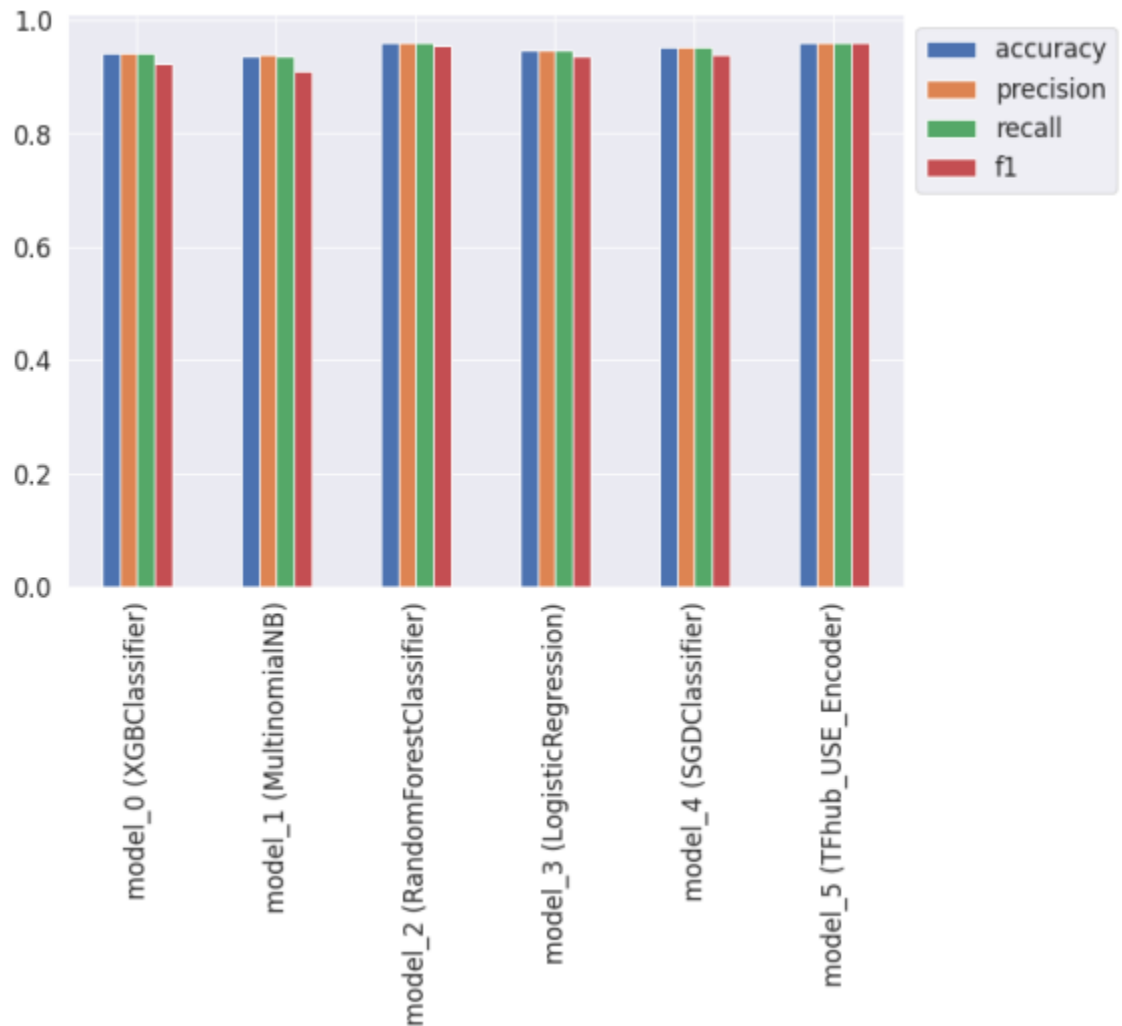
```
models_results_df = pd.DataFrame(data={'model_0 (XGBClassifier)':␣
    ↳model_0_results,
                                     'model_1 (MultinomialNB)':␣
    ↳model_1_results,
```

```
                                     'model_2 (RandomForestClassifier)' :␣
    ↳model_2_results,
                                     'model_3 (LogisticRegression)':␣
    ↳model_3_results,
                                     'model_4 (SGDClassifier)' :␣
    ↳model_4_results,
                                     'model_5 (TFhub_USE_Encoder)' :␣
    ↳model_5_results}).transpose()
models_results_df
```

