In this notebook, You will do amazon review classification with BERT.[Download data from this link]

```
It contains 5 parts as below.  Detailed instrctions are given in the each cell.
please read every comment we have written.
    1. Preprocessing
    2. Creating a BERT model from the Tensorflow HUB.
    3. Tokenization
    4. getting the pretrained embedding Vector for a given review from the
BERT.
    5. Using the embedding data apply NN and classify the reviews.
    6. Creating a Data pipeline for BERT Model.
```

instructions:

```
    1. Don't change any Grader Functions. Don't manipulate any Grader
functions.
    If you manipulate any, it will be considered as plagiarised.

    2. Please read the instructions on the code cells and markdown cells. We
will explain what to write.

    3. please return outputs in the same format what we asked. Eg. Don't return
List if we are asking for a numpy array.

    4. Please read the external links that we are given so that you will learn
the concept behind the code that you are writing.

    5. We are giving instructions at each section if necessary, please follow
them.
```

Every Grader function has to return True.

In [ ]:

```
#in this assignment you need two files reviews.csv and tokenization file
#you can use gdown module to import both the files in colab from Google drive
#the syntax is for gdown is !gdown --id file_id
#please run the below cell to import the required files
```

In [1]:

```
!gdown --id 1GsD8JlAc_0yJ-1151LNr6rLw83RRUPgt
!gdown --id 13exfXiyiByluh1PfYK1EyZyizqxeCVG9
```

```
/usr/local/lib/python3.7/dist-packages/gdown/cli.py:131: FutureWarning: Option `--id` wa
s deprecated in version 4.3.1 and will be removed in 5.0. You don't need to pass it anym
ore to use a file ID.
  category=FutureWarning,
Downloading...
From: https://drive.google.com/uc?id=1GsD8JlAc_0yJ-1151LNr6rLw83RRUPgt
To: /content/Reviews.csv
100% 301M/301M [00:03<00:00, 85.8MB/s]
/usr/local/lib/python3.7/dist-packages/gdown/cli.py:131: FutureWarning: Option `--id` wa
s deprecated in version 4.3.1 and will be removed in 5.0. You don't need to pass it anym
ore to use a file ID.
  category=FutureWarning,
Downloading...
From: https://drive.google.com/uc?id=13exfXiyiByluh1PfYK1EyZyizqxeCVG9
To: /content/tokenization.py
100% 17.3k/17.3k [00:00<00:00, 27.2MB/s]
```

In [2]:

```
#all imports
import numpy as np
import pandas as pd
import tensorflow as tf
import tensorflow_hub as hub
from tensorflow.keras.models import Model
```

In [3]:

```
tf.test.gpu_device_name()
```

Out[3]:

```
'/device:GPU:0'
```

Grader function 1

In [4]:

```
def grader_tf_version():
    assert((tf.__version__)>'2')
    return True
grader_tf_version()
```

Out[4]:

```
True
```

Part-1: Preprocessing

In [5]:

```
#Read the dataset - Amazon fine food reviews
reviews = pd.read_csv(r"Reviews.csv")
#check the info of the dataset
reviews.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 568454 entries, 0 to 568453
Data columns (total 10 columns):
 #   Column                  Non-Null Count   Dtype 
---  ------                  --------------   ----- 
 0   Id                      568454 non-null  int64 
 1   ProductId               568454 non-null  object
 2   UserId                  568454 non-null  object
 3   ProfileName             568438 non-null  object
 4   HelpfulnessNumerator    568454 non-null  int64 
 5   HelpfulnessDenominator  568454 non-null  int64 
 6   Score                   568454 non-null  int64 
 7   Time                    568454 non-null  int64 
 8   Summary                 568427 non-null  object
 9   Text                    568454 non-null  object
dtypes: int64(5), object(5)
memory usage: 43.4+ MB
```

In [15]:

```
#get only 2 columns - Text, Score
#drop the NAN values
reviews = reviews[['Text','Score']]
reviews.head()
```

Out[15]:

	Text	Score
0	I have bought several of the Vitality canned d...	5
1	Product arrived labeled as Jumbo Salted Peanut...	1
2	This is a confection that has been around a fe...	4
3	If you are looking for the secret ingredient i...	2
4	Great taffy at a great price. There was a wid...	5

Checking for null values - As can be observed from the below code there are no null values in the data.

In [16]:
```
reviews.isnull().apply(sum)
```

Out[16]:
```
Text      0
Score     0
dtype: int64
```

In [17]:
```
#if score> 3, set score = 1
#if score<=2, set score = 0
#if score == 3, remove the rows.

def binary_conversion(x):
  if x > 3:
    return 1
  elif x<=2:
    return 0
  return None

reviews['Score'] = reviews['Score'].apply(binary_conversion)
reviews.head()
```

Out[17]:

	Text	Score
0	I have bought several of the Vitality canned d...	1.0
1	Product arrived labeled as Jumbo Salted Peanut...	0.0
2	This is a confection that has been around a fe...	1.0
3	If you are looking for the secret ingredient i...	0.0
4	Great taffy at a great price. There was a wid...	1.0

In [18]:
```
sum(reviews.Score.isnull())
```

Out[18]:
```
42640
```

In [19]:
```
reviews.dropna(inplace = True)
print(reviews.shape)
```

```
(525814, 2)
```

Grader function 2

In [20]:
```
def grader_reviews():
    temp_shape = (reviews.shape == (525814, 2)) and (reviews.Score.value_counts()[1]==44
    assert(temp_shape == True)
    return True
grader_reviews()
```

Out[20]:
```
True
```

In [21]:
```
def get_wordlen(x):
    return len(x.split())
reviews['len'] = reviews.Text.apply(get_wordlen)
reviews = reviews[reviews.len<50]
reviews = reviews.sample(n=100000, random_state=30)
```

In [22]:
```
#remove HTML from the Text column and save in the Text column only
import re
```

```
def remove_html(x):
  return re.sub("<.*?>", '', x)

reviews['Text'] = reviews['Text'].apply(remove_html)
```

