PHASE 4

SENTIMENT ANALYSIS FOR MARKETING

MEMBERS

- SOUNDHAR BALAJI.B
- RADHIKA.M
- ROHANSHAJ.K.R
- VIGNESH.V
- NELSON JOSEPH.M

INTRODUCTION:

- In the realm of natural language processing and sentiment analysis, the journey to extract meaningful insights from text data commences with the critical steps of loading and preprocessing the dataset. These initial stages serve as the foundation upon which the entire sentiment analysis solution is built.{BERT}

- Loading the dataset is akin to unearthing a treasure trove of textual information. It is the act of retrieving the raw data that will be the lifeblood of your analysis. The source could be diverse - from social media posts, customer reviews, or any corpus of text that holds the sentiment of interest.

- However, raw text data is rarely ready for analysis in its pristine form. Preprocessing is the transformative process that makes the data amenable to machine learning and natural language processing algorithms. It involves a series of steps like text cleaning, tokenization, removing stop words, stemming, and lemmatization. This ensures that the data is standardized, uniform, and free from noise, thus enhancing the quality of insights derived.

- In this part of the project, we will delve into the crucial tasks of loading the dataset, understanding its structure, and undertaking the necessary preprocessing steps. This groundwork sets the stage for subsequent phases, including feature engineering, model development, and sentiment analysis. With a well-prepared dataset, the journey towards understanding and harnessing sentiment within the textual data can begin.

TASK:

Phase 4: Development Part 2

In this part you will continue building your project.
Continue building the sentiment analysis solution by:

- Employing NLP techniques
- Generating insights.

DATASET :https://www.kaggle.com/datasets/crowdflower/twitter-airline-sentiment

NOTEBOOK LINK :https://colab.research.google.com/drive/19yAguvwdFVJv9GEz8b-Q3O280pzWMfLS

In [74]:
```
pip install emoji
```

```
Requirement already satisfied: emoji in /usr/local/lib/python3.10/dist-packages (2.8.0)
```

In [75]:
```
!pip install transformers
```

```
Requirement already satisfied: transformers in /usr/local/lib/python3.10/dist-packages (4.34.1)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-packages (from transformers) (3.12.4)
Requirement already satisfied: huggingface-hub<1.0,>=0.16.4 in /usr/local/lib/python3.10/dist-packages (from transformers) (0.17.3)
Requirement already satisfied: numpy>=1.17 in /usr/local/lib/python3.10/dist-packages (from transformers) (1.23.5)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.10/dist-packages (from transformers) (23.2)
Requirement already satisfied: pyyaml>=5.1 in /usr/local/lib/python3.10/dist-packages (from transformers) (6.0.1)
Requirement already satisfied: regex!=2019.12.17 in /usr/local/lib/python3.10/dist-packages (from transformers) (2023.6.3)
Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-packages (from transformers) (2.31.0)
Requirement already satisfied: tokenizers<0.15,>=0.14 in /usr/local/lib/python3.10/dist-packages (from transformers) (0.14.1)
Requirement already satisfied: safetensors>=0.3.1 in /usr/local/lib/python3.10/dist-packages (from transformers) (0.4.0)
Requirement already satisfied: tqdm>=4.27 in /usr/local/lib/python3.10/dist-packages (from transformers) (4.66.1)
Requirement already satisfied: fsspec in /usr/local/lib/python3.10/dist-packages (from huggingface-hub<1.0,>=0.16.4->transformers) (2023.6.0)
Requirement already satisfied: typing-extensions>=3.7.4.3 in /usr/local/lib/python3.10/dist-packages (from huggingface-hub<1.0,>=0.16.4->trans
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests->transformers) (3.3.0)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests->transformers) (3.4)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests->transformers) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests->transformers) (2023.7.22)
```

In [76]:
```
pip install torch
```

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Requirement already satisfied: torch in /usr/local/lib/python3.10/dist-packages (2.1.0+cu118)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-packages (from torch) (3.12.4)
Requirement already satisfied: typing-extensions in /usr/local/lib/python3.10/dist-packages (from torch) (4.5.0)
Requirement already satisfied: sympy in /usr/local/lib/python3.10/dist-packages (from torch) (1.12)
Requirement already satisfied: networkx in /usr/local/lib/python3.10/dist-packages (from torch) (3.2)
Requirement already satisfied: jinja2 in /usr/local/lib/python3.10/dist-packages (from torch) (3.1.2)
Requirement already satisfied: fsspec in /usr/local/lib/python3.10/dist-packages (from torch) (2023.6.0)
Requirement already satisfied: triton==2.1.0 in /usr/local/lib/python3.10/dist-packages (from torch) (2.1.0)
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.10/dist-packages (from jinja2->torch) (2.1.3)
Requirement already satisfied: mpmath>=0.19 in /usr/local/lib/python3.10/dist-packages (from sympy->torch) (1.3.0)
```

In [77]:
```
!pip install transformers
```