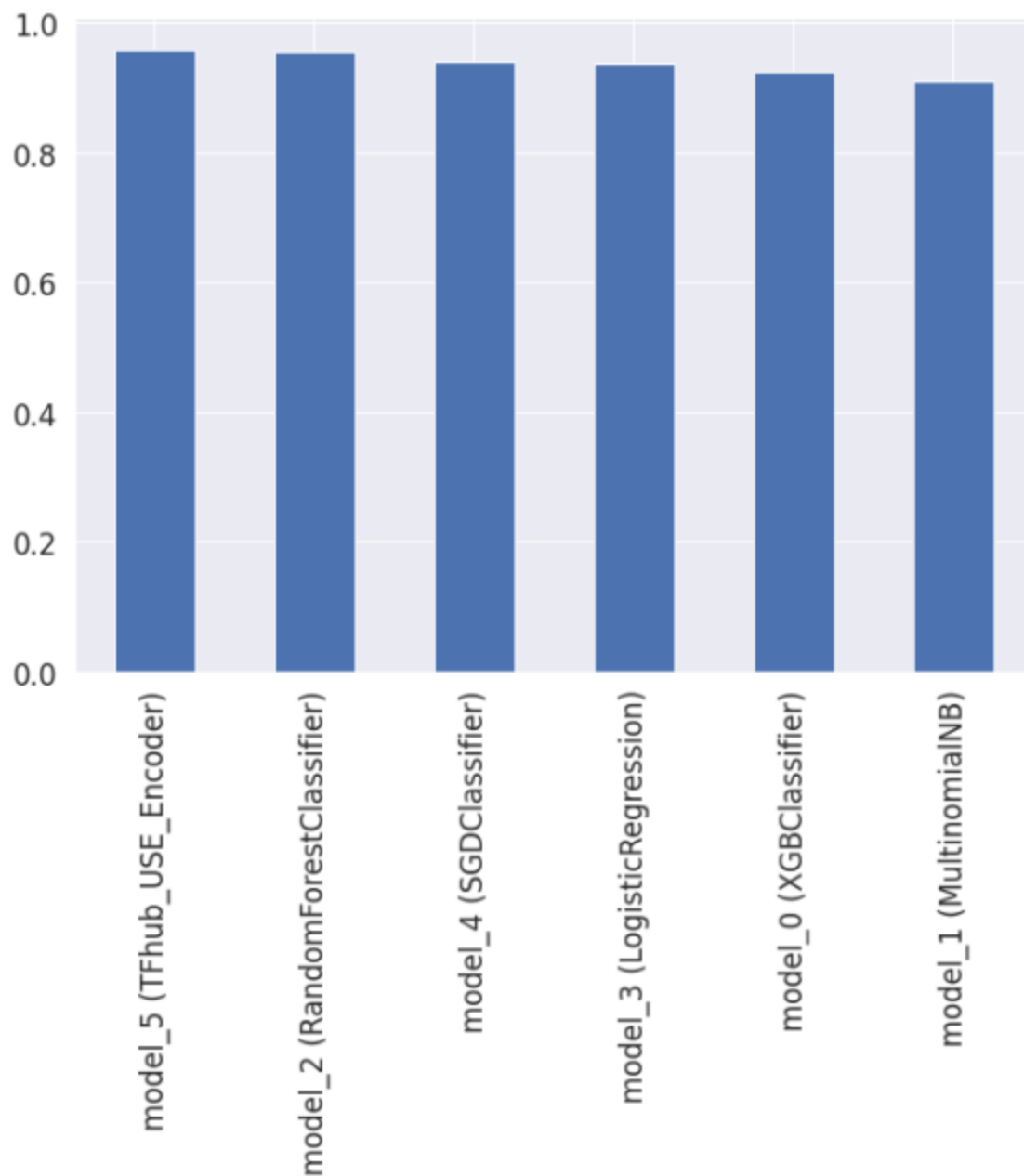
	accuracy	precision	recall	f1
model_0 (XGBClassifier)	94.165494	0.941692	0.941655	0.924009
model_1 (MultinomialNB)	93.524167	0.939469	0.935242	0.910356
model_2 (RandomForestClassifier)	96.152041	0.960755	0.961520	0.956044
model_3 (LogisticRegression)	94.806820	0.946604	0.948068	0.935988
model_4 (SGDClassifier)	95.104020	0.951104	0.951040	0.940153
model_5 (TFhub_USE_Encoder)	96.152041	0.958954	0.961520	0.959556

```
# Reduce the accuracy to the same scale as other metrics
models_results_df["accuracy"] = models_results_df["accuracy"]/100
```

```
# Plot and compare all of the model results
models_results_df.plot(kind="bar", figsize=(10,7)).legend(bbox_to_anchor=(1.0,1.0,0));
```



```
# Sort model results by f1-score
models_results_df.sort_values("f1", ascending=False)["f1"].plot(kind="bar", figsize=(10, 7));
```



```
# Confusion matrix  
cm_0 = confusion_matrix(val_labels, y0_predict)  
cm_0
```

```
array([[5922,    6],  
       [ 367,   98]])
```

```
cm_1 = confusion_matrix(val_labels, y1_predict)  
cm_1
```

```
array([[5928,    0],
       [ 414,   51]])
```

```
cm_2 = confusion_matrix(val_labels, y2_predict)
cm_2
```

```
array([[5913,   15],
       [ 231,  234]])
```

```
cm_3 = confusion_matrix(val_labels, y3_predict)
cm_3
```

```
array([[5915,   13],
       [ 319,  146]])
```

```
cm_4 = confusion_matrix(val_labels, y4_predict)
cm_4
```

```
array([[5920,    8],
       [ 305,  160]])
```

```