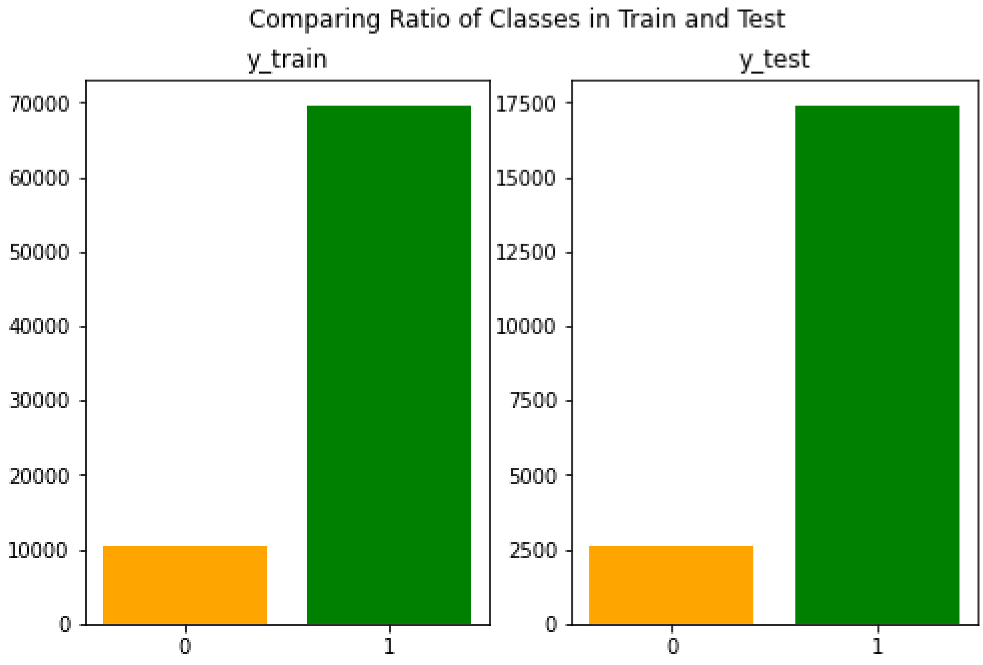
In [23]:
```
#print head 5
print(reviews.head(5))
```

```
                                                     Text  Score  len
64117   The tea was of great quality and it tasted lik...    1.0   30
418112  My cat loves this.  The pellets are nice and s...    1.0   31
357829  Great product. Does not completely get rid of ...    1.0   41
175872  This gum is my favorite!  I would advise every...    1.0   27
178716  I also found out about this product because of...    1.0   22
```

In [25]:
```
#split the data into train and test data(20%) with Stratify sampling, random state 33
from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(reviews['Text'], reviews['Score'], t
                                                    random_state = 33)
```

In [33]:
```
vals_tr = y_train.value_counts()
vals_te = y_test.value_counts()
```

In [44]:
```
#plot bar graphs of y_train and y_test
import matplotlib.pyplot as plt
fig, (ax1, ax2) = plt.subplots(1, 2)
fig.set_figheight(5)
fig.set_figwidth(8)
fig.suptitle('Comparing Ratio of Classes in Train and Test')
ax1.bar(vals_tr.index, vals_tr.values, color = ['green', 'orange'])
ax1.set_title("y_train")
ax1.set_xticks([0, 1])
ax2.bar(vals_te.index, vals_te.values, color = ['green', 'orange'])
ax2.set_title("y_test")
ax2.set_xticks([0, 1])
plt.show()
```



In [45]:
```
#saving to disk. if we need, we can load preprocessed data directly.
reviews.to_csv('preprocessed.csv', index=False)
```

Part-2: Creating BERT Model

If you want to know more about BERT, You can watch live sessions on Transformers and BERt.
we will strongly recommend you to read Transformers, BERT Paper and, This blog.

For this assignment, we are using BERT uncased Base model.
It uses L=12 hidden layers (i.e., Transformer blocks), a hidden size of H=768, and A=12 attention heads.

In [46]:

```
## Loading the Pretrained Model from tensorflow HUB
tf.keras.backend.clear_session()

# maximum length of a seq in the data we have, for now i am making it as 55. You can cha
max_seq_length = 55

#BERT takes 3 inputs

#this is input words. Sequence of words represented as integers
input_word_ids = tf.keras.layers.Input(shape=(max_seq_length,), dtype=tf.int32, name="in

#mask vector if you are padding anything
input_mask = tf.keras.layers.Input(shape=(max_seq_length,), dtype=tf.int32, name="input_

#segment vectors. If you are giving only one sentence for the classification, total seg
#If you are giving two sentenced with [sep] token separated, first seq segment vectors a
#second seq segment vector are 1's
segment_ids = tf.keras.layers.Input(shape=(max_seq_length,), dtype=tf.int32, name="segme

#bert layer
bert_layer = hub.KerasLayer("https://tfhub.dev/tensorflow/bert_en_uncased_L-12_H-768_A-1
pooled_output, sequence_output = bert_layer([input_word_ids, input_mask, segment_ids])

#Bert model
#We are using only pooled output not sequence out.
#If you want to know about those, please read https://www.kaggle.com/questions-and-answe
bert_model = Model(inputs=[input_word_ids, input_mask, segment_ids], outputs=pooled_outp
```

In [47]:

```
bert_model.summary()
```

```
Model: "model"
________________________________________________________________________________________
__________
 Layer (type)                   Output Shape         Param #     Connected to

========================================================================================
==========
 input_word_ids (InputLayer)    [(None, 55)]         0           []


 input_mask (InputLayer)        [(None, 55)]         0           []


 segment_ids (InputLayer)       [(None, 55)]         0           []


 keras_layer (KerasLayer)       [(None, 768),        109482241   ['input_word_ids[0]
[0]',
                                     (None, 55, 768)]              'input_mask[0][0]',

                                                                   'segment_ids[0][0]']



==================================================================================================
Total params: 109,482,241
Trainable params: 0
Non-trainable params: 109,482,241
__________________________________________________________________________________________________
```

