In this notebook, You will do amazon review classification with BERT.[Download data from this (https://www.kaggle.com/snap/amazon-fine-food-reviews/data) 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
```

In [3]:

```
!pip install tensorflow_text>=2.0.0rc0
!pip install sentencepiece
!pip install tf_sentencepiece

#!pip install bert-tensorflow
#!pip install --upgrade bert
!pip install tokenization
!pip install bert-for-tf2
!pip install pandas
```

```
Requirement already satisfied: sentencepiece in c:\users\sowjanya\appdata\ro
aming\python\python39\site-packages (0.1.97)
Requirement already satisfied: tf_sentencepiece in c:\users\sowjanya\appdata
\roaming\python\python39\site-packages (0.1.3)
Requirement already satisfied: tokenization in c:\users\sowjanya\appdata\roa
ming\python\python39\site-packages (1.0.7)
Requirement already satisfied: regex in c:\users\sowjanya\anaconda3\envs\tf-
gpu\lib\site-packages (from tokenization) (2022.10.31)
Requirement already satisfied: bert-for-tf2 in c:\users\sowjanya\appdata\roa
ming\python\python39\site-packages (0.14.9)
Requirement already satisfied: py-params>=0.9.6 in c:\users\sowjanya\appdata
\roaming\python\python39\site-packages (from bert-for-tf2) (0.10.2)
Requirement already satisfied: params-flow>=0.8.0 in c:\users\sowjanya\appda
ta\roaming\python\python39\site-packages (from bert-for-tf2) (0.8.2)
Requirement already satisfied: tqdm in c:\users\sowjanya\anaconda3\envs\tf-g
pu\lib\site-packages (from params-flow>=0.8.0->bert-for-tf2) (4.64.1)
Requirement already satisfied: numpy in c:\users\sowjanya\anaconda3\envs\tf-
gpu\lib\site-packages (from params-flow>=0.8.0->bert-for-tf2) (1.23.5)
Requirement already satisfied: colorama in c:\users\sowjanya\anaconda3\envs
\tf-gpu\lib\site-packages (from tqdm->params-flow>=0.8.0->bert-for-tf2) (0.
4.6)
Collecting pandas
  Downloading pandas-1.5.2-cp39-cp39-win_amd64.whl (10.9 MB)
     ---------------------------------------- 10.9/10.9 MB 1.5 MB/s eta 0:0
0:00
Requirement already satisfied: numpy>=1.20.3 in c:\users\sowjanya\anaconda3
\envs\tf-gpu\lib\site-packages (from pandas) (1.23.5)
Requirement already satisfied: python-dateutil>=2.8.1 in c:\users\sowjanya\a
naconda3\envs\tf-gpu\lib\site-packages (from pandas) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in c:\users\sowjanya\anaconda3\e
nvs\tf-gpu\lib\site-packages (from pandas) (2022.6)
Requirement already satisfied: six>=1.5 in c:\users\sowjanya\anaconda3\envs
\tf-gpu\lib\site-packages (from python-dateutil>=2.8.1->pandas) (1.16.0)
Installing collected packages: pandas
Successfully installed pandas-1.5.2
```

In [4]:

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

import warnings
warnings.filterwarnings("ignore")

from tensorflow.keras.callbacks import TerminateOnNaN,ReduceLROnPlateau,EarlyStopping,Learn
from keras.callbacks import TensorBoard
```

In [5]:

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

Out[5]:

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

Grader function 1

In [6]:

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

Out[6]:

```
True
```

Part-1: Preprocessing

In [ ]:

```
from google.colab import drive
drive.mount('/content/drive')
```

In [11]:

```
#Read the dataset - Amazon fine food reviews
reviews = pd.read_csv("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 [12]:

```
#get only 2 columns - Text, Score
drop_columns = ['Id', 'ProductId', 'UserId', 'ProfileName', 'HelpfulnessNumerator', 'Helpfu
reviews = reviews.drop(drop_columns, axis=1)
```

In [13]:

```
reviews['Score'].isna().sum(), reviews['Text'].isna().sum()
```

Out[13]:

```
(0, 0)
```

In [14]:

```
#drop the NAN values
reviews = reviews.dropna()
```

In [15]:

```
#if score == 3, remove the rows.
reviews.drop(reviews[reviews['Score'] == 3].index, inplace = True)
#if score> 3, set score = 1
#if score<=2, set score = 0
reviews['Score'] = (reviews['Score'] > 3).astype(int)
reviews.head()
```

Out[15]:

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

In [16]:

```
reviews.shape
```

Out[16]:

```
(525814, 2)
```

In [17]:

```
reviews.Score.value_counts()
```

Out[17]:

```
1    443777
0     82037
Name: Score, dtype: int64
```

In [18]:

```
reviews.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 525814 entries, 0 to 568453
Data columns (total 2 columns):
 #   Column  Non-Null Count   Dtype 
---  ------  --------------   ----- 
 0   Score   525814 non-null  int32 
 1   Text    525814 non-null  object
dtypes: int32(1), object(1)
memory usage: 10.0+ MB
```

In [19]:

```
reviews.describe()
```

Out[19]:

	Score
count	525814.000000
mean	0.843981
std	0.362874
min	0.000000
25%	1.000000
50%	1.000000
75%	1.000000
max	1.000000

Grader function 2

In [20]:

```
def grader_reviews():
    temp_shape = (reviews.shape == (525814, 2)) and (reviews.Score.value_counts()[1] == 443
    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)
reviews.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 100000 entries, 64117 to 19261
Data columns (total 3 columns):
 #   Column  Non-Null Count   Dtype 
---  ------  --------------   ----- 
 0   Score   100000 non-null  int32 
 1   Text    100000 non-null  object
 2   len     100000 non-null  int64 
dtypes: int32(1), int64(1), object(1)
memory usage: 2.7+ MB
```

In [22]:

```
reviews.head(5)
```

Out[22]:

	Score	Text	len
64117	1	The tea was of great quality and it tasted lik...	30
418112	1	My cat loves this. The pellets are nice and s...	31
357829	1	Great product. Does not completely get rid of ...	41
175872	1	This gum is my favorite! I would advise every...	27
178716	1	I also found out about this product because of...	22

In [23]:

```
reviews["Text"].iloc[64]
```

Out[23]:

```
'THE BEST garlic oil ever, hands down!<br />Try it on pop corn WOW!!<br />BU
T a 2 yr. old could have packaged it better GRR!!'
```

In [24]:

```
#remove HTML from the Text column and save in the Text column only
def remove_html(text):

  #Delete all the tags like "< anyword >"
  clean = re.compile('<.*?>')
  text=re.sub(clean,' ',text)

  #Remove all the newlines('\n'), tabs('\t'), "-", "\".
  text= re.sub(r"[\n\t-]*", "", text)

  return text
```

In [25]:

```
reviews.shape[0]
```

Out[25]:

```
100000
```

In [26]:

```
removed_html_text_data=[]

for i in tqdm(range(reviews.shape[0])):
  removed_html_text_data.append(remove_html(reviews['Text'].values[i]))
```

```
100%|██████████| 100000/100000 [00:04<00:00, 24839.80it/s]
```

In [27]:

```
#print head 5
reviews['Text'] = removed_html_text_data
reviews.head(5)
```

Out[27]:

	Score	Text	len
64117	1	The tea was of great quality and it tasted lik...	30
418112	1	My cat loves this. The pellets are nice and s...	31
357829	1	Great product. Does not completely get rid of ...	41
175872	1	This gum is my favorite! I would advise every...	27
178716	1	I also found out about this product because of...	22

In [28]:

```
reviews["Text"].iloc[64]
```

Out[28]:

```
'THE BEST garlic oil ever, hands down! Try it on pop corn WOW!! BUT a 2 yr.
old could have packaged it better GRR!!'
```

In [29]:

```
reviews.columns
```

Out[29]:

```
Index(['Score', 'Text', 'len'], dtype='object')
```

In [30]:

```
reviews.shape
```

Out[30]:

```
(100000, 3)
```

In [31]:

```
X = pd.DataFrame()
X['Text'] = reviews['Text']
X['len'] = reviews['len']
y = pd.DataFrame()
y['Score'] = reviews['Score']
```

In [33]:

```
!pip install scikit-learn
```

```
Collecting scikit-learn
  Downloading scikit_learn-1.1.3-cp39-cp39-win_amd64.whl (7.6 MB)
     ---------------------------------------- 7.6/7.6 MB 1.7 MB/s eta 0:00:0
0
Collecting joblib>=1.0.0
  Downloading joblib-1.2.0-py3-none-any.whl (297 kB)
     ------------------------------------ 298.0/298.0 kB 2.0 MB/s eta 0:0
0:00
Requirement already satisfied: numpy>=1.17.3 in c:\users\sowjanya\anaconda3
\envs\tf-gpu\lib\site-packages (from scikit-learn) (1.23.5)
Collecting threadpoolctl>=2.0.0
  Downloading threadpoolctl-3.1.0-py3-none-any.whl (14 kB)
Requirement already satisfied: scipy>=1.3.2 in c:\users\sowjanya\anaconda3\e
nvs\tf-gpu\lib\site-packages (from scikit-learn) (1.9.3)
Installing collected packages: threadpoolctl, joblib, scikit-learn
Successfully installed joblib-1.2.0 scikit-learn-1.1.3 threadpoolctl-3.1.0
```

In [34]:

```
#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(X,y, test_size=0.20, stratify=y,random_
```

In [35]:

```
print(X_train.shape)
print(X_test.shape)
print(y_train.shape)
print(y_test.shape)
```

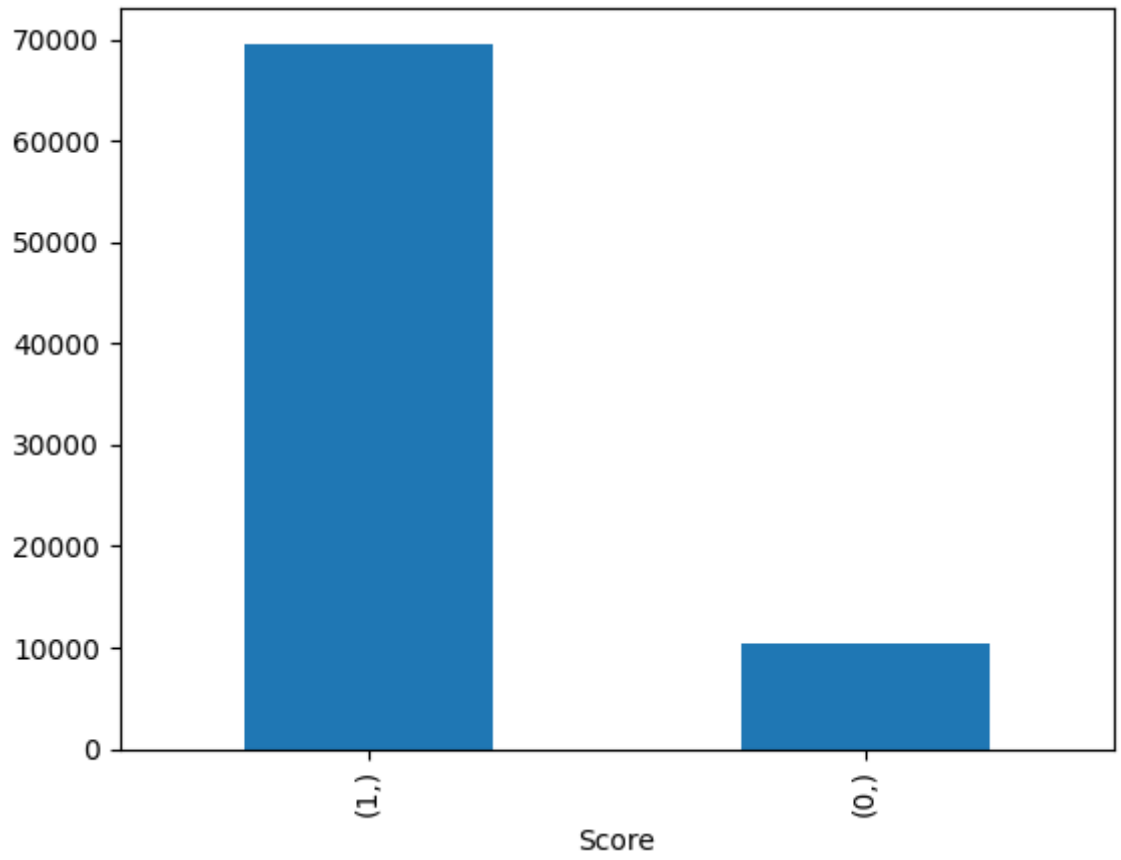
```
(80000, 2)
(20000, 2)
(80000, 1)
(20000, 1)
```

In [36]:

```
#Bar graph for y_train
import matplotlib.pyplot as plt
y_train.value_counts().plot(kind='bar')
```

Out[36]:

```
<AxesSubplot: xlabel='Score'>
```

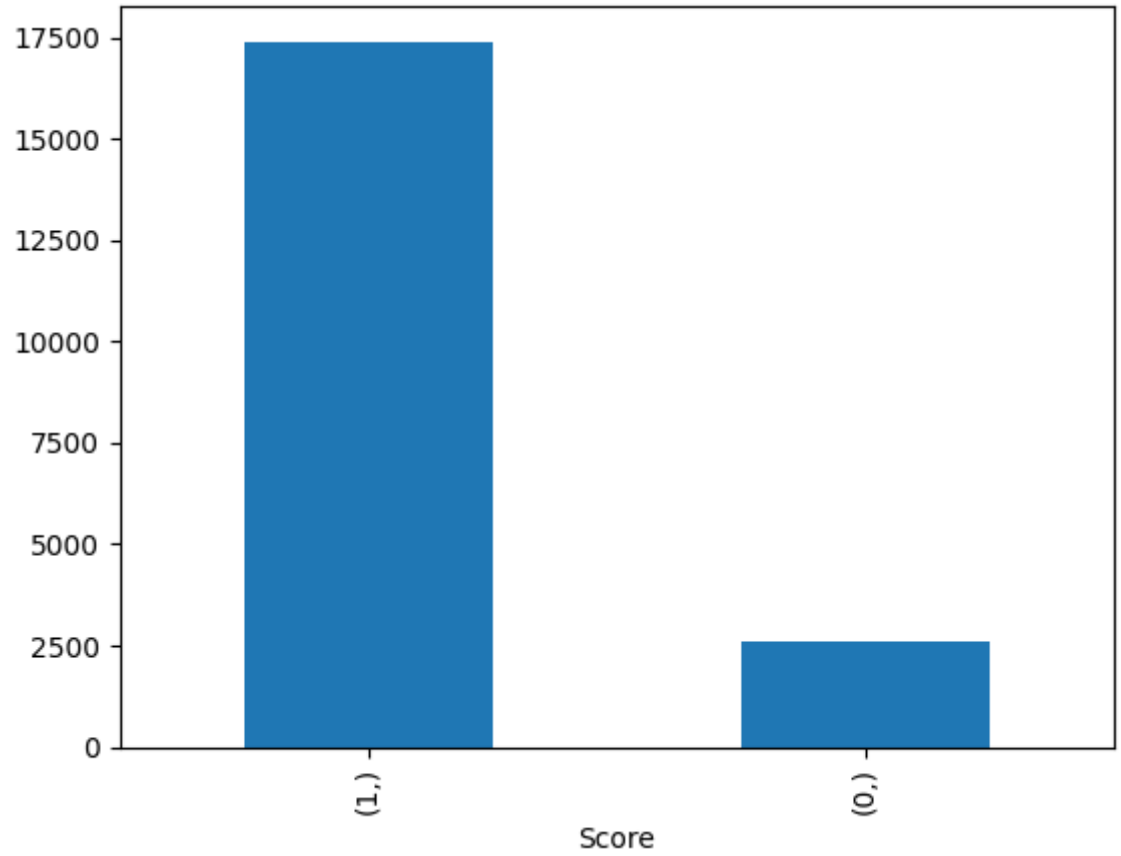


In [37]:

```
#Bar Graph for y_test data
y_test.value_counts().plot(kind='bar')
```

Out[37]:

```
<AxesSubplot: xlabel='Score'>
```



In [38]:

```
#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 (https://jalammar.github.io/illustrated-transformer/), BERT Paper (https://arxiv.org/abs/1810.04805) and, This blog (https://jalammar.github.io/a-visual-guide-to-using-bert-for-the-first-time/).