cm_5 = confusion_matrix(val_labels, y5_predict)
cm_5
```

```
array([[5851,   77],
       [ 169,  296]])
```

```
sns.set(font_scale=1.5)
# Plot the confusion matrix for each model
fig, axs = plt.subplots(3, 2, figsize=(10, 14))
sns.heatmap(confusion_matrix(val_labels, y0_predict),
            annot=True,
            cbar=False,
            fmt='d',
            ax=axs[0, 0],
            cmap= 'Purples'
            )
axs[0, 0].set_title('model_0 (XGBClassifier)')
axs[0, 0].set_xlabel("True label")
axs[0, 0].set_ylabel("Predicted label")

sns.heatmap(confusion_matrix(val_labels, y1_predict),
            annot=True,
            cbar=False,
            fmt='d',
            ax=axs[0, 1],
            cmap='PuRd'
            )
```

```

axs[0, 1].set_title('model_1 (MultinomialNB)')
axs[0, 1].set_xlabel("True label")
axs[0, 1].set_ylabel("Predicted label")

sns.heatmap(confusion_matrix(val_labels, y2_predict),
             annot=True,
             cbar=False,
             fmt='d',
             ax=axs[1, 0],
             cmap='Reds'
            )
axs[1, 0].set_title('model_2 (RandomForestClassifier)')
axs[1, 0].set_xlabel("True label")
axs[1, 0].set_ylabel("Predicted label")

sns.heatmap(confusion_matrix(val_labels, y3_predict),
             annot=True,
             cbar=False,
             fmt='d',
             ax=axs[1, 1],
             cmap='Greens'
            )
axs[1, 1].set_title('model_3 (LogisticRegression)')
axs[1, 1].set_xlabel("True label")
axs[1, 1].set_ylabel("Predicted label")

