Building a Smarter AI powered spam classifier

TEAM SPARROW

OVERVIEW:

In this project, we will be covering a simple approach to email classification(spam or not spam) using BERT

Steps are:

- We will load our data - mainly sentences and labels-span or not spam
- Load these in bert to generate an contextualized embedding vector of length 768
-
  - We will first apply preprocessing using the preprocessor object , refer the documentation
-
  - We will pass this preprocessed text to our model to generate the contexutailized embedding vector
- Finally pass this embedding vector to single neuron in output to do binary classificaton
- For maximizing performance we will be balancing our dataset and use a dropout layer to regularize the model and prevent overfitting

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

```
Drive already mounted at /content/drive; to attempt to forcibly
remount, call drive.mount("/content/drive", force_remount=True).
```

Loading Dependencies

Includes

- Tensorflow_hub : Place where all tenseorflow pretrained models are stored.
- Pandas : For data loading, manipulation and wrangling.
- Tensorflow_text : Allows addditional NLP text processing capablities outside scope of tensorflow
- Skelarn : For doing data evaluation and splitting
- Matplotlib : For visualization

```
# installing tensorflow_text
!pip install tensorflow-text
```

```
Collecting tensorflow-text
  Downloading tensorflow_text-2.14.0-cp310-cp310-
manylinux_2_17_x86_64.manylinux2014_x86_64.whl (6.5 MB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 6.5/6.5 MB 50.1 MB/s eta
0:00:00
ent already satisfied: tensorflow-hub>=0.13.0 in
/usr/local/lib/python3.10/dist-packages (from tensorflow-text)
(0.15.0)
Requirement already satisfied: tensorflow<2.15,>=2.14.0 in
/usr/local/lib/python3.10/dist-packages (from tensorflow-text)
(2.14.0)
Requirement already satisfied: absl-py>=1.0.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (1.4.0)
Requirement already satisfied: astunparse>=1.6.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (1.6.3)
Requirement already satisfied: flatbuffers>=23.5.26 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (23.5.26)
Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1
in /usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (0.5.4)
Requirement already satisfied: google-pasta>=0.1.1 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (0.2.0)
Requirement already satisfied: h5py>=2.9.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (3.9.0)
Requirement already satisfied: libclang>=13.0.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (16.0.6)
Requirement already satisfied: ml-dtypes==0.2.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (0.2.0)
Requirement already satisfied: numpy>=1.23.5 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (1.23.5)
Requirement already satisfied: opt-einsum>=2.3.2 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (3.3.0)
Requirement already satisfied: packaging in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (23.2)
Requirement already satisfied: protobuf!=4.21.0,!=4.21.1,!=4.21.2,!
=4.21.3,!=4.21.4,!=4.21.5,<5.0.0dev,>=3.20.3 in
/usr/local/lib/python3.10/dist-packages (from
```

```
tensorflow<2.15,>=2.14.0->tensorflow-text) (3.20.3)
Requirement already satisfied: setuptools in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (67.7.2)
Requirement already satisfied: six>=1.12.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (1.16.0)
Requirement already satisfied: termcolor>=1.1.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (2.3.0)
Requirement already satisfied: typing-extensions>=3.6.6 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (4.5.0)
Requirement already satisfied: wrapt<1.15,>=1.11.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (1.14.1)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (0.34.0)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (1.59.0)