```
Requirement already satisfied: transformers in /usr/local/lib/python3.10/dist-packages (4.34.1)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-packages (from transformers) (3.12.4)
Requirement already satisfied: huggingface-hub<1.0,>=0.16.4 in /usr/local/lib/python3.10/dist-packages (from transformers) (0.17.3)
Requirement already satisfied: numpy>=1.17 in /usr/local/lib/python3.10/dist-packages (from transformers) (1.23.5)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.10/dist-packages (from transformers) (23.2)
Requirement already satisfied: pyyaml>=5.1 in /usr/local/lib/python3.10/dist-packages (from transformers) (6.0.1)
Requirement already satisfied: regex!=2019.12.17 in /usr/local/lib/python3.10/dist-packages (from transformers) (2023.6.3)
Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-packages (from transformers) (2.31.0)
Requirement already satisfied: tokenizers<0.15,>=0.14 in /usr/local/lib/python3.10/dist-packages (from transformers) (0.14.1)
Requirement already satisfied: safetensors>=0.3.1 in /usr/local/lib/python3.10/dist-packages (from transformers) (0.4.0)
Requirement already satisfied: tqdm>=4.27 in /usr/local/lib/python3.10/dist-packages (from transformers) (4.66.1)
Requirement already satisfied: fsspec in /usr/local/lib/python3.10/dist-packages (from huggingface-hub<1.0,>=0.16.4->transformers) (2023.6.0)
Requirement already satisfied: typing-extensions>=3.7.4.3 in /usr/local/lib/python3.10/dist-packages (from huggingface-hub<1.0,>=0.16.4->trans
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests->transformers) (3.3.0)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests->transformers) (3.4)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests->transformers) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests->transformers) (2023.7.22)
```

In [78]:
```
pip install nltk
```

```
Requirement already satisfied: nltk in /usr/local/lib/python3.10/dist-packages (3.8.1)
Requirement already satisfied: click in /usr/local/lib/python3.10/dist-packages (from nltk) (8.1.7)
Requirement already satisfied: joblib in /usr/local/lib/python3.10/dist-packages (from nltk) (1.3.2)
Requirement already satisfied: regex>=2021.8.3 in /usr/local/lib/python3.10/dist-packages (from nltk) (2023.6.3)
Requirement already satisfied: tqdm in /usr/local/lib/python3.10/dist-packages (from nltk) (4.66.1)
```

In [79]:
```
pip install pydot
```

```
Requirement already satisfied: pydot in /usr/local/lib/python3.10/dist-packages (1.4.2)
Requirement already satisfied: pyparsing>=2.1.4 in /usr/local/lib/python3.10/dist-packages (from pydot) (3.1.1)
```

In [80]:
```
pip install graphviz
```

```
Requirement already satisfied: graphviz in /usr/local/lib/python3.10/dist-packages (0.20.1)
```

In [81]:
```
pip install tensorflow
```