```

```

sns.heatmap(confusion_matrix(val_labels, y4_predict),
             annot=True,
             cbar=False,
             fmt='d',
             ax=axs[2, 0],
             cmap='Oranges'
            )
axs[2, 0].set_title('model_4 (SGDClassifier)')
axs[2, 0].set_xlabel("True label")
axs[2, 0].set_ylabel("Predicted label")

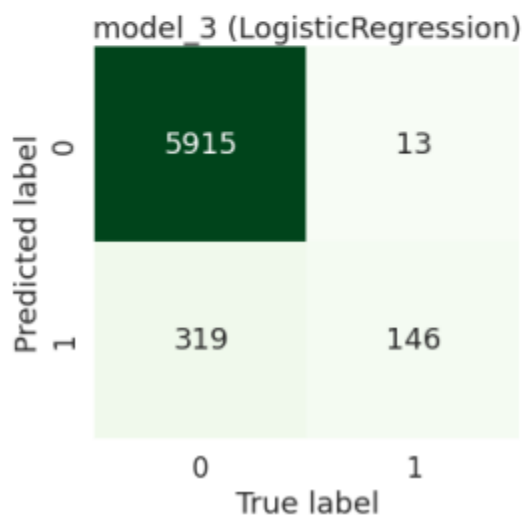
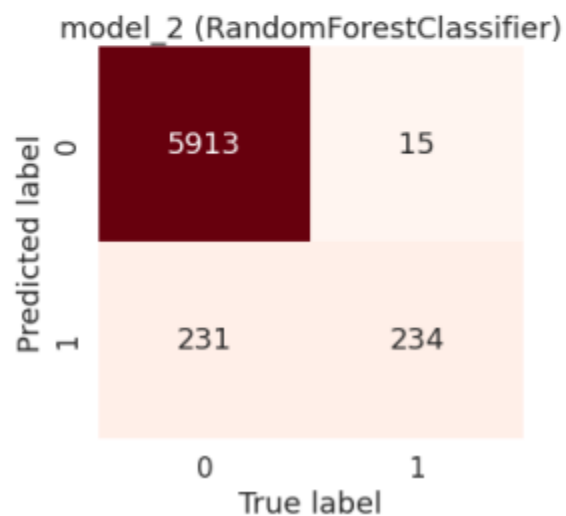
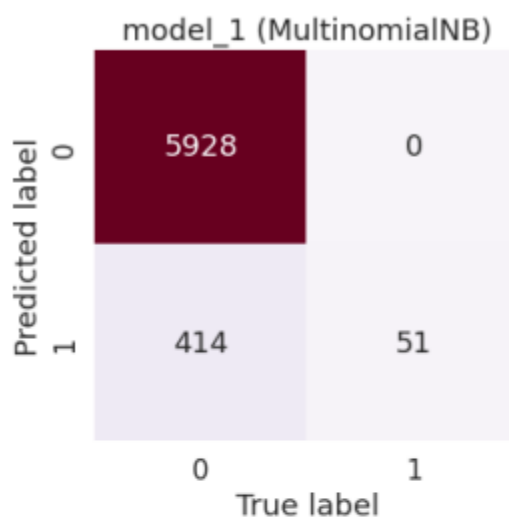
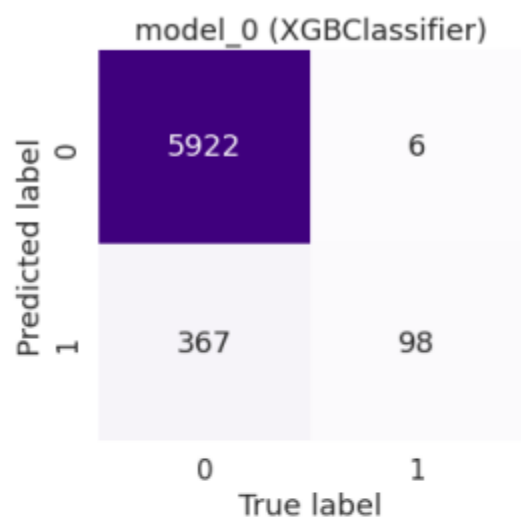
sns.heatmap(confusion_matrix(val_labels, y5_predict),
             annot=True,
             cbar=False,
             fmt='d',
             ax=axs[2, 1],

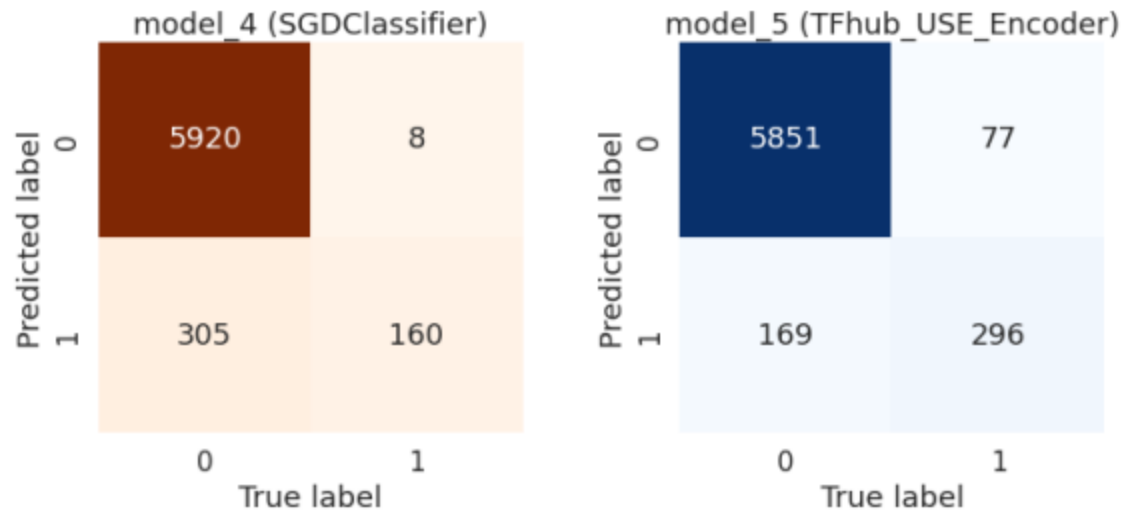
```

```

        cmap='Blues'
    )
    axs[2, 1].set_title('model_5 (TFhub_USE_Encoder)')
    axs[2, 1].set_xlabel("True label")
    axs[2, 1].set_ylabel("Predicted label")
    plt.tight_layout();