Requirement already satisfied: tensorboard<2.15,>=2.14 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (2.14.1)
Requirement already satisfied: tensorflow-estimator<2.15,>=2.14.0
in /usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (2.14.0)
Requirement already satisfied: keras<2.15,>=2.14.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorflow<2.15,>=2.14.0->tensorflow-text) (2.14.0)
Requirement already satisfied: wheel<1.0,>=0.23.0 in
/usr/local/lib/python3.10/dist-packages (from astunparse>=1.6.0-
>tensorflow<2.15,>=2.14.0->tensorflow-text) (0.41.2)
Requirement already satisfied: google-auth<3,>=1.6.3 in
/usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14-
>tensorflow<2.15,>=2.14.0->tensorflow-text) (2.17.3)
Requirement already satisfied: google-auth-oauthlib<1.1,>=0.5 in
/usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14-
>tensorflow<2.15,>=2.14.0->tensorflow-text) (1.0.0)
Requirement already satisfied: markdown>=2.6.8 in
/usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14-
>tensorflow<2.15,>=2.14.0->tensorflow-text) (3.5)
Requirement already satisfied: requests<3,>=2.21.0 in
/usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14-
>tensorflow<2.15,>=2.14.0->tensorflow-text) (2.31.0)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0
in /usr/local/lib/python3.10/dist-packages (from
tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
```

```
(0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in
/usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14-
>tensorflow<2.15,>=2.14.0->tensorflow-text) (3.0.1)
Requirement already satisfied: cachetools<6.0,>=2.0.0 in
/usr/local/lib/python3.10/dist-packages (from google-auth<3,>=1.6.3-
>tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
(5.3.2)
Requirement already satisfied: pyasn1-modules>=0.2.1 in
/usr/local/lib/python3.10/dist-packages (from google-auth<3,>=1.6.3-
>tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
(0.3.0)
Requirement already satisfied: rsa<5,>=3.1.4 in
/usr/local/lib/python3.10/dist-packages (from google-auth<3,>=1.6.3-
>tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
(4.9)
Requirement already satisfied: requests-oauthlib>=0.7.0 in
/usr/local/lib/python3.10/dist-packages (from google-auth-
oauthlib<1.1,>=0.5->tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0-
>tensorflow-text) (1.3.1)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from requests<3,>=2.21.0-
>tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
(3.3.1)
Requirement already satisfied: idna<4,>=2.5 in
/usr/local/lib/python3.10/dist-packages (from requests<3,>=2.21.0-
>tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
(3.4)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.10/dist-packages (from requests<3,>=2.21.0-
>tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
(2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.10/dist-packages (from requests<3,>=2.21.0-
>tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
(2023.7.22)
Requirement already satisfied: MarkupSafe>=2.1.1 in
/usr/local/lib/python3.10/dist-packages (from werkzeug>=1.0.1-
>tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
(2.1.3)
Requirement already satisfied: pyasn1<0.6.0,>=0.4.6 in
/usr/local/lib/python3.10/dist-packages (from pyasn1-modules>=0.2.1-
>google-auth<3,>=1.6.3->tensorboard<2.15,>=2.14-
>tensorflow<2.15,>=2.14.0->tensorflow-text) (0.5.0)
Requirement already satisfied: oauthlib>=3.0.0 in
/usr/local/lib/python3.10/dist-packages (from requests-
oauthlib>=0.7.0->google-auth-oauthlib<1.1,>=0.5-
>tensorboard<2.15,>=2.14->tensorflow<2.15,>=2.14.0->tensorflow-text)
(3.2.2)
```

```
Installing collected packages: tensorflow-text
Successfully installed tensorflow-text-2.14.0
```

```
import tensorflow_hub as hub
import pandas as pd
import tensorflow_text as text
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
import numpy as np
```