For this assignment, we are using BERT uncased Base model (https://tfhub.dev/tensorflow/bert_en_uncased_L-12_H-768_A-12/1).
It uses L=12 hidden layers (i.e., Transformer blocks), a hidden size of H=768, and A=12 attention heads.

In [39]:

```
!pip install pydot
!pip install graphviz
!pip install pydot_ng
```

```
Collecting pydot
  Downloading pydot-1.4.2-py2.py3-none-any.whl (21 kB)
Requirement already satisfied: pyparsing>=2.1.4 in c:\users\sowjanya\anacond
a3\envs\tf-gpu\lib\site-packages (from pydot) (3.0.9)
Installing collected packages: pydot
Successfully installed pydot-1.4.2
Collecting graphviz
  Downloading graphviz-0.20.1-py3-none-any.whl (47 kB)
     ---------------------------------------- 47.0/47.0 kB 168.0 kB/s eta 0:0
0:00
Installing collected packages: graphviz
Successfully installed graphviz-0.20.1
Collecting pydot_ng
  Downloading pydot_ng-2.0.0-py2.py3-none-any.whl (20 kB)
Requirement already satisfied: pyparsing>=2.0.1 in c:\users\sowjanya\anacond
a3\envs\tf-gpu\lib\site-packages (from pydot_ng) (3.0.9)
Installing collected packages: pydot_ng
Successfully installed pydot_ng-2.0.0
```

In [40]:

```
tf.keras.backend.clear_session()
#BERT takes 3 inputs
#this is input words. Sequence of words represented as integers
#mask vector if you are padding anything
#segment vectors. If you are giving only one sentence for the classification, total seg vec
#If you are giving two sentenced with [sep] token separated, first seq segment vectors are
#second seq segment vector are 1's
max_seq_length = 55
input_word_ids = tf.keras.Input(shape=(max_seq_length,), dtype=tf.int32, name="input_word_i
input_mask = tf.keras.Input(shape=(max_seq_length,), dtype=tf.int32, name="input_mask")
input_type_ids = tf.keras.Input(shape=(max_seq_length,), dtype=tf.int32, name="input_type_i
bert_layer = hub.KerasLayer("https://tfhub.dev/tensorflow/bert_en_uncased_L-12_H-768_A-12/1
#bert_inputs = dict(input_word_ids = input_word_ids,input_mask = input_mask, input_type_ids
pooled_output, sequence_output = bert_layer([input_word_ids, input_mask, input_type_ids])

bert_model = Model(inputs=[input_word_ids, input_mask, input_type_ids], outputs=pooled_outp
```

```
WARNING:tensorflow:Please fix your imports. Module tensorflow.python.trainin
g.tracking.data_structures has been moved to tensorflow.python.trackable.dat
a_structures. The old module will be deleted in version 2.11.
```

In [41]:

```
bert_model.compile(optimizer="adam",loss="binary_crossentropy",metrics="accuracy")
```

In [42]:

```
#bert_model,bert_layer = create_model()
#bert_model.compile(optimizer=tf.keras.optimizers.Adam(learning_rate=1e-5),loss= tf.keras.l
bert_model.summary()
```

```
Model: "model"
__________________________________________________________________________________
_____________________
 Layer (type)                Output Shape              Param #     Connected t
o
==================================================================================
=====================
 input_word_ids (InputLayer)    [(None, 55)]         0           []

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

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

 keras_layer (KerasLayer)       [(None, 768),        109482241   ['input_wor
d_ids[0][0]',
                                 (None, 55, 768)]                 'input_mas
k[0][0]',
                                                                  'input_typ
e_ids[0][0]']

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

In [43]:

```
bert_model.input
```

Out[43]:

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

In [44]:

```
bert_model.output
```

Out[44]:

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

Part-3: Tokenization

In [45]:

```
# 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

label_list = [0,1] # Label categories
max_seq_length = 55  # maximum length of (token) input sequences
train_batch_size = 32

#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()

tokenizer = bert.bert_tokenization.FullTokenizer(vocab_file=vocab_file, do_lower_case=do_lo
```

Grader function 3

In [46]:

```
#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[46]:

```
True
```

In [ ]:

```
# maximum number of tokens is 55(We already given this to BERT layer above) so shape is (No
# 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_mas
# Create a segment input for train and test. We are using only one sentence so all zeros. T
```