```





```
# Save the best model
model_5.save('tfhub_use_encoder.h5')
```

0.8 Finding the Most Wrong Examples

```
# Create DataFrame with validation sentences and best performing model_5
↳ prediction labels + probabilities
val_df = pd.DataFrame({"text": val_sentences,
                       "target": val_labels,
                       "pred": y5_predict,
                       "pred_prob": tf.squeeze(model_5_pred_probs)})
val_df.head()
```

```

              text  ...    pred_prob
0      turn it in abc for 20 20 sobering  ...  5.430939e-02
1  oh no thursdays is noodle day what have you do...  ...  7.533444e-05
2      here we go let s do this people icrs2016  ...  5.501849e-03
3  water in me and around me sam sierra michael b...  ...  2.714794e-05
4    awesome beginner gopro mounts super to use  ...  9.277188e-07
```

```
[5 rows x 4 columns]
```

```
# Find the wrong predictions and sort by prediction probabilities
most_wrong = val_df[val_df["target"] != val_df["pred"]].sort_values("pred_prob",
↪ascending=False)
most_wrong
```

	text	...	pred_prob
4272	lgbtqhatestrumppay but luvs homophobic misogyn...	...	0.998966
4506	the makes the trump candidacy wohwhile donalddt...	...	0.994312
558	what lies these dt suppoers are spreading look...	...	0.992918
1344	ali spoke the truth about white folks period f...	...	0.992009
6054	i award thee most cucked tweet in history prep...	...	0.991659
...
2382	this newyearseve may our resolutions b 2 end p...	...	0.000192
5222	2 99 2016release ebook book the summer that me...	...	0.000079
1063	funny can t get rid of 7 1stammendment so many...	...	0.000040
5568	good afternoon sweety send me letter	...	0.000026
1153	i m blessedt iconic lovebeingalegend	...	0.000001

[246 rows x 4 columns]

```
# False positives
most_wrong.head()
```

	text	...	pred_prob
4272	lgbtqhatestrumppay but luvs homophobic misogyn...	...	0.998966
4506	the makes the trump candidacy wohwhile donalddt...	...	0.994312
558	what lies these dt suppoers are spreading look...	...	0.992918
1344	ali spoke the truth about white folks period f...	...	0.992009
6054	i award thee most cucked tweet in history prep...	...	0.991659

[5 rows x 4 columns]

```
# False negative
most_wrong.tail()
```

	text	...	pred_prob
2382	this newyearseve may our resolutions b 2 end p...	...	0.000192
5222	2 99 2016release ebook book the summer that me...	...	0.000079
1063	funny can t get rid of 7 1stammendment so many...	...	0.000040
5568	good afternoon sweety send me letter	...	0.000026
1153	i m blessedt iconic lovebeingalegend	...	0.000001

[5 rows x 4 columns]

```
# Check the false positives (model predicted 1 when should've been 0)
for row in most_wrong[:10].itertuples():
    _, text, target, pred, pred_prob = row
    print(f"Target: {target}, Pred: {pred}, Prob: {pred_prob}")
    print(f"Text:\n{text}\n")
    print("----\n")
```

Target: 0, Pred: 1.0, Prob: 0.998965859413147

Text:

lgbtqhatestrumppay but luvs homophobic misogynist antisemitic death cult
masquerading as a religion

Target: 0, Pred: 1.0, Prob: 0.9943115711212158

Text:

the makes the trump candidacy wohwhile donaldrumphastinyhands
tinydancerfoinyhands

Target: 0, Pred: 1.0, Prob: 0.9929178357124329

Text:

what lies these dt suppoers are spreading looks like propaganda from the 1930s

Target: 0, Pred: 1.0, Prob: 0.9920094013214111

Text:

ali spoke the truth about white folks period facts idiot moron
theverycoreofamerica

Target: 0, Pred: 1.0, Prob: 0.9916594624519348

Text:

i award thee most cucked tweet in history prep the bull you insufferable faggot
sbc16