In [48]:

```python
bert_model.output
```

Out[48]:

```
<KerasTensor: shape=(None, 768) dtype=float32 (created by layer 'keras_layer')>
```

Part-3: Tokenization

In [49]:

```python
#getting Vocab file
vocab_file = bert_layer.resolved_object.vocab_file.asset_path.numpy()
do_lower_case = bert_layer.resolved_object.do_lower_case.numpy()
```

In [55]:

```python
!pip install sentencepiece
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/publ
ic/simple/
Collecting sentencepiece
  Downloading sentencepiece-0.1.97-cp37-cp37m-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl (1.3 MB)
     |████████████████████████████████| 1.3 MB 14.3 MB/s
Installing collected packages: sentencepiece
Successfully installed sentencepiece-0.1.97
```

In [56]:

```python
import tokenization #We have given tokenization.py file
```

In [ ]:

```python
# Create tokenizer " Instantiate FullTokenizer"
# name must be "tokenizer"
# the FullTokenizer takes two parameters 1. vocab_file and 2. do_lower_case
# we have created these in the above cell ex: FullTokenizer(vocab_file, do_lower_case )
# please check the "tokenization.py" file the complete implementation
```

In [57]:

```python
# if you are getting error for sentencepiece module you can install it using below comma
#!pip install sentencepiece
tokenizer = tokenization.FullTokenizer(vocab_file,do_lower_case )
```

Grader function 3

In [58]:

```python
#it has to give no error
def grader_tokenize(tokenizer):
    out = False
    try:
        out=('[CLS]' in tokenizer.vocab) and ('[SEP]' in tokenizer.vocab)
    except:
        out = False
    assert(out==True)
    return out
grader_tokenize(tokenizer)
```

Out[58]: True

In [ ]:

```
# Create train and test tokens (X_train_tokens, X_test_tokens) from (X_train, X_test) us

# add '[CLS]' at start of the Tokens and '[SEP]' at the end of the tokens.

# maximum number of tokens is 55(We already given this to BERT layer above) so shape is

# if it is less than 55, add '[PAD]' token else truncate the tokens length.(similar to p

# Based on padding, create the mask for Train and Test ( 1 for real token, 0 for '[PAD]'
# it will also same shape as input tokens (None, 55) save those in X_train_mask, X_test_

# Create a segment input for train and test. We are using only one sentence so all zeros

# type of all the above arrays should be numpy arrays

# after execution of this cell, you have to get
# X_train_tokens, X_train_mask, X_train_segment
# X_test_tokens, X_test_mask, X_test_segment
```

In [93]:

```
len(X_train_tokens[0])
```

Out[93]: 36

In [109…

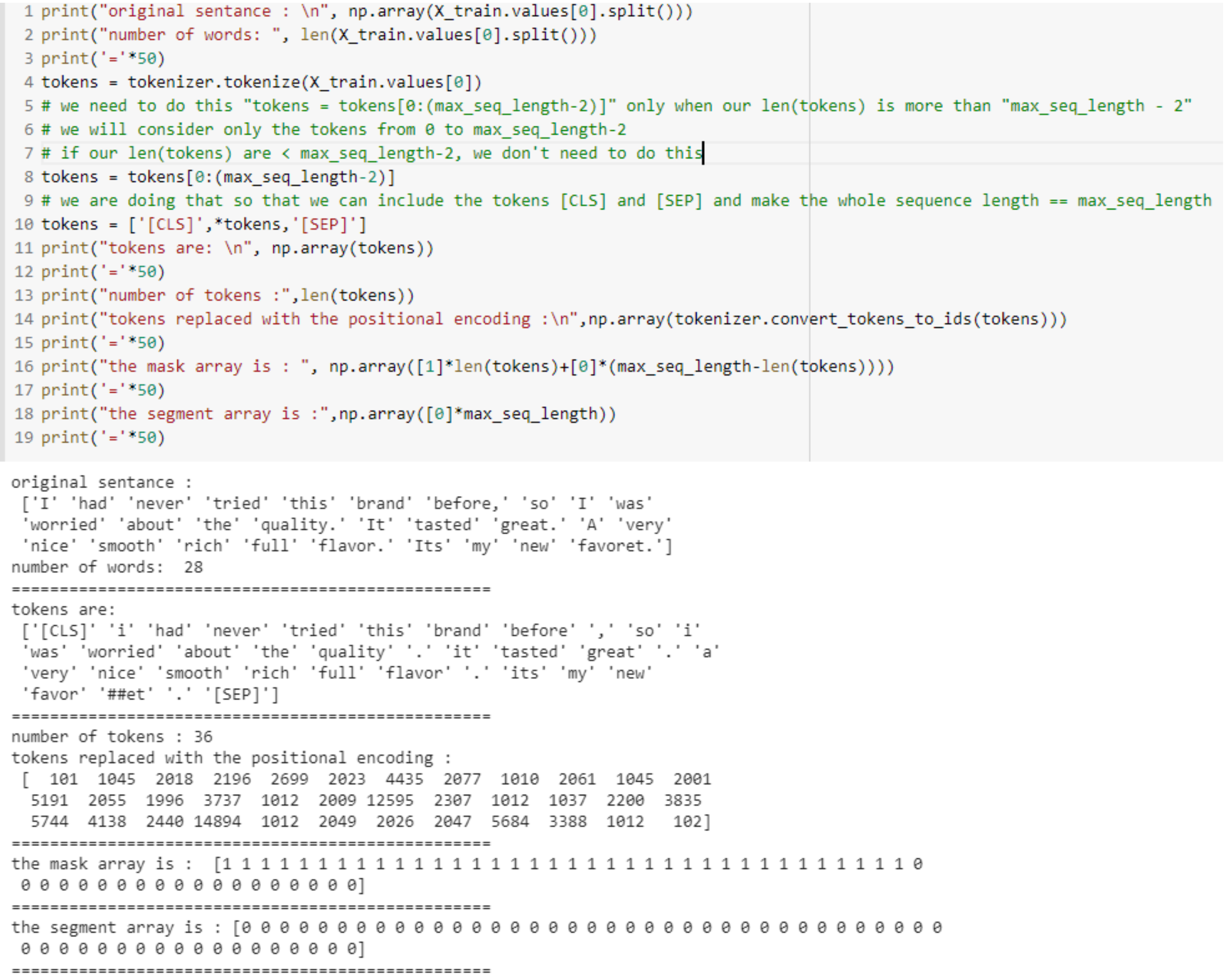
```
train_tokens = []
train_mask = []
train_segment = []
for text in X_train.values:
  tokens = tokenizer.tokenize(text)
  if len(tokens) > (max_seq_length-2):
    tokens = tokens[0:(max_seq_length-2)]
  tokens = ['[CLS]', *tokens, '[SEP]']
  token_length = len(tokens)
  if len(tokens) < max_seq_length:
    pad = ["[PAD]"]
    tokens.extend(pad*(max_seq_length - len(tokens)))
  tokens = np.array(tokens)
  mask = np.array([1]*token_length+ [0]*(max_seq_length - token_length))
  segment = np.array([0]*max_seq_length)
  train_tokens.append(np.array(tokenizer.convert_tokens_to_ids(tokens)))
  train_mask.append(mask)
  train_segment.append(segment)

X_train_tokens = np.array(train_tokens)
X_train_mask = np.array(train_mask)
X_train_segment = np.array(train_segment)
```