Loading Data

- Read Data
- Display data USING PANDAS

```
# load data
df = pd.read_csv('/content/drive/MyDrive/CLG _VK_18_/spam_data.csv')

df.head()
```

```
  Category                                            Message
0      ham  Go until jurong point, crazy.. Available only ...
1      ham                      Ok lar... Joking wif u oni...
2     spam  Free entry in 2 a wkly comp to win FA Cup fina...
3      ham  U dun say so early hor... U c already then say...
4      ham  Nah I don't think he goes to usf, he lives aro...
```

Data Analysis

- Check the description by grouping by category :
- no of data points for each category - count
- no of unique values in each category - unique

```
# check count and unique and top values and their frequency
df['Category'].value_counts()
```

```
ham     4825
spam     747
Name: Category, dtype: int64
```

Clearly dataset is imbalanced - not so much but still it can affect our model. Need to use some type of regulariztion like downsampling dataset for mazority class

Downsampling Dataset

Includes:

- Check percentage of unbalances.
- Creating 2 new dataframes out of existing one.
- Taking any random minority no of samples - `(747)` for majority class `(4825)`.
- Creating a balanced dataset by concating 2 new data frames.

```
# check percentange of data - states how much data needs to be
balanced
str(round(747/4825,2))+'%'
```

```
{"type":"string"}
```

```
# creating 2 new dataframe as df_ham , df_spam

df_spam = df[df['Category']=='spam']
print("Spam Dataset Shape:", df_spam.shape)

df_ham = df[df['Category']=='ham']
print("Ham Dataset Shape:", df_ham.shape)
```

```
Spam Dataset Shape: (747, 2)
Ham Dataset Shape: (4825, 2)
```

```
# downsampling ham dataset - take only random 747 example
# will use df_spam.shape[0] - 747

df_ham_downsampled = df_ham.sample(df_spam.shape[0])
df_ham_downsampled.shape
```

```
(747, 2)
```

```
# concating both dataset - df_spam and df_ham_balanced to create
df_balanced dataset
df_balanced = pd.concat([df_spam , df_ham_downsampled])
df_balanced.head()
```

```
   Category                                                Message
2      spam  Free entry in 2 a wkly comp to win FA Cup fina...
5      spam  FreeMsg Hey there darling it's been 3 week's n...
8      spam  WINNER!! As a valued network customer you have...
9      spam  Had your mobile 11 months or more? U R entitle...
11     spam  SIX chances to win CASH! From 100 to 20,000 po...
```

```
df_balanced['Category'].value_counts()
```

```
spam    747
ham     747
Name: Category, dtype: int64
```

```
df_balanced.sample(10)
```

```
     Category                                                Message
5041     spam  Natalie (20/F) is inviting you to be her frien...
```

```
3713      ham                                  Wat u doing there?
1172     spam  Got what it takes 2 take part in the WRC Rally...
1217     spam  You have 1 new voicemail. Please call 08719181...
403       ham                The hair cream has not been shipped.
4863     spam  **FREE MESSAGE**Thanks for using the Auction S...
2503      ham  Ola would get back to you maybe not today but ...
5267      ham       Anything lar then ü not going home 4 dinner?
2719     spam  18 days to Euro2004 kickoff! U will be kept in...
3678      ham        Great! So what attracts you to the brothas?
```

Data Prepration

1. Create Numerical Repersentation Of Category - One hot encoding

- Create a new column
- Use `df[col].apply(lambda function)`
- Lambda Function - if spam return 1, else return 0 (for ham) - ternary operators : [`lambda x : value expression else value`]

```
# creating numerical repersentation of category - one hot encoding
df_balanced['spam'] = df_balanced['Category'].apply(lambda x:1 if
x=='spam' else 0)

# displaying data - spam -1 , ham-0
df_balanced.sample(4)
```

```
     Category                                            Message  spam
928       ham                K:)i will give my kvb acc details:)     0
435       ham  You available now? I'm like right around hills...     0
2760      ham  Can meh? Thgt some will clash... Really ah, i ...     0
4682      ham                          Are you staying in town ?     0
```

1. Do train-test split

- split dataset into 80-20 ratio with 80% train and remaing as test
- for eveness of data we will use `stratify` agrument which ensures same ratio of both category is loaded for each case, even if one categoy has more training samples - prevents overfitting

Store our data in:

- `X_train, y_train` - traininge set(training_data and labels respectively)
- `X_test,, y_test` - testing set(testing_data and labels)

```
# loading train test split
from sklearn.model_selection import train_test_split

X_train, X_test , y_train, y_test =
train_test_split(df_balanced['Message'], df_balanced['spam'],
```

```
                                                    stratify =
df_balanced['spam'])

# check for startification
y_train.value_counts()
```

```
1    560
0    560
Name: spam, dtype: int64
```

```
560/560
```

```
1.0
```

```
y_test.value_counts()
```

```
1    187
0    187
Name: spam, dtype: int64
```

```
187/187
```

```
1.0
```

-> Almost similar, means data is downsampled now

Model Creation

Our Model is BERT , which will do 2 thing:

- Preporcess our training data that will be feeded - includes **adding additional token CLF , PAD and SEP** to genrate `input_mask`, `input_type_ids`, `input_word_ids(token given to each word in  sentences)`
- Note: no of words in sentence - 128/ max length of sentence can be 128

Downloading BERT

Model specification :

- Layers - 12
- Hidden layers - 768 - embedding size
- Attention - 12 Name - Bert Small --- This model has 2 parts:
- Bert_preprocessor - preprocess the text to be BERT ready
- Bert_encoder - do the actual encoding
  Steps:

Preprocessor

- create a keras hub layer from the preprocessing url

Encoder

- create a keras hub layer from the encoder/ model url

Awesome functionality provided by Tf hub API

```
                                +
```

Creating our own model using functional model api- link old layers to new layers rather than building it(in a sequential way) and allows sharing of layers too

Info:

- Text the embedding as input - text_input
- Create a Sinlge output dense layer
- Add dropout to reduce overfitting

```
# downloading preprocessing files and model
bert_preprocessor =
hub.KerasLayer('https://tfhub.dev/tensorflow/bert_en_uncased_preproces
s/3')
bert_encoder =
hub.KerasLayer('https://tfhub.dev/tensorflow/bert_en_uncased_L-12_H-
768_A-12/4')
```

Process And Encode Data

Use functional API to process and encode data in the layers itself

- Create a input layers with shape() , type - tf.string, and layer name - text - `TEXT_INPUT`
- Pass TEXT_INPUT into bert_prerocessor - `PREPROCESSED TEXT[*]`
- Pass the above[*] to encoder - `EMBEED`
- pass pooled_outputs of EMBEED to dropout layer - `DROPOUT`
- create a dense layer with activation as `sigmoid` `OUTPUTS`
- Create out MODEL (inputs - text_input, outputs - dropout)

```
import tensorflow as tf

text_input = tf.keras.layers.Input(shape = (), dtype = tf.string, name
= 'Inputs')
preprocessed_text = bert_preprocessor(text_input)
embeed = bert_encoder(preprocessed_text)
```

```
dropout = tf.keras.layers.Dropout(0.1, name = 'Dropout')
(embeed['pooled_output'])
outputs = tf.keras.layers.Dense(1, activation = 'sigmoid', name =
'Dense')(dropout)

# creating final model
model = tf.keras.Model(inputs = [text_input], outputs = [outputs])

# check summary of model
model.summary()
```

```
Model: "model_2"
__________________________________________________________________________
_______________________
 Layer (type)                Output Shape              Param #
Connected to
==========================================================================
===========================
 Inputs (InputLayer)         [(None,)]                 0         []


 keras_layer_2 (KerasLayer)  {'input_type_ids': (None,    0
['Inputs[0][0]']
                             128),
                              'input_mask': (None, 128)
                             , 'input_word_ids': (None,
                              128)}


 keras_layer_3 (KerasLayer)  {'encoder_outputs': [(None   1094822
['keras_layer_2[0][0]',
                             , 128, 768),                41
'keras_layer_2[0][1]',
                              (None, 128, 768),
'keras_layer_2[0][2]']
                              (None, 128, 768),
                              (None, 128, 768),
                              (None, 128, 768),
                              (None, 128, 768),
                              (None, 128, 768),
                              (None, 128, 768),
```

```
                                (None, 128, 768),
                                (None, 128, 768),
                                (None, 128, 768),
                                (None, 128, 768)],
                                'default': (None, 768),
                                'sequence_output': (None,
                                128, 768),
                                'pooled_output': (None, 7
                               68)}


 Dropout (Dropout)           (None, 768)                  0
['keras_layer_3[0][13]']


 Dense (Dense)               (None, 1)                    769
['Dropout[0][0]']


==================================================================
============================
Total params: 109483010 (417.64 MB)
Trainable params: 769 (3.00 KB)
Non-trainable params: 109482241 (417.64 MB)
__________________________________________________________________
__________________________
```