Target: 0, Pred: 1.0, Prob: 0.9753319621086121

Text:

straight white men are viciously under attack they are often the real victims

Target: 0, Pred: 1.0, Prob: 0.9751490950584412

Text:

reason 638 on why i don t suppo modern day feminism it s no longer about women s rights in america

Target: 0, Pred: 1.0, Prob: 0.9630975127220154

Text:

i can t believe any american would vote for her so many scandals

Target: 0, Pred: 1.0, Prob: 0.9623082876205444

Text:

prayfororlando can we show love amp not hate by clifton w 0

Target: 0, Pred: 1.0, Prob: 0.9607369899749756

Text:

just herd you re podcast no man deserves to be called a man after he rapes a women scumofthreah

```
# Check the false negatives (model predicted 0 when should've been 1)
for row in most_wrong[-10:].itertuples():
```

```
_, text, target, pred, pred_prob = row
print(f"Target: {target}, Pred: {pred}, Prob: {pred_prob}")
print(f"Text:\n{text}\n")
print("----\n")
```

Target: 1, Pred: 0.0, Prob: 0.001167581183835864

Text:

great aicle of truth about trc needs comments back up why it s needed indigenenous via

Target: 1, Pred: 0.0, Prob: 0.0008611972443759441

Text:

now ask yourself if you really want to follow i m done

Target: 1, Pred: 0.0, Prob: 4.03911508328747e-05

Text:

funny can t get rid of 7 1st ammendment so many distractions and lousy qb maybe
next year probab

Target: 1, Pred: 0.0, Prob: 0.000704584876075387

Text:

ouuh fuck it bustymilf

Target: 1, Pred: 0.0, Prob: 0.0004778062575496733

Text:

you can still be

Target: 1, Pred: 0.0, Prob: 0.0004640818515326828

Text:

note i was just able to pop this zit on my neck that s been there for days i ve
beensqueezing it for days

Target: 1, Pred: 0.0, Prob: 0.00019191103638149798

Text:

this newyearseve may our resolutions b 2 end problems like amp domesticviolence
by turning 2 god of love

Target: 1, Pred: 0.0, Prob: 7.872624701121822e-05

Text:

2 99 2016release ebook book the summer that melted everything a novel by tiffany
mcdaniel via

Target: 1, Pred: 0.0, Prob: 4.03911508328747e-05

Text:

funny can t get rid of 7 1st ammendment so many distractions and lousy qb maybe
next year probab

Target: 1, Pred: 0.0, Prob: 2.6166002498939633e-05

Text:

good afternoon sweetie send me letter

Target: 1, Pred: 0.0, Prob: 1.3290167544255382e-06

Text:

i m blessedt iconic lovebeingalegend

0.9 Another Option: Using DistilBertTokenizerFast

```
tokenizer = DistilBertTokenizerFast.from_pretrained('distilbert-base-uncased')
```

```
Downloading: 0%|          | 0.00/232k [00:00<?, ?B/s]
```

```
Downloading: 0%|          | 0.00/466k [00:00<?, ?B/s]
```

```
Downloading: 0%|          | 0.00/28.0 [00:00<?, ?B/s]
```

```
train_encodings = tokenizer(train_sentences, truncation=True, padding=True)  
val_encodings = tokenizer(val_sentences, truncation=True, padding=True)
```

```
train_dataset = tf.data.Dataset.from_tensor_slices((  
    dict(train_encodings),  
    train_labels  
))  
val_dataset = tf.data.Dataset.from_tensor_slices((  
    dict(val_encodings),  
    val_labels  
))
```

```
train_dataset
```

```
<TensorSliceDataset shapes: ({input_ids: (46,), attention_mask: (46,)}, ()),  
types: ({input_ids: tf.int32, attention_mask: tf.int32}, tf.int32)>
```

```
len(val_labels)
```