In [112…

```
test_tokens = []
test_mask = []
test_segment = []
for text in X_test.values:
  tokens = tokenizer.tokenize(text)
  if len(tokens) > (max_seq_length-2):
    tokens = tokens[0:(max_seq_length-2)]
  tokens = ['[CLS]', *tokens, '[SEP]']
  token_length = len(tokens)
  if len(tokens) < max_seq_length:
    pad = ["[PAD]"]
    tokens.extend(pad*(max_seq_length - len(tokens)))
  tokens = np.array(tokens)
  mask = np.array([1]*token_length+ [0]*(max_seq_length - token_length))
  segment = np.array([0]*max_seq_length)
  test_tokens.append(np.array(tokenizer.convert_tokens_to_ids(tokens)))
```

```
    test_mask.append(mask)
    test_segment.append(segment)

X_test_tokens = np.array(test_tokens)
X_test_mask = np.array(test_mask)
X_test_segment = np.array(test_segment)
```

Example



```
print("original sentance : \n", np.array(X_train.values[0].split()))
print("number of words: ", len(X_train.values[0].split()))
print('='*50)
tokens = tokenizer.tokenize(X_train.values[0])
# we need to do this "tokens = tokens[0:(max_seq_length-2)]" only when our len(tokens) is more than "max_seq_length - 2"
# we will consider only the tokens from 0 to max_seq_length-2
# if our len(tokens) are < max_seq_length-2, we don't need to do this
tokens = tokens[0:(max_seq_length-2)]
# we are doing that so that we can include the tokens [CLS] and [SEP] and make the whole sequence length == max_seq_length
tokens = ['[CLS]',*tokens,'[SEP]']
print("tokens are: \n", np.array(tokens))
print('='*50)
print("number of tokens :",len(tokens))
print("tokens replaced with the positional encoding :\n",np.array(tokenizer.convert_tokens_to_ids(tokens)))
print('='*50)
print("the mask array is : ", np.array([1]*len(tokens)+[0]*(max_seq_length-len(tokens))))
print('='*50)
print("the segment array is :",np.array([0]*max_seq_length))
print('='*50)
```

```
original sentance :
 ['I' 'had' 'never' 'tried' 'this' 'brand' 'before,' 'so' 'I' 'was'
 'worried' 'about' 'the' 'quality.' 'It' 'tasted' 'great.' 'A' 'very'
 'nice' 'smooth' 'rich' 'full' 'flavor.' 'Its' 'my' 'new' 'favoret.']
number of words:  28
==================================================
tokens are:
 ['[CLS]' 'i' 'had' 'never' 'tried' 'this' 'brand' 'before' ',' 'so' 'i'
 'was' 'worried' 'about' 'the' 'quality' '.' 'it' 'tasted' 'great' '.' 'a'
 'very' 'nice' 'smooth' 'rich' 'full' 'flavor' '.' 'its' 'my' 'new'
 'favor' '##et' '.' '[SEP]']
==================================================
number of tokens : 36
tokens replaced with the positional encoding :
 [  101  1045  2018  2196  2699  2023  4435  2077  1010  2061  1045  2001
  5191  2055  1996  3737  1012  2009 12595  2307  1012  1037  2200  3835
  5744  4138  2440 14894  1012  2049  2026  2047  5684  3388  1012   102]
==================================================
the mask array is :  [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
==================================================
the segment array is : [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
==================================================
```

In [113…

```
import pickle
```

In [114…

```
##save all your results to disk so that, no need to run all again.
pickle.dump((X_train, X_train_tokens, X_train_mask, X_train_segment, y_train),open('trai
pickle.dump((X_test, X_test_tokens, X_test_mask, X_test_segment, y_test),open('test_data
```

In [ ]:

```
#you can load from disk
#X_train, X_train_tokens, X_train_mask, X_train_segment, y_train = pickle.load(open("tra
#X_test, X_test_tokens, X_test_mask, X_test_segment, y_test = pickle.load(open("test_dat
```

Grader function 4

In [115…

```
def grader_alltokens_train():
    out = False

    if type(X_train_tokens) == np.ndarray:

        temp_shapes = (X_train_tokens.shape[1]==max_seq_length) and (X_train_mask.shape[
        (X_train_segment.shape[1]==max_seq_length)
        segment_temp = not np.any(X_train_segment)

        mask_temp = np.sum(X_train_mask==0) == np.sum(X_train_tokens==0)

        no_cls = np.sum(X_train_tokens==tokenizer.vocab['[CLS]'])==X_train_tokens.shape[

        no_sep = np.sum(X_train_tokens==tokenizer.vocab['[SEP]'])==X_train_tokens.shape[

        out = temp_shapes and segment_temp and mask_temp and no_cls and no_sep

    else:
        print('Type of all above token arrays should be numpy array not list')
        out = False
    assert(out==True)
    return out

grader_alltokens_train()
```