In [47]:

```
def create_bert_inputs(input_data,tokenizer):

    input_tokens  = []
    input_mask    = []
    input_segment = []

    for reviews in input_data["Text"]:              # reviews = "[CLS]" + reviews + "[SEP]"
        tokens = tokenizer.tokenize(reviews)                 # split words in review
        if len(tokens) >= 54:                                # if length of sentence is
            tokens = tokens[:53]
        tokens = ['[CLS]',*tokens,'[SEP]']                   # add ['CLS'] to start and

        if len(tokens)<55:                           # if it is less than 55, add '[PAD]' to
            while len(tokens) < 55:                  # add the word ['PAD'] in remaining pla
                tokens.append('[PAD]')

        masked=[]
        for i in tokens:
            if i!='[PAD]':                           # fill mask_array with 0 in place of ['
                masked.append(1)
            else:
                masked.append(0)
        input_mask.append(masked)

        tokens = tokenizer.convert_tokens_to_ids(tokens)         # adding positional encodi
        input_tokens.append(tokens)

        segment = [0]*55                                         # since inputting only 1 s
        input_segment.append(segment)

    input_tokens  =  np.array(input_tokens)                      # type of all the above ar
    input_mask    =  np.array(input_mask)
    input_segment =  np.array(input_segment)

    return input_tokens,input_mask,input_segment
```

In [48]:

```
X_train_tokens,X_train_mask,X_train_segment = create_bert_inputs(X_train,tokenizer)  ## Tra

X_test_tokens,X_test_mask,X_test_segment    = create_bert_inputs(X_test,tokenizer)   ## Tes
```

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 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]
==================================================
```

In [49]:

```
import pickle
```

In [50]:

```
##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('train_d
pickle.dump((X_test, X_test_tokens, X_test_mask, X_test_segment, y_test),open('test_data.pk
```

In [51]:

```
#you can load from disk
# Create train and test tokens (X_train_tokens, X_test_tokens) from (X_train, X_test) using
# 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
X_train, X_train_tokens, X_train_mask, X_train_segment, y_train = pickle.load(open("train_d
X_test, X_test_tokens, X_test_mask, X_test_segment, y_test = pickle.load(open("test_data.pk
```

Grader function 4

In [52]:

```
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[1]=
        (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[0]

        no_sep = np.sum(X_train_tokens==tokenizer.vocab['[SEP]'])==X_train_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_train()
```

Out[52]:

```
True
```

Grader function 5

In [53]:

```
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]==m
        (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[53]:

```
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 [54]:

```
bert_model.input
```

Out[54]:

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

In [55]:

```
bert_model.output
```

Out[55]:

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

In [56]:

```
X_train_segment[:5]
```

Out[56]:

```
array([[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],
       [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],
       [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],
       [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],
       [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 [58]:

```
log_dir='tensorboard_data/tb_bert'
model_save_path='./models/bert_model.h5'

filepath="best_model.hdf5"
CheckPoint = ModelCheckpoint(filepath=model_save_path, monitor='val_accuracy',  verbose=1,

tb   = TensorBoard(log_dir=log_dir)

callbacks = [CheckPoint,tb]
```

In [59]:

```
# 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 connecti
#tokens_array,mask_array,segment_array = create_bert_inputs(input_data,tokenizer)
# Creating inputs for bert model
from sklearn.metrics import confusion_matrix,f1_score,classification_report

X_train_pooled_output = bert_model.predict([X_train_tokens, X_train_mask, X_train_segment],
X_train_pred_labels = X_train_pooled_output.argmax(axis=1)
```

```
2500/2500 [==============================] - 746s 297ms/step
```

In [60]:

```
# 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],batch_
X_test_pred_labels = X_test_pooled_output.argmax(axis=1)
```

```
625/625 [==============================] - 183s 294ms/step
```

In [62]:

```
##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 [63]:

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

In [68]:

```
X_train_pooled_output.shape, X_test_pooled_output.shape
```

Out[68]:

```
((80000, 768), (20000, 768))
```

In [69]:

```
len(y_train.shape), len(y_test.shape)
```

Out[69]:

```
(2, 2)
```

In [70]:

```
X_train_pooled_output
```

Out[70]:

```
array([[-0.900273  , -0.34739542, -0.9403269 , ..., -0.90477073,
        -0.65887487,  0.9167845 ],
       [-0.8217009 , -0.28934422, -0.8032384 , ..., -0.75571686,
        -0.66162056,  0.8885183 ],
       [-0.8107029 , -0.39052856, -0.86496013, ..., -0.81251943,
        -0.6491288 ,  0.89500415],
       ...,
       [-0.58643985, -0.44026846, -0.9627425 , ..., -0.8420664 ,
        -0.64556086,  0.7161623 ],
       [-0.51534706, -0.23186147, -0.9440779 , ..., -0.8851118 ,
        -0.5005765 ,  0.60448426],
       [-0.91460544, -0.5183219 , -0.8648384 , ..., -0.7172572 ,
        -0.75686437,  0.9463819 ]], dtype=float32)
```

In [73]:

```
X_train_tokens.shape
```

Out[73]:

```
(80000, 55)
```

In [74]:

```
X_train_mask.shape
```

Out[74]:

```
(80000, 55)
```

Grader function 6

In [75]:

```
y_train = np.squeeze(y_train)
y_test = np.squeeze(y_test)
```

In [76]:

```
#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[76]:

```
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 [81]:

```
!pip install pydot
!pip install graphviz
```

```
Requirement already satisfied: pydot in c:\users\sowjanya\anaconda3\envs\tf-
gpu\lib\site-packages (1.4.2)
Requirement already satisfied: pyparsing>=2.1.4 in c:\users\sowjanya\anacond
a3\envs\tf-gpu\lib\site-packages (from pydot) (3.0.9)
Requirement already satisfied: graphviz in c:\users\sowjanya\anaconda3\envs
\tf-gpu\lib\site-packages (0.20.1)
```

In [77]:

```
##imports
from tensorflow.keras.layers import Input, Dense, Activation, Dropout, LSTM
from tensorflow.keras.models import Model
```

In [78]:

```
from tensorflow.keras import regularizers
##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],))
##create an NN and
bert_emb = Input(shape=(768,),name="bert_emb")
x = Dense(256,activation="relu",kernel_initializer="he_normal",kernel_regularizer=regulariz
#x=Dropout(0.5)(x)
x = Dense(128,activation="relu",kernel_initializer="he_normal",kernel_regularizer=regulariz
#x=Dropout(0.4)(x)
x = Dense(64,activation="relu",kernel_initializer="he_normal",kernel_regularizer=regularize
#x=Dropout(0.3)(x)
x = Dense(32,activation="relu",kernel_initializer="he_normal",kernel_regularizer=regularize
output = Dense(2, activation='softmax', name='output')(x)
model = Model(inputs=[bert_emb],outputs=[output])
```

In [83]:

```
model.summary()
```

```
Model: "model_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 bert_emb (InputLayer)       [(None, 768)]             0

 dense (Dense)               (None, 256)               196864

 dense_1 (Dense)             (None, 128)               32896

 dense_2 (Dense)             (None, 64)                8256

 dense_3 (Dense)             (None, 32)                2080

 output (Dense)              (None, 2)                 66

=================================================================
Total params: 240,162
Trainable params: 240,162
Non-trainable params: 0
_________________________________________________________________
```

In [84]:

```
#Model Architechture:
#tf.keras.utils.plot_model(model,show_shapes=False, show_layer_names=True, rankdir='TB',exp
```

In [85]:

```
import tensorflow
from tensorflow.keras.callbacks import TensorBoard
from tensorflow.keras.callbacks import ModelCheckpoint
from sklearn.metrics import roc_auc_score
from tensorflow.keras.optimizers import Adam
import datetime
from tensorflow.keras.utils import to_categorical

## AUC score
def aucroc(y_true, y_pred):
    return tf.py_function(roc_auc_score, (y_true, y_pred), tf.double)

Y_train_ohe = to_categorical(y_train)  ## converting y_train and y_test to one hot encoded
Y_test_ohe = to_categorical(y_test)

## TENSORBOARD callback
tb = TensorBoard(log_dir='./Graph', histogram_freq=2,write_graph=True, write_images=True)
tb.set_model(model)

model.compile(loss='categorical_crossentropy',optimizer=Adam(learning_rate=0.001),metrics=[
```

In [86]:

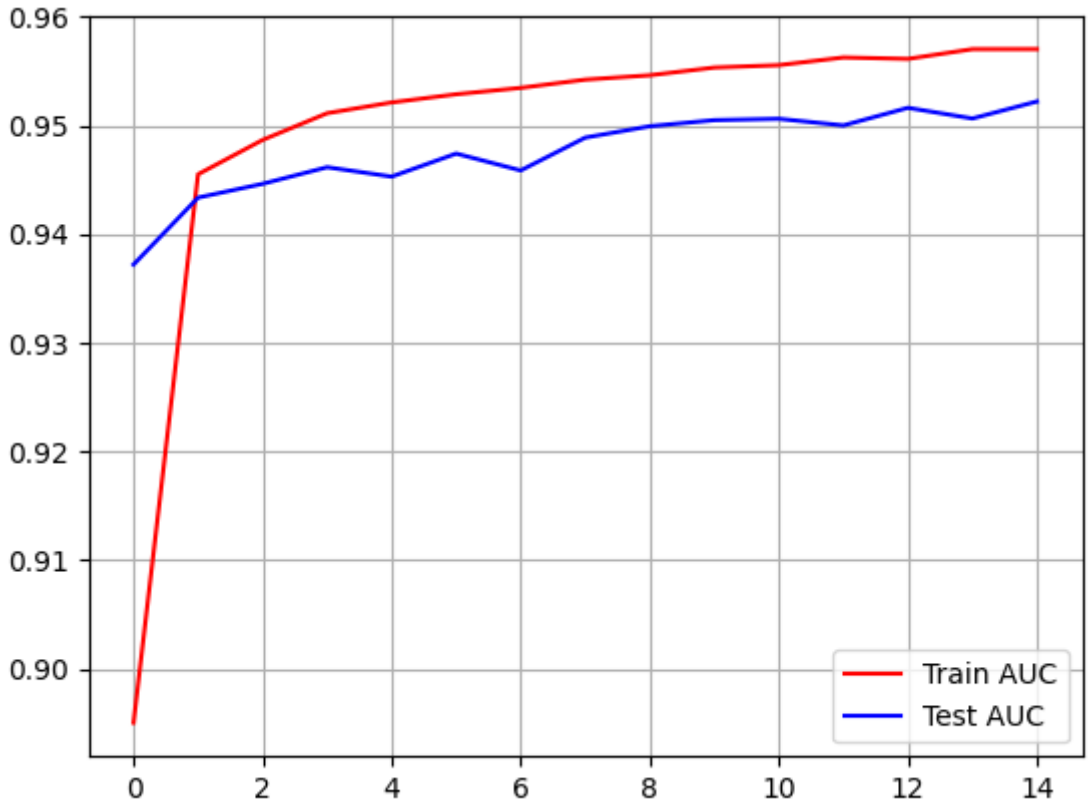
```
history = model.fit(X_train_pooled_output,Y_train_ohe,epochs=15,batch_size=150,validation_d
```