6393

```
training_args = TFTrainingArguments(
    output_dir='./results',          # output directory
    num_train_epochs=3,              # total number of training epochs
    per_device_train_batch_size=16,  # batch size per device during training
    per_device_eval_batch_size=64,   # batch size for evaluation
    warmup_steps=500,                # number of warmup steps for learning rate
    ↪scheduler
    weight_decay=0.01,               # strength of weight decay
    logging_dir='./logs',            # directory for storing logs
    logging_steps=10,
)

with training_args.strategy.scope():
    model_6 = TFDistilBertForSequenceClassification.
    ↪from_pretrained("distilbert-base-uncased")

trainer = TFTrainer(
    model=model_6,                   # the instantiated Transformers
    ↪model to be trained
    args=training_args,              # training arguments, defined above
    train_dataset=train_dataset,     # training dataset
    eval_dataset=val_dataset         # evaluation dataset
)

trainer.train()
```

```
score_6 = trainer.evaluate(val_dataset)
score_6
```

```
{'eval_loss': 0.12932125091552735}
```

```
trainer.predict(val_dataset)
```

```
PredictionOutput(predictions=array([[ 3.2038417, -3.2720242],
 [ 4.1385026, -4.1992965],
 [ 3.5704398, -3.624197 ]],
 ...,
 [ 4.1603084, -4.2755566],
 [ 4.133188 , -4.2293296],
 [ 4.1415644, -4.2415414]], dtype=float32), label_ids=array([0, 0, 0, ...,
0, 0, 0], dtype=int32), metrics={'eval_loss': 0.1284922504425049})
```



```
y6_predict_proba=trainer.predict(val_dataset)[0]
```

```
y6_predict=np.argmax(y6_predict_proba,axis=-1)
```

```
# Get model_6 results
```

```
model_6_results = calculate_results(y_true=val_labels,  
                                   y_pred= y6_predict)
```

```
model_6_results
```

```
{'accuracy': 96.5274519005162,  
 'f1': 0.9644764593802877,  
 'precision': 0.9639728208229673,  
 'recall': 0.9652745190051619}
```

```
model_6_results_df=pd.DataFrame(data={'model_6 (DistilBertTokenizerFast)':  
    ↪model_6_results}).transpose()  
model_6_results_df
```

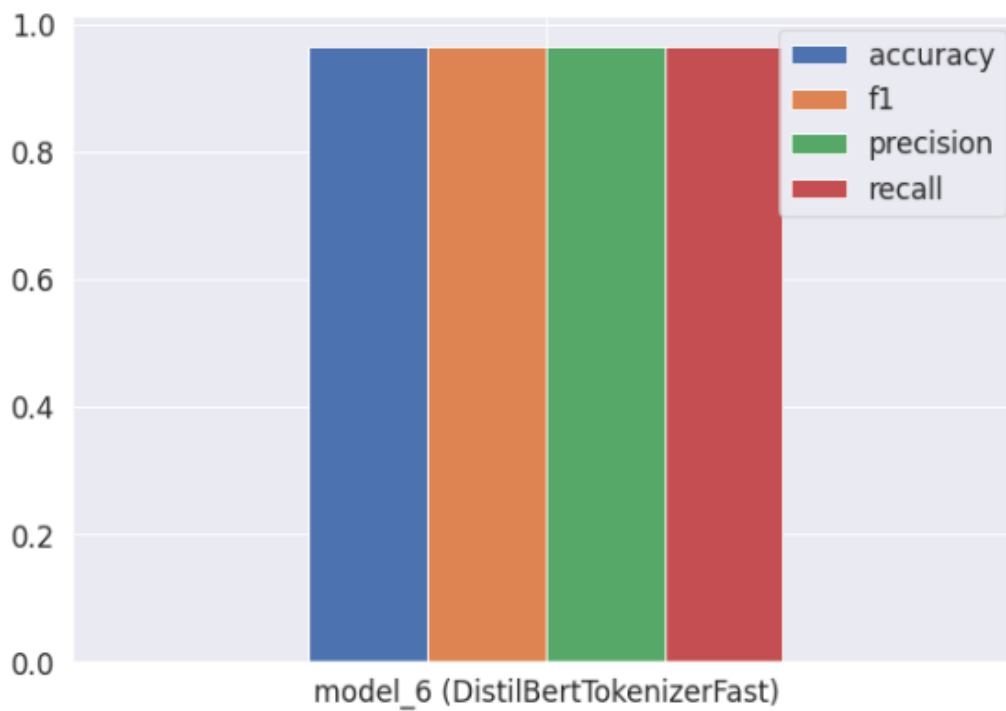
	accuracy	f1	precision	recall
model_6 (DistilBertTokenizerFast)	96.527452	0.964476	0.963973	0.965275

```
# Reduce the accuracy to the same scale as other metrics
```

```
model_6_results_df["accuracy"]= model_6_results_df["accuracy"]/100
```

```
model_6_results_df.plot(kind="bar", figsize=(10, 7))
```

```
plt.xticks(rotation='horizontal');
```