Out[115]:

```
True
```

Grader function 5

In [116…

```
def grader_alltokens_test():
    out = False
    if type(X_test_tokens) == np.ndarray:

        temp_shapes = (X_test_tokens.shape[1]==max_seq_length) and (X_test_mask.shape[1]
        (X_test_segment.shape[1]==max_seq_length)

        segment_temp = not np.any(X_test_segment)

        mask_temp = np.sum(X_test_mask==0) == np.sum(X_test_tokens==0)

        no_cls = np.sum(X_test_tokens==tokenizer.vocab['[CLS]'])==X_test_tokens.shape[0]

        no_sep = np.sum(X_test_tokens==tokenizer.vocab['[SEP]'])==X_test_tokens.shape[0]

        out = temp_shapes and segment_temp and mask_temp and no_cls and no_sep

    else:
        print('Type of all above token arrays should be numpy array not list')
        out = False
    assert(out==True)
    return out
grader_alltokens_test()
```

Out[116]:

```
True
```

Part-4: Getting Embeddings from BERT Model

We already created the BERT model in the part-2 and input data in the part-3. We will utlize those two and will get the embeddings for each sentence in the Train and test data.

In [117…

```
bert_model.input
```

Out[117]:

```
[<KerasTensor: shape=(None, 55) dtype=int32 (created by layer 'input_word_ids')>,
 <KerasTensor: shape=(None, 55) dtype=int32 (created by layer 'input_mask')>,
 <KerasTensor: shape=(None, 55) dtype=int32 (created by layer 'segment_ids')>]
```

In [118…

```
bert_model.output
```

Out[118]:

```
<KerasTensor: shape=(None, 768) dtype=float32 (created by layer 'keras_layer')>
```

In [119…

```
# get the train output, BERT model will give one output so save in
# X_train_pooled_output
#this cell will take some time to execute, make sure thay you have stable internet conne
X_train_pooled_output = bert_model.predict([X_train_tokens,X_train_mask,X_train_segment]
```

In [120…

```
# get the test output, BERT model will give one output so save in
# X_test_pooled_output
X_test_pooled_output = bert_model.predict([X_test_tokens,X_test_mask,X_test_segment])
```

In [121…

```
##save all your results to disk so that, no need to run all again.
pickle.dump((X_train_pooled_output, X_test_pooled_output),open('final_output.pkl','wb'))
```

In [ ]:

```
#X_train_pooled_output, X_test_pooled_output= pickle.load(open('final_output.pkl', 'rb')
```

Grader function 6

In [122…

```
#now we have X_train_pooled_output, y_train
#X_test_pooled_ouput, y_test

#please use this grader to evaluate
def greader_output():
    assert(X_train_pooled_output.shape[1]==768)
    assert(len(y_train)==len(X_train_pooled_output))
    assert(X_test_pooled_output.shape[1]==768)
    assert(len(y_test)==len(X_test_pooled_output))
    assert(len(y_train.shape)==1)
    assert(len(X_train_pooled_output.shape)==2)
    assert(len(y_test.shape)==1)
    assert(len(X_test_pooled_output.shape)==2)
    return True
greader_output()
```

Out[122]:

```
True
```

Part-5: Training a NN with 768 features

Create a NN and train the NN.
1. **You have to use AUC as metric. Do not use tf.keras.metrics.AUC**
 You have to write custom code for AUC and print it at the end of each epoch
2. You can use any architecture you want.
3. You have to use tensorboard to log all your metrics and Losses. You have to send those logs.
4. Print the loss and metric at every epoch.
5. You have to submit without overfitting and underfitting.

In [126…

```
##imports
from tensorflow.keras.layers import Input, Dense, Activation, Dropout, LSTM, Flatten
from tensorflow.keras.initializers import HeNormal
from tensorflow.keras.regularizers import L2
from tensorflow.keras.optimizers import Adam
from tensorflow.compat.v1.keras.layers import CuDNNLSTM
from tensorflow.keras.models import Model
```

In [127…

```
from sklearn.metrics import roc_auc_score
def auc( y_true, y_pred ) :
    score = tf.py_function( lambda y_true, y_pred : roc_auc_score( y_true, y_pred, avera
                        [y_true, y_pred],
                        'float32',
                       name='sklearnAUC' )
    return score
```