Compiling model

- Optimizer - ADAM
- Loss - binary_crossentropy
- metrics - accuracy , precesion and recall

```
Metrics = [tf.keras.metrics.BinaryAccuracy(name = 'accuracy'),
           tf.keras.metrics.Precision(name = 'precision'),
           tf.keras.metrics.Recall(name = 'recall')
           ]

model.compile(optimizer ='adam',
              loss = 'binary_crossentropy',
              metrics = Metrics)
```

```
#@title Optional
# optional - defining tensorflow callbacks
import tensorflow as tf
import datetime
%load_ext tensorboard

!rm -rf ./logs/
log_dir = "logs/fit/" + datetime.datetime.now().strftime("%Y%m%d-%H%M
%S")
tensorboard_callback=tf.keras.callbacks.TensorBoard(log_dir=log_dir,
histogram_freq=1)
```

```
The tensorboard extension is already loaded. To reload it, use:
  %reload_ext tensorboard
```

Training Model

- Recomended to use `GPU` - providing so many training data
- We traing our model on training set
- For 10 epochs only - so model don't overfit - given enough training data

```
%tensorboard --logdir logs/fit
```

```
Reusing TensorBoard on port 6006 (pid 3229), started 1:03:18 ago. (Use
'!kill 3229' to kill it.)
```

```
<IPython.core.display.Javascript object>
```

```
history = model.fit(X_train, y_train, epochs = 10 , callbacks =
[tensorboard_callback])
```

```
Epoch 1/10
35/35 [==============================] - 48s 1s/step - loss: 0.6358 -
accuracy: 0.6500 - precision: 0.6567 - recall: 0.6286
Epoch 2/10
35/35 [==============================] - 38s 1s/step - loss: 0.4922 -
accuracy: 0.8286 - precision: 0.8345 - recall: 0.8196
Epoch 3/10
35/35 [==============================] - 37s 1s/step - loss: 0.4205 -
accuracy: 0.8607 - precision: 0.8435 - recall: 0.8857
Epoch 4/10
35/35 [==============================] - 38s 1s/step - loss: 0.3736 -
accuracy: 0.8768 - precision: 0.8728 - recall: 0.8821
Epoch 5/10
35/35 [==============================] - 38s 1s/step - loss: 0.3400 -
accuracy: 0.8955 - precision: 0.8866 - recall: 0.9071
Epoch 6/10
35/35 [==============================] - 37s 1s/step - loss: 0.3129 -
accuracy: 0.8991 - precision: 0.8914 - recall: 0.9089
```

```
Epoch 7/10
35/35 [==============================] - 38s 1s/step - loss: 0.2966 -
accuracy: 0.9045 - precision: 0.9009 - recall: 0.9089
Epoch 8/10
35/35 [==============================] - 39s 1s/step - loss: 0.2790 -
accuracy: 0.9143 - precision: 0.9042 - recall: 0.9268
Epoch 9/10
35/35 [==============================] - 37s 1s/step - loss: 0.2674 -
accuracy: 0.9134 - precision: 0.9069 - recall: 0.9214
Epoch 10/10
35/35 [==============================] - 38s 1s/step - loss: 0.2560 -
accuracy: 0.9116 - precision: 0.9109 - recall: 0.9125
```

Model Evaluation

- Evaulating model performance using `model.evaluate(X_test, y_test)`
- Predicting X_test - `y_pred` -- Checking its values as 1 or 0
- Getting Confusion matrix -- Flattening y_pred -- Ploting consufion matrix
- Getting classification report

```
# Evaluating performace
model.evaluate(X_test,y_test)
```

```
12/12 [==============================] - 5s 359ms/step - loss: 0.2729
- accuracy: 0.9198 - precision: 0.9026 - recall: 0.9412

[0.272863507270813, 0.9197860956192017, 0.9025641083717346,
0.9411764740943909]
```

```
# getting y_pred by predicting over X_text and flattening it
y_pred = model.predict(X_test)
y_pred = y_pred.flatten() # require to be in one dimensional array ,
for easy maniputation
```

```
12/12 [==============================] - 4s 335ms/step
```

```
# checking the results y_pred
import numpy as np

y_pred = np.where(y_pred>0.5,1,0 )
y_pred
```