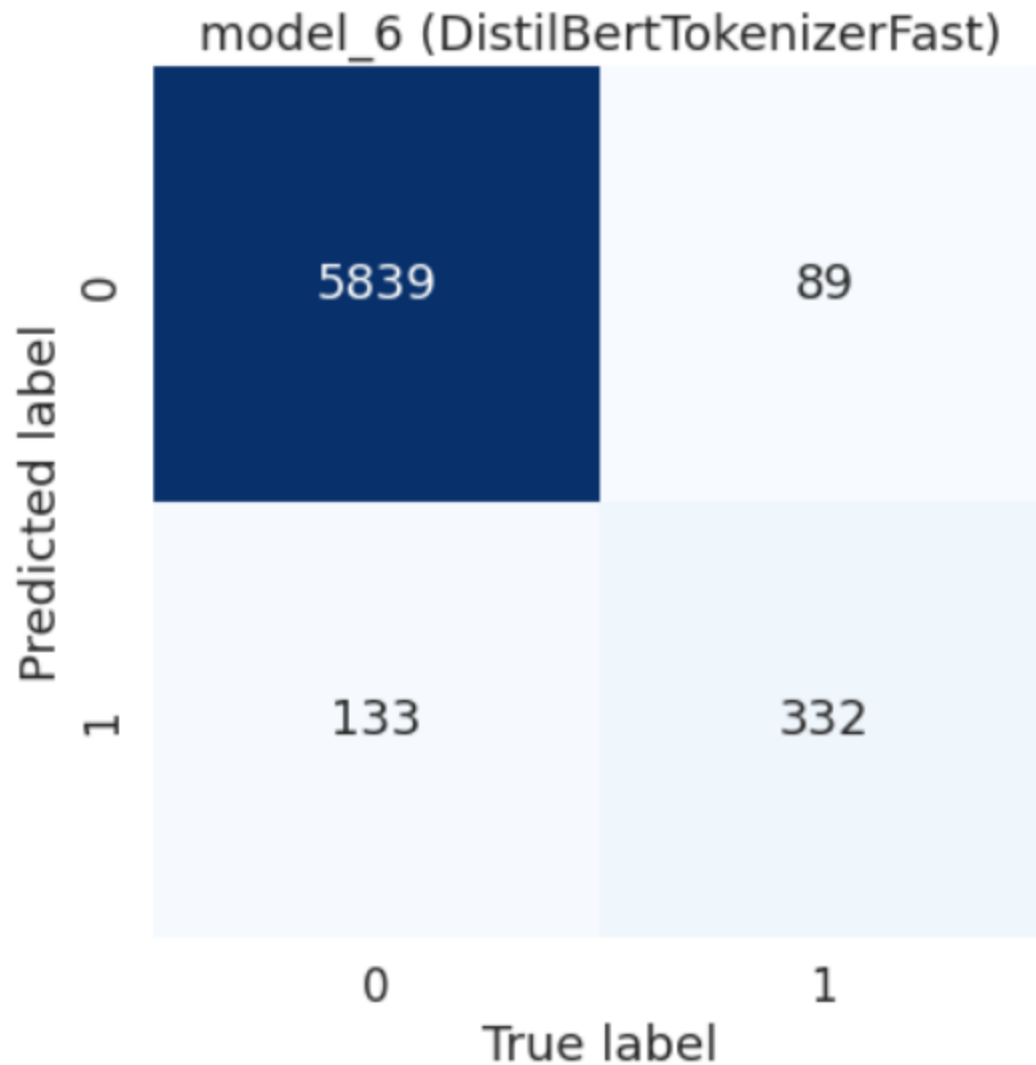

```
np.unique(val_labels,return_counts=True)
```

```
(array([0, 1]), array([5928, 465]))
```

```
cm_6 = confusion_matrix(val_labels, y6_predict)
cm_6
```

```
array([[5839, 89],
       [133, 332]])
```

```
# Plot the confusion matrix for model_6
plt.figure(figsize=(6,6))
sns.heatmap(confusion_matrix(val_labels, y6_predict),
            annot=True,
            cbar=False,
            fmt='d',
            cmap='Blues'
            )
plt.title('model_6 (DistilBertTokenizerFast)')
plt.xlabel('True label')
plt.ylabel('Predicted label');
```



```
trainer.save_model("distilbert_model")
```

Recommendation

- Collect more hate tweets data.
- Check the most wrong predictions as shown in the EDA and fix some wrong labels.
- Although model_5 was the best performing model in the early stage of experimenting, it was beaten later by model_6 (DistilBertTokenizerFast) which gave an f1-score of 0.964. So I would recommend using model_6.