In [138…

```
X_train_pooled_output.shape
```

Out[138]:

```
(80000, 768)
```

In [139…

```
X_test_pooled_output.shape
```

Out[139]:

```
(20000, 768)
```

In [135…

```
v = X_train_pooled_output.reshape(80000, 768, 1)
v.shape
```

Out[135]:

```
(80000, 768, 1)
```

In [140…

```
w = X_test_pooled_output.reshape(20000, 768, 1)
```

In [144…

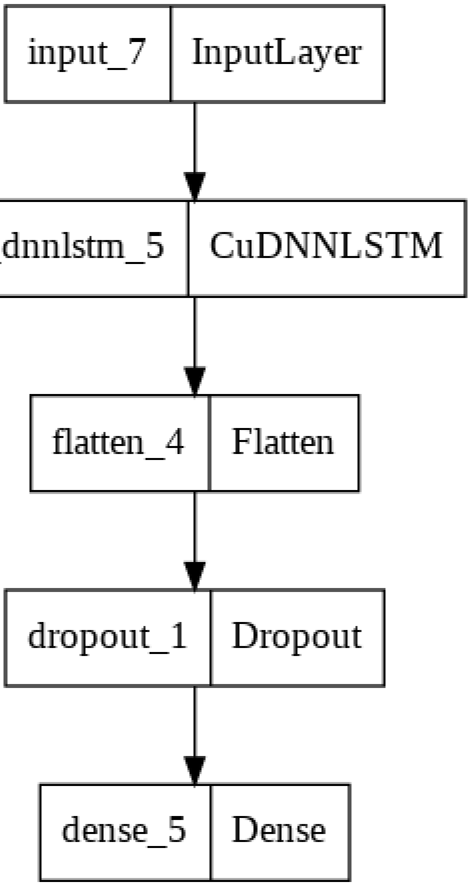
```
##create an Neural Network and train your model on X_train_pooled_output and y_train
# you can start as follows
input_layer = Input(shape = (X_train_pooled_output.shape[1],1))
lstm_layer = CuDNNLSTM(64, return_sequences = True)(input_layer)
print(lstm_layer.get_shape())
flat1 = Flatten()(lstm_layer)
print(flat1.get_shape())
dense = Dense(32,activation = 'relu', kernel_initializer = HeNormal(), kernel_regularize
print(dense.get_shape())
dropout = Dropout(0.5)(flat1)
print(dropout.get_shape())
output = Dense(2, activation = 'softmax')(dropout)
model = Model(input_layer, output)
model.compile(loss = 'categorical_crossentropy', optimizer = Adam(learning_rate = 0.0006

print(model.summary())
```

```
(None, 768, 64)
(None, 49152)
(None, 32)
(None, 49152)
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 768, 1)]          0

 cu_dnnlstm (CuDNNLSTM)      (None, 768, 64)           17152

 flatten (Flatten)           (None, 49152)             0

 dropout (Dropout)           (None, 49152)             0

 dense_1 (Dense)             (None, 2)                 98306

=================================================================
Total params: 115,458
Trainable params: 115,458
Non-trainable params: 0
_________________________________________________________________
None
```

In [141…

```
tf.keras.utils.plot_model(
    model, to_file='model.png', show_shapes=False, show_layer_names=True,
    rankdir='TB', expand_nested=False, dpi=96
)
```

Out[141]:



In [159…

```
tf.keras.backend.clear_session()
!rm -rf ./logs/
```

In [150…

```
from sklearn.preprocessing import OneHotEncoder
ohe = OneHotEncoder()
target_train = ohe.fit_transform(y_train.values.reshape(-1,1)).toarray()
target_test = ohe.transform(y_test.values.reshape(-1,1)).toarray()
```

In [152…

```
#to avoid the error: Creating variables on a non-first call to a function decorated with
#reference: https://stackoverflow.com/questions/58352326/running-the-tensorflow-2-0-code
tf.config.run_functions_eagerly(True)
```