```
Requirement already satisfied: tensorflow in /usr/local/lib/python3.10/dist-packages (2.14.0)
Requirement already satisfied: absl-py>=1.0.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (1.4.0)
Requirement already satisfied: astunparse>=1.6.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (1.6.3)
Requirement already satisfied: flatbuffers>=23.5.26 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (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) (0.5.4)
Requirement already satisfied: google-pasta>=0.1.1 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (0.2.0)
Requirement already satisfied: h5py>=2.9.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (3.9.0)
Requirement already satisfied: libclang>=13.0.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (16.0.6)
Requirement already satisfied: ml-dtypes==0.2.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (0.2.0)
Requirement already satisfied: numpy>=1.23.5 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (1.23.5)
Requirement already satisfied: opt-einsum>=2.3.2 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (3.3.0)
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Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-packages (from tensorflow) (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/d
Requirement already satisfied: setuptools in /usr/local/lib/python3.10/dist-packages (from tensorflow) (67.7.2)
Requirement already satisfied: six>=1.12.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (1.16.0)
Requirement already satisfied: termcolor>=1.1.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (2.3.0)
Requirement already satisfied: typing-extensions>=3.6.6 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (4.5.0)
Requirement already satisfied: wrapt<1.15,>=1.11.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (1.14.1)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (0.34.0)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (1.59.0)
Requirement already satisfied: tensorboard<2.15,>=2.14 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (2.14.1)
Requirement already satisfied: tensorflow-estimator<2.15,>=2.14.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (2.14.0)
Requirement already satisfied: keras<2.15,>=2.14.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow) (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) (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.
Requirement already satisfied: google-auth-oauthlib<1.1,>=0.5 in /usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14->tensor
Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14->tensorflow) (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) (2.31
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-
Requirement already satisfied: werkzeug>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14->tensorflow) (3.0.0)
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
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,
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->
Requirement already satisfied: requests-oauthlib>=0.7.0 in /usr/local/lib/python3.10/dist-packages (from google-auth-oauthlib<1.1,>=0.5->tenso
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests<3,>=2.21.0->tensorboard<2.15
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->ten
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,>=2.1
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests<3,>=2.21.0->tensorboard<2.15,>=2.1
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->te
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.
Requirement already satisfied: oauthlib>=3.0.0 in /usr/local/lib/python3.10/dist-packages (from requests-oauthlib>=0.7.0->google-auth-oauthlib
```

In [82]:
```
pip install tensorflow==2.14.0
```

```
Requirement already satisfied: tensorflow==2.14.0 in /usr/local/lib/python3.10/dist-packages (2.14.0)
Requirement already satisfied: absl-py>=1.0.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (1.4.0)
Requirement already satisfied: astunparse>=1.6.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (1.6.3)
Requirement already satisfied: flatbuffers>=23.5.26 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (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==2.14.0) (0.5.4
Requirement already satisfied: google-pasta>=0.1.1 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (0.2.0)
Requirement already satisfied: h5py>=2.9.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (3.9.0)
Requirement already satisfied: libclang>=13.0.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (16.0.6)
Requirement already satisfied: ml-dtypes==0.2.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (0.2.0)
Requirement already satisfied: numpy>=1.23.5 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (1.23.5)
Requirement already satisfied: opt-einsum>=2.3.2 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (3.3.0)
Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (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/d
Requirement already satisfied: setuptools in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (67.7.2)
Requirement already satisfied: six>=1.12.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (1.16.0)
Requirement already satisfied: termcolor>=1.1.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (2.3.0)
Requirement already satisfied: typing-extensions>=3.6.6 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (4.5.0)
Requirement already satisfied: wrapt<1.15,>=1.11.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (1.14.1)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (0.34
Requirement already satisfied: grpcio<2.0,>=1.24.3 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (1.59.0)
Requirement already satisfied: tensorboard<2.15,>=2.14 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (2.14.1)
Requirement already satisfied: tensorflow-estimator<2.15,>=2.14.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (2.14.0
Requirement already satisfied: keras<2.15,>=2.14.0 in /usr/local/lib/python3.10/dist-packages (from tensorflow==2.14.0) (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==2.14.0) (0.4
Requirement already satisfied: google-auth<3,>=1.6.3 in /usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14->tensorflow==2.1
Requirement already satisfied: google-auth-oauthlib<1.1,>=0.5 in /usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14->tensor
Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.10/dist-packages (from tensorboard<2.15,>=2.14->tensorflow==2.14.0)
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>tensorflow==2.14. 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-Requirement already satisfied: werkzeug>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from
tensorboard<2.15,>=2.14->tensorflow==2.14.0) ( 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 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, 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-> Requirement already satisfied: requests-oauthlib>=0.7.0 in
/usr/local/lib/python3.10/dist-packages (from google-auth-oauthlib<1.1,>=0.5->tenso Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from requests<3,>=2.21.0->tensorboard<2.15 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->ten 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,>=2.1 Requirement already satisfied:
certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests<3,>=2.21.0->tensorboard<2.15,>=2.1 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->te 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. Requirement already satisfied:
oauthlib>=3.0.0 in /usr/local/lib/python3.10/dist-packages (from requests-oauthlib>=0.7.0->google-auth-oauthlib
```

In [83]:
```
import numpy as np
import pandas as pd

import re
import emoji
import re

from nltk.stem import PorterStemmer
from tensorflow.keras.preprocessing.text import Tokenizer
from sklearn.model_selection import train_test_split
pd.set_option('display.max_colwidth',200)
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.preprocessing.text import Tokenizer
import matplotlib.pyplot as plt
import tensorflow as tf
import torch
# importing nn module
import torch.nn as nn
```