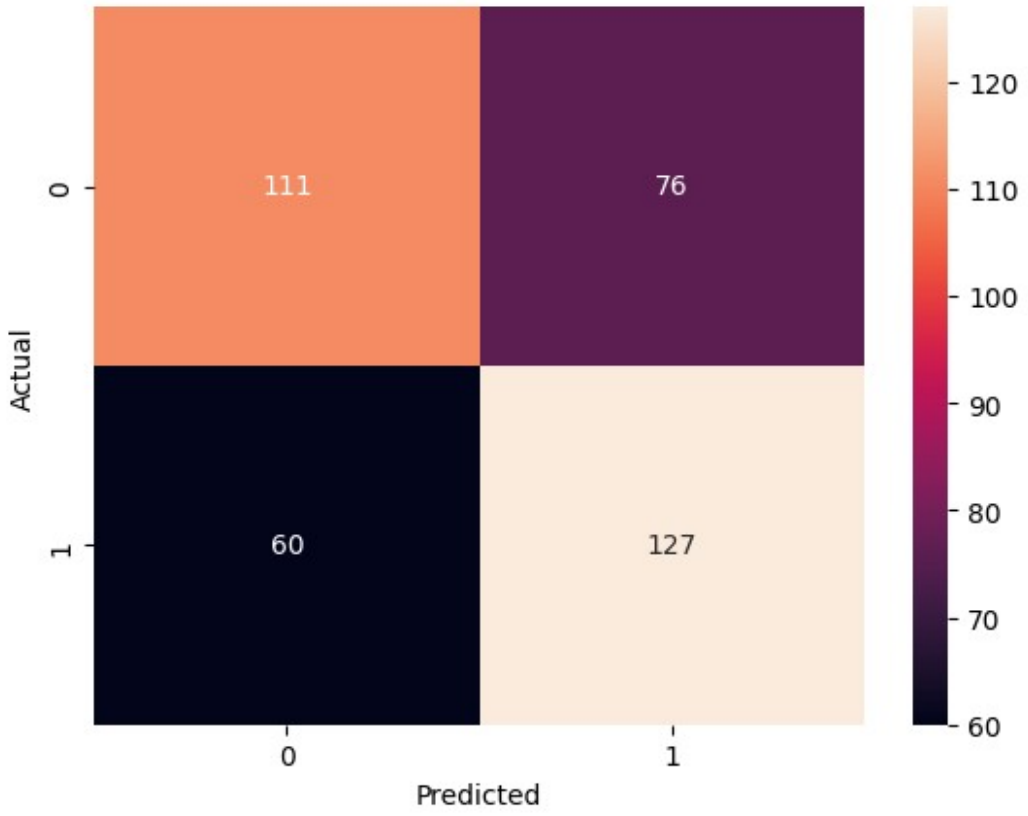
```
array([1, 1, 1, 0, 1, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 0, 0, 1, 1, 0, 0,
0,
       0, 0, 1, 1, 0, 0, 0, 1, 1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1,
1,
```

```
       1, 1, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 1, 0, 1, 0, 1, 1, 1,
1,
       0, 0, 1, 1, 1, 0, 1, 0, 0, 0, 1, 1, 1, 0, 1, 0, 0, 1, 1, 0, 0,
1,
       0, 0, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 1, 1, 1, 0, 0, 1,
1,
       1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0, 1, 1,
1,
       0, 1, 0, 1, 0, 0, 0, 1, 0, 1, 0, 1, 1, 0, 1, 0, 0, 0, 0, 1, 0,
0,
       1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 0, 0, 0, 1, 0, 1, 1, 0, 0, 0,
1,
       1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0, 1, 1,
1,
       0, 1, 0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1,
0,
       0, 0, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1, 0, 0, 1, 1, 1, 0, 0, 0,
1,
       1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 1, 0, 0, 0,
1,
       0, 1, 1, 0, 0, 1, 0, 1, 0, 1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 1, 0,
1,
       1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0, 1, 0, 1, 0,
0,
       1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 0, 1,
0,
       1, 0, 0, 1, 1, 0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 1, 0, 0,
0,
       0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 1, 1, 1, 0, 1, 0, 0, 0, 1, 1, 0,
1])
```