In [160…

```
#%load_ext tensorboard
#import datetime, os
#from tensorflow.keras.callbacks import ModelCheckpoint
filepath="weights_copy.best.hdf5"
checkpoint = ModelCheckpoint(filepath, monitor='val_auc', verbose=1, save_best_only = Tr
log_dir = os.path.join("logs",'fits', datetime.datetime.now().strftime("%Y%m%d-%H%M%S"))
#tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir,histogram_freq=1)
model.fit(x = v, y = target_train, validation_data = (w, target_test), epochs = 30, batc
          callbacks = [checkpoint]) #, tensorboard_callback])
```

```
Epoch 1/30
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/structured_function.p
```

```
y:265: UserWarning: Even though the `tf.config.experimental_run_functions_eagerly` optio
n is set, this option does not apply to tf.data functions. To force eager execution of t
f.data functions, please use `tf.data.experimental.enable_debug_mode()`.
  "Even though the `tf.config.experimental_run_functions_eagerly` "
```

```
1000/1000 [==============================] - ETA: 0s - loss: 0.1950 - auc: 0.9442
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/structured_function.p
y:265: UserWarning: Even though the `tf.config.experimental_run_functions_eagerly` optio
n is set, this option does not apply to tf.data functions. To force eager execution of t
f.data functions, please use `tf.data.experimental.enable_debug_mode()`.
  "Even though the `tf.config.experimental_run_functions_eagerly` "
```

```
Epoch 1: val_auc improved from -inf to 0.94731, saving model to weights_copy.best.hdf5
1000/1000 [==============================] - 55s 55ms/step - loss: 0.1950 - auc: 0.9442
- val_loss: 0.1897 - val_auc: 0.9473
Epoch 2/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1934 - auc: 0.9435
Epoch 2: val_auc improved from 0.94731 to 0.94841, saving model to weights_copy.best.hdf
5
1000/1000 [==============================] - 55s 55ms/step - loss: 0.1934 - auc: 0.9435
- val_loss: 0.1859 - val_auc: 0.9484
Epoch 3/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1943 - auc: 0.9445
Epoch 3: val_auc did not improve from 0.94841
1000/1000 [==============================] - 55s 55ms/step - loss: 0.1943 - auc: 0.9445
- val_loss: 0.1814 - val_auc: 0.9478
Epoch 4/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1925 - auc: 0.9449
Epoch 4: val_auc did not improve from 0.94841
1000/1000 [==============================] - 55s 55ms/step - loss: 0.1926 - auc: 0.9449
- val_loss: 0.1940 - val_auc: 0.9478
Epoch 5/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1935 - auc: 0.9448
Epoch 5: val_auc improved from 0.94841 to 0.94870, saving model to weights_copy.best.hdf
5
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1936 - auc: 0.9448
- val_loss: 0.1815 - val_auc: 0.9487
Epoch 6/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1927 - auc: 0.9449
Epoch 6: val_auc improved from 0.94870 to 0.94878, saving model to weights_copy.best.hdf
5
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1927 - auc: 0.9449
- val_loss: 0.1793 - val_auc: 0.9488
Epoch 7/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1911 - auc: 0.9456
Epoch 7: val_auc improved from 0.94878 to 0.94905, saving model to weights_copy.best.hdf
5
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1910 - auc: 0.9457
- val_loss: 0.1788 - val_auc: 0.9491
Epoch 8/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1904 - auc: 0.9455
Epoch 8: val_auc did not improve from 0.94905
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1904 - auc: 0.9455
- val_loss: 0.1809 - val_auc: 0.9487
Epoch 9/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1906 - auc: 0.9455
Epoch 9: val_auc improved from 0.94905 to 0.94975, saving model to weights_copy.best.hdf
5
1000/1000 [==============================] - 55s 55ms/step - loss: 0.1906 - auc: 0.9455
- val_loss: 0.1800 - val_auc: 0.9498
Epoch 10/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1920 - auc: 0.9466
Epoch 10: val_auc did not improve from 0.94975
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1920 - auc: 0.9466
- val_loss: 0.1804 - val_auc: 0.9495
Epoch 11/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1883 - auc: 0.9471
```

```
Epoch 11: val_auc did not improve from 0.94975
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1883 - auc: 0.9471
- val_loss: 0.1920 - val_auc: 0.9494
Epoch 12/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1896 - auc: 0.9470
Epoch 12: val_auc improved from 0.94975 to 0.95002, saving model to weights_copy.best.hd
f5
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1896 - auc: 0.9470
- val_loss: 0.1774 - val_auc: 0.9500
Epoch 13/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1886 - auc: 0.9476
Epoch 13: val_auc did not improve from 0.95002
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1886 - auc: 0.9476
- val_loss: 0.1930 - val_auc: 0.9494
Epoch 14/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1890 - auc: 0.9467
Epoch 14: val_auc improved from 0.95002 to 0.95035, saving model to weights_copy.best.hd
f5
1000/1000 [==============================] - 55s 55ms/step - loss: 0.1890 - auc: 0.9467
- val_loss: 0.2236 - val_auc: 0.9504
Epoch 15/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1890 - auc: 0.9477
Epoch 15: val_auc did not improve from 0.95035
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1891 - auc: 0.9477
- val_loss: 0.1764 - val_auc: 0.9502
Epoch 16/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1879 - auc: 0.9476
Epoch 16: val_auc improved from 0.95035 to 0.95039, saving model to weights_copy.best.hd
f5
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1879 - auc: 0.9476
- val_loss: 0.1831 - val_auc: 0.9504
Epoch 17/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1880 - auc: 0.9472
Epoch 17: val_auc improved from 0.95039 to 0.95051, saving model to weights_copy.best.hd
f5
1000/1000 [==============================] - 55s 55ms/step - loss: 0.1880 - auc: 0.9472
- val_loss: 0.1761 - val_auc: 0.9505
Epoch 18/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1877 - auc: 0.9474
Epoch 18: val_auc did not improve from 0.95051
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1877 - auc: 0.9474
- val_loss: 0.1857 - val_auc: 0.9498
Epoch 19/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1898 - auc: 0.9472
Epoch 19: val_auc did not improve from 0.95051
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1899 - auc: 0.9471
- val_loss: 0.1812 - val_auc: 0.9493
Epoch 20/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1874 - auc: 0.9477
Epoch 20: val_auc did not improve from 0.95051
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1874 - auc: 0.9477
- val_loss: 0.1786 - val_auc: 0.9504
Epoch 21/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1883 - auc: 0.9474
Epoch 21: val_auc did not improve from 0.95051
1000/1000 [==============================] - 53s 53ms/step - loss: 0.1884 - auc: 0.9473
- val_loss: 0.1910 - val_auc: 0.9505
Epoch 22/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1857 - auc: 0.9481
Epoch 22: val_auc did not improve from 0.95051
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1857 - auc: 0.9481
- val_loss: 0.1769 - val_auc: 0.9505
Epoch 23/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1867 - auc: 0.9481
Epoch 23: val_auc improved from 0.95051 to 0.95092, saving model to weights_copy.best.hd
f5
```

```
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1867 - auc: 0.9481
- val_loss: 0.1763 - val_auc: 0.9509
Epoch 24/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1860 - auc: 0.9483
Epoch 24: val_auc improved from 0.95092 to 0.95114, saving model to weights_copy.best.hd
f5
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1860 - auc: 0.9483
- val_loss: 0.1749 - val_auc: 0.9511
Epoch 25/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1865 - auc: 0.9481
Epoch 25: val_auc improved from 0.95114 to 0.95120, saving model to weights_copy.best.hd
f5
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1865 - auc: 0.9481
- val_loss: 0.1772 - val_auc: 0.9512
Epoch 26/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1858 - auc: 0.9485
Epoch 26: val_auc did not improve from 0.95120
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1858 - auc: 0.9485
- val_loss: 0.1782 - val_auc: 0.9509
Epoch 27/30
1000/1000 [==============================] - ETA: 0s - loss: 0.1847 - auc: 0.9491
Epoch 27: val_auc did not improve from 0.95120
1000/1000 [==============================] - 53s 53ms/step - loss: 0.1847 - auc: 0.9491
- val_loss: 0.1822 - val_auc: 0.9512
Epoch 28/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1857 - auc: 0.9484
Epoch 28: val_auc improved from 0.95120 to 0.95167, saving model to weights_copy.best.hd
f5
1000/1000 [==============================] - 52s 52ms/step - loss: 0.1857 - auc: 0.9484
- val_loss: 0.1809 - val_auc: 0.9517
Epoch 29/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1859 - auc: 0.9488
Epoch 29: val_auc did not improve from 0.95167
1000/1000 [==============================] - 53s 53ms/step - loss: 0.1858 - auc: 0.9488
- val_loss: 0.1820 - val_auc: 0.9514
Epoch 30/30
 999/1000 [============================>.] - ETA: 0s - loss: 0.1852 - auc: 0.9482
Epoch 30: val_auc did not improve from 0.95167
1000/1000 [==============================] - 54s 54ms/step - loss: 0.1852 - auc: 0.9483
- val_loss: 0.1754 - val_auc: 0.9510
```

Out[160]:

```
<keras.callbacks.History at 0x7f949c135350>
```

Tried creating tensorboard graphs but got - 'Function' object has no attribute '_concrete_stateful_fn'. I was unable to debug the error, I couldn't find any solution on the internet as well.