```
Epoch 1/15
534/534 [==============================] - 4s 7ms/step - loss: 0.6022 - a
ccuracy: 0.8931 - aucroc: 0.8950 - val_loss: 0.3863 - val_accuracy: 0.909
8 - val_aucroc: 0.9372
Epoch 2/15
534/534 [==============================] - 3s 6ms/step - loss: 0.3410 - a
ccuracy: 0.9140 - aucroc: 0.9455 - val_loss: 0.2953 - val_accuracy: 0.923
9 - val_aucroc: 0.9434
Epoch 3/15
534/534 [==============================] - 3s 6ms/step - loss: 0.3005 - a
ccuracy: 0.9149 - aucroc: 0.9487 - val_loss: 0.2821 - val_accuracy: 0.918
1 - val_aucroc: 0.9446
Epoch 4/15
534/534 [==============================] - 3s 6ms/step - loss: 0.2702 - a
ccuracy: 0.9183 - aucroc: 0.9511 - val_loss: 0.2675 - val_accuracy: 0.918
8 - val_aucroc: 0.9462
Epoch 5/15
534/534 [==============================] - 4s 7ms/step - loss: 0.2564 - a
ccuracy: 0.9193 - aucroc: 0.9521 - val_loss: 0.2420 - val_accuracy: 0.924
1 - val_aucroc: 0.9453
Epoch 6/15
534/534 [==============================] - 3s 6ms/step - loss: 0.2418 - a
ccuracy: 0.9222 - aucroc: 0.9529 - val_loss: 0.2398 - val_accuracy: 0.922
3 - val_aucroc: 0.9474
Epoch 7/15
534/534 [==============================] - 4s 7ms/step - loss: 0.2349 - a
ccuracy: 0.9225 - aucroc: 0.9535 - val_loss: 0.2656 - val_accuracy: 0.909
5 - val_aucroc: 0.9459
Epoch 8/15
534/534 [==============================] - 4s 7ms/step - loss: 0.2302 - a
ccuracy: 0.9216 - aucroc: 0.9542 - val_loss: 0.2197 - val_accuracy: 0.926
1 - val_aucroc: 0.9489
Epoch 9/15
534/534 [==============================] - 3s 6ms/step - loss: 0.2201 - a
ccuracy: 0.9254 - aucroc: 0.9546 - val_loss: 0.2122 - val_accuracy: 0.928
7 - val_aucroc: 0.9499
Epoch 10/15
534/534 [==============================] - 3s 6ms/step - loss: 0.2206 - a
ccuracy: 0.9233 - aucroc: 0.9553 - val_loss: 0.2130 - val_accuracy: 0.927
3 - val_aucroc: 0.9505
Epoch 11/15
534/534 [==============================] - 4s 7ms/step - loss: 0.2154 - a
ccuracy: 0.9238 - aucroc: 0.9556 - val_loss: 0.2148 - val_accuracy: 0.929
8 - val_aucroc: 0.9506
Epoch 12/15
534/534 [==============================] - 4s 7ms/step - loss: 0.2072 - a
ccuracy: 0.9266 - aucroc: 0.9563 - val_loss: 0.2031 - val_accuracy: 0.927
9 - val_aucroc: 0.9500
Epoch 13/15
534/534 [==============================] - 4s 7ms/step - loss: 0.2107 - a
ccuracy: 0.9245 - aucroc: 0.9561 - val_loss: 0.1993 - val_accuracy: 0.930
7 - val_aucroc: 0.9516
Epoch 14/15
534/534 [==============================] - 3s 6ms/step - loss: 0.2053 - a
ccuracy: 0.9255 - aucroc: 0.9570 - val_loss: 0.2326 - val_accuracy: 0.913
```