Not so understandable so plotting confusion matrix and classification report for good visualization

```
# importing consfusion maxtrix
from sklearn.metrics import confusion_matrix , classification_report

# creating confusion matrix
cm = confusion_matrix(y_test,y_pred)
cm

array([[168,  19],
       [ 11, 176]])

# plotting as graph - importing seaborn
import seaborn as sns

# creating a graph out of confusion matrix
sns.heatmap(cm, annot = True, fmt = 'd')
```

```
plt.xlabel('Predicted')
plt.ylabel('Actual')

Text(50.722222222222214, 0.5, 'Actual')
```




```
# printing classification report
print(classification_report(y_test , y_pred))
```

```
              precision    recall  f1-score   support

           0       0.94      0.90      0.92       187
           1       0.90      0.94      0.92       187

    accuracy                           0.92       374
   macro avg       0.92      0.92      0.92       374
weighted avg       0.92      0.92      0.92       374
```

Good Precesion And Recall Score, but can be improved

Model Prediction

- We will be predicting data on text coprus, value > 5 is most likely be `spam`

```
predict_text = [
                # Spam
                'URGENT! You have won a 1 week FREE membership in our
£100,000 Prize Jackpot! Txt the word: CLAIM to No: 81010 T&C
www.dbuk.net LCCLTD POBOX 4403LDNW1A7RW18',
                'WINNER!! As a valued network customer you have been
selected to receivea £900 prize reward! To claim call 09061701461.
Claim code KL341. Valid 12 hours only.',
                'England v Macedonia - dont miss the goals/team news.
Txt ur national team to 87077 eg ENGLAND to 87077 Try:WALES, SCOTLAND
4txt/ú1.20 POBOXox36504W45WQ 16+',

                #ham
                'U still going to the mall?',
                'Haha awesome, be there in a minute.',
                'Shit that is really shocking and scary, cant imagine
for a second. Def up for night out. Do u think there is somewhere i
could crash for night, save on taxi?'
]

test_results = model.predict(predict_text)
```

```
1/1 [==============================] - 1s 799ms/step
```

```
output = np.where(test_results>0.5,'spam', 'ham')

output
```

```
array([['spam'],
       ['spam'],
       ['spam'],
       ['ham'],
       ['ham'],
       ['ham']], dtype='<U4')
```

Additional Content

- Create a function which will take in `sentece array` and return the embedding vector for entire sentece - `pooled_output`

  STEPS: To do so inside the we follow 3 steps:

1. We `pass the sentence array to bert_preprocessor` as it can act a function point and name it **preprocessed_text**
2. Now we `pass this preprocessed sentence into encoder` and it return a embedding vector dictonary

3. We retun only the `pooled output` as we are interested in only the entire sentence encoding

---

Later we compare the embedding vector using `cosine - similarity from sklearn.metrics.parwiase` class

```
def get_embedding(sentence_arr):
    'takes in sentence array and return embedding vector'
    preprocessed_text = bert_preprocessor(sentence_arr)
    embeddings = bert_encoder(preprocessed_text)['pooled_output']
    return embeddings

e = get_embedding([
                'We'd all like to get a $10,000 deposit on our bank
accounts out of the blue, but winning a prize—especially if you've
never entered a contest',
                'The image you sent is a UI bug, I can check that your
article is marked as regular and is not in the monetization program.'
])



# load similartiy score
from sklearn.metrics.pairwise import cosine_similarity

# check similarity score
print(f'Similarity score between 1st sentence(spam) and second
sentence(spam) : {cosine_similarity([e[0]] , [e[1]])}')
```

```
Similarity score between 1st sentence(spam) and second
sentence(spam) : [[0.853919]]
```

- Not exact similarity, may show un expected results as can be seen - they are somewhat similar but its false as spam and actual can't be same