In [163…

```
model.save('best_model.hdf5')
```

Part-6: Creating a Data pipeline for BERT Model

1. Pipeline is a way to codify and automate the workflow.

2. Download the test.csv file from here here </pre>

In [ ]:

```
#there is an alterante way to load files from Google drive directly to your Colab sessio
# you can use gdown module to import the files as follows
#for example for test.csv you can write your code as !gdown --id file_id (remove the # f
```

In [161…

```
!gdown --id 1QwjqTsqTX2vdy7fTmeXjxP3dq8IAVLpo
```

```
/usr/local/lib/python3.7/dist-packages/gdown/cli.py:131: FutureWarning: Option `--id` wa
s deprecated in version 4.3.1 and will be removed in 5.0. You don't need to pass it anym
ore to use a file ID.
  category=FutureWarning,
Downloading...
From: https://drive.google.com/uc?id=1QwjqTsqTX2vdy7fTmeXjxP3dq8IAVLpo
To: /content/test.csv
100% 62.1k/62.1k [00:00<00:00, 66.9MB/s]
```

In [172…

```
#read the csv file
test_df = pd.read_csv('test.csv', encoding = 'utf-8')
```

In [173…

```
test_df.head()
```

Out[173]:

	Text
0	Just opened Greenies Joint Care (individually ...
1	This product rocks :) My mom was very happy w/...
2	The product was fine, but the cost of shipping...
3	I love this soup. It's great as part of a meal...
4	Getting ready to order again. These are great ...

1. You have to write a function that takes the test_df,trained model and the required parameters as input.

1. Perform all the preproceesing steps inside the function.

- Remove all the html tags
- Now do tokenization [Part 3 as mentioned above]
- Create tokens,mask array and segment array
- Get Embeddings from BERT Model [Part 4 as mentioned above] , let it be X_test
- Print the shape of output(X_test.shape).You should get (352,768)

1. Predit the output of X_test with the neural network model which we trained earlier.

2. Return the occurences of class labels from the function.
   The output should be the count of datapoints classified as 1 or 0.

</pre>

In [196…

```
def remove_html(x):
  return re.sub("<.*?>", '', x)

def pipeline(X_test, filepath):
  '''
  Function takes test datapoints and the filepath where the weights of the optimal model
  Returns the no. of datapoints belonging to each class as predictions of the test datap
  '''

  #removing html tags from the data
  X_test['Text'] = X_test['Text'].apply(remove_html)

  #creating tokens, mask and segment for test data
  test_tokens = []
  test_mask = []
  test_segment = []
  for text in X_test.values:
    tokens = tokenizer.tokenize(text[0])
    if len(tokens) > (max_seq_length-2):
      tokens = tokens[0:(max_seq_length-2)]
    tokens = ['[CLS]', *tokens, '[SEP]']
    token_length = len(tokens)
    if len(tokens) < max_seq_length:
      pad = ["[PAD]"]
      tokens.extend(pad*(max_seq_length - len(tokens)))
    tokens = np.array(tokens)
    mask = np.array([1]*token_length+ [0]*(max_seq_length - token_length))
    segment = np.array([0]*max_seq_length)
    test_tokens.append(np.array(tokenizer.convert_tokens_to_ids(tokens)))
    test_mask.append(mask)
    test_segment.append(segment)

  X_test_tokens = np.array(test_tokens)
  X_test_mask = np.array(test_mask)
  X_test_segment = np.array(test_segment)

  #getting BERT embeddings for test data
  X_test_pooled = bert_model.predict([X_test_tokens,X_test_mask,X_test_segment])

  #printing the shape of the embeddings obtained
  print(X_test_pooled.shape)

  #reshaping X_test_pooled for CuDNNLSTM - as it needs 3dim input
  org_shape = X_test_pooled.shape
  X_test_pooled = X_test_pooled.reshape(org_shape[0], org_shape[1], 1)
```

```
    #model architecture
    input_layer = Input(shape = (X_train_pooled_output.shape[1],1))
    lstm_layer = CuDNNLSTM(64, return_sequences = True)(input_layer)
    flat1 = Flatten()(lstm_layer)
    dense = Dense(32,activation = 'relu', kernel_initializer = HeNormal(), kernel_regulari
    dropout = Dropout(0.5)(flat1)
    output = Dense(2, activation = 'softmax')(dropout)
    model = Model(input_layer, output)
    #loading the weights of the best model we got
    model.load_weights(filepath)
    model.compile(loss = 'categorical_crossentropy', optimizer = Adam(learning_rate = 0.00

    preds = model.predict(X_test_pooled)
    y_pred = preds[:,1]
    print("No. of datapoints classified as belonging to class 0: ",sum(y_pred<0.5))
    print("No. of datapoints classified as belonging to class 1: ",sum(y_pred>=0.5))

    return (sum(y_pred<0.5), sum(y_pred>=0.5))
```

In [197…

```
no_of_0, no_of_1 = pipeline(test_df, filepath)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/structured_function.p
y:265: UserWarning: Even though the `tf.config.experimental_run_functions_eagerly` optio
n is set, this option does not apply to tf.data functions. To force eager execution of t
f.data functions, please use `tf.data.experimental.enable_debug_mode()`.
  "Even though the `tf.config.experimental_run_functions_eagerly` "
(352, 768)
No. of datapoints classified as belonging to class 0:  30
No. of datapoints classified as belonging to class 1:  322
```

Please write your observations at the end of notebook and explain each and every step you followed in solving this assignment.

In [207…

```
from prettytable import PrettyTable


x = PrettyTable()
x.field_names = ["Features", "Model", "Epochs", "Train AUC", "Validation AUC"]
x.add_row(["BERT embeddings for text data", "CuDNNLSTM", 28, 0.9484, 0.9516])

print(x)
```

```
+-------------------------------+-----------+--------+-----------+----------------+
|            Features           |   Model   | Epochs | Train AUC | Validation AUC |
+-------------------------------+-----------+--------+-----------+----------------+
| BERT embeddings for text data | CuDNNLSTM |   28   |   0.9484  |     0.9516     |
+-------------------------------+-----------+--------+-----------+----------------+
```

Observations:

1. The difference between train AUC and validation AUC is low. Therefore, there is no overfit/ underfit.

2. The use of BERT embeddings enabled us to achieve a good AUC of over 95% in very less epochs even using a simple model with very less no. of trainable parameters in the order of 100,000.

3. LSTM is good with capturing patterns. BERT embeddings + a simple LSTM model like the one used here can achieve good results with low computational resuorces in less training time. Hence, NLP with transfer learning is an effective approach.