```
2 - val_aucroc: 0.9506
Epoch 15/15
534/534 [==============================] - 3s 6ms/step - loss: 0.2040 - a
ccuracy: 0.9263 - aucroc: 0.9570 - val_loss: 0.2045 - val_accuracy: 0.925
7 - val_aucroc: 0.9522
```

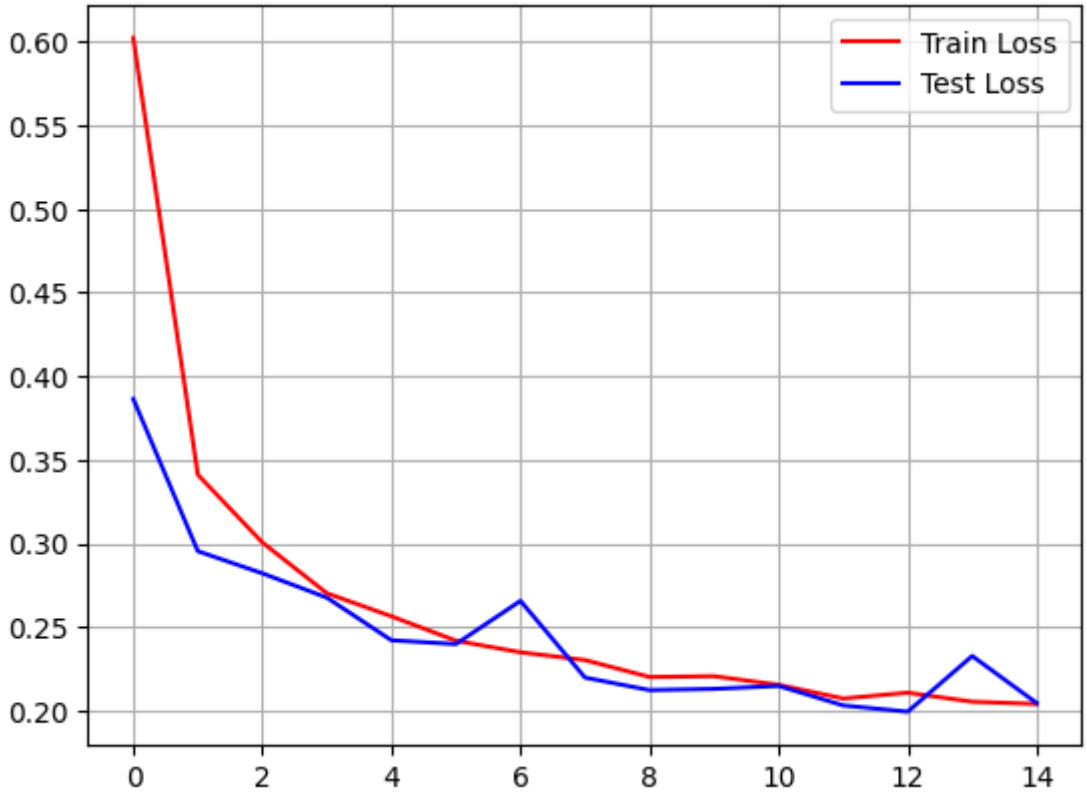
In [87]:

```
from matplotlib import pyplot as plt
plt.plot(history.history['aucroc'], 'r')
plt.plot(history.history['val_aucroc'], 'b')
plt.legend({'Train AUC': 'r', 'Test AUC':'g'})
plt.grid()
plt.show()
```



In [88]:

```
plt.plot(history.history['loss'], 'r')
plt.plot(history.history['val_loss'], 'b')
plt.legend({'Train Loss': 'r', 'Test Loss':'g'})
plt.grid()
plt.show()
```



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 (https://drive.google.com/file/d/1Qwjq TsqTX2vdy7fTmeXjxP3dq8IAVLpo/view?usp=sharing)

In [ ]:

```
#there is an alterante way to load files from Google drive directly to your Colab session
# 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 # from
```

In [89]:

```
#read the csv file
test_df= pd.read_csv('test.csv')
```

In [94]:

```
test_df.head()
```

Out[94]:

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

1. You have to write a function that takes the test_df,trained model and the required parameters as input.
2. 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)
3. Predit the output of X_test with the neural network model which we trained earlier.

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

In [90]:

```
def Test_data_embedding(input_data, model, tokenizer):

    input_data.dropna(subset = ["Text"], inplace=True)                                  # r
    input_data['Text'] = input_data['Text'].str.replace(r'<[^<>]*>', '', regex=True)    # r

    tokens_array,mask_array,segment_array = create_bert_inputs(input_data,tokenizer)    # C

    X_test = model.predict([tokens_array,mask_array,segment_array])                     # E
    print('Shape of X_test after embedding using BERT model :',X_test.shape)

    return X_test
```

In [91]:

```
X_test = Test_data_embedding(test_df, bert_model, tokenizer)
```

```
11/11 [==============================] - 3s 287ms/step
Shape of X_test after embedding using BERT model : (352, 768)
```

In [92]:

```
# predicting class label from previously for previous model
prediction = model.predict(X_test)
predicted_y = prediction.argmax(axis=-1)
```

```
11/11 [==============================] - 0s 4ms/step
```

In [93]:

```
test_df['predicted_y'] = predicted_y
test_df.head(5)
```

Out[93]:

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

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

```
From the above dataframe, for each text review the corresponding class label/sentiment
score is provided and from observing the above given 5 observations.

The prediction was made using the previously trained neural network model.
```

In this assignmet,the BERT uncased model model was used.

The Steps for predicting the class labels are :

In the Preprocessing step the input dataset was performed,followed by splitting to train and test dataset.

Then the BERT uncased model was downloaded from tensorflow HUB and the model was createed.

The BERT model needs 3 inputs : word_ids/tokens, input mask and segment_ids.The maximum size allowed for all these 3 inputs is 55. If the length of input was less than 55 padding was performed and if the length of input was greater than 55 truncation was performed

The tokens were created using the tokenizer module which has functions for converting words to tokens and for positional encoding.

The mask input was created by filling 0s to the places that were padded(represented by 'PAD') and 1s to the other places.

The segment_ids were made to all zeros as here we are giving only one sentence at a time.

Then Embedding was obtained by giving these 3 inputs to the BERT model. The output was of 768 dimension.

Then a simple neural network was created with the embedding vector given as the input and it was trained with 15 epochs.

The model gave an a test accuracy of 0.9257 and test AUC score of 0.9522.

Then the test dataset 'test_df' was provided.

While creating data pipeline above process was repeated with in a function. It was preprocessed, inputs for BERT model were created and embedding was obtained. after that previously trained neural network model to predict the sentiment scores for the reviews.