```
#library for progress bar
from tqdm import notebook
from torch.utils.data import TensorDataset, DataLoader, RandomSampler, SequentialSampler


#library for computing class weights
from sklearn.utils.class_weight import compute_class_weight

from sklearn.metrics import classification_report


import time
import datetime
```

In [84]:
```
# Checking if GPU is available.
if torch.cuda.is_available():
  device=torch.device('cuda')
```

In [85]:
```
print(device)
torch.cuda.get_device_name(0)
# Current GPU is Tesla T4
```

```
cuda
```

Out [85]: 'Tesla T4'

In [86]:
```
data = pd.read_csv('Tweets.csv')
```

In [87]:
```
data.head()
```

Out [87]:

	tweet_id	airline_sentiment	airline_sentiment_confidence	negativereason	negativereason_confidence	airline	airline_sentimen
0	570306133677760513	neutral	1.0000	NaN	NaN	Virgin America	NaN
1	570301130888122368	positive	0.3486	NaN	0.0000	Virgin America	NaN
2	570301083672813571	neutral	0.6837	NaN	NaN	Virgin America	NaN
3	570301031407624196	negative	1.0000	Bad Flight	0.7033	Virgin America	NaN
4	570300817074462722	negative	1.0000	Can't Tell	1.0000	Virgin America	NaN

In [88]:
```
data
```

Out [88]:

	tweet_id	airline_sentiment	airline_sentiment_confidence	negativereason	negativereason_confidence	airline	airline_se
0	570306133677760513	neutral	1.0000	NaN	NaN	Virgin America	NaN
1	570301130888122368	positive	0.3486	NaN	0.0000	Virgin America	NaN

	tweet_id	airline_sentiment	airline_sentiment_confidence	negativereason	negativereason_confidence	airline	airline_se
2	570301083672813571	neutral	0.6837	NaN	NaN	Virgin America	NaN
3	570301031407624196	negative	1.0000	Bad Flight	0.7033	Virgin America	NaN
4	570300817074462722	negative	1.0000	Can't Tell	1.0000	Virgin America	NaN
...	...	...	...	...	...	...	...
13504	569846356409339906	positive	1.0000	NaN	NaN	American	NaN
13505	569846302663688192	negative	1.0000	Customer Service Issue	0.6834	American	NaN
13506	569846045892608001	negative	1.0000	Customer Service Issue	0.6414	American	NaN
13507	569846023553720321	negative	1.0000	Customer Service Issue	0.6681	American	NaN
13508	569845438494457856	negative	1.0000	Cancelled Flight	1.0000	American	NaN

13509 rows × 15 columns

In [88]:

In [89]:
```
#PREPROCESSING
```

In [90]:
```
confidence_threshold = 0.6

data = data.drop(data.query("airline_sentiment_confidence < @confidence_threshold").index, axis=0).reset_index(
```

In [91]:
```
tweets_df = pd.concat([data['text'], data['airline_sentiment']], axis=1)
tweets_df
```

Out [91]:

	text	airline_sentiment
0	@VirginAmerica What @dhepburn said.	neutral
1	@VirginAmerica I didn't today... Must mean I need to take another trip!	neutral
2	@VirginAmerica it's really aggressive to blast obnoxious "entertainment" in your guests' faces & they have little recourse	negative
3	@VirginAmerica and it's a really big bad thing about it	negative
4	@VirginAmerica seriously would pay $30 a flight for seats that didn't have this playing.\nit's really the only bad thing about flying VA	negative
...	...	...
13278	@AmericanAir thank you for doing the best you could to get me rebooked. Agent on phone & addtl resolution on DM was very much appreciated.	positive
13279	@AmericanAir no email no phone call no nothing. You've screwed with my flight and my family/Friends flights. You Cancelled Flighted reservations for	negative
13280	@AmericanAir If you care, could you have someone call me to explain what is going on.	negative
13281	Hey @AmericanAir why automated call me and then hang up at 4:45 am!?! And why can't I reschedule Cancelled Flighted flights via web!?! Come on!!!	negative
13282	@AmericanAir from a service rep but that hasn't happened	negative

13283 rows × 2 columns

In [92]:
```
tweets_df.isna().sum().sum()
```

Out [92]: 0

In [93]:
```
tweets_df['airline_sentiment'].value_counts()
```

Out [93]:
```
negative    8238
neutral     2851
positive    2194
Name: airline_sentiment, dtype: int64
```

In [94]:
```
sentiment_ordering = ['negative', 'neutral', 'positive']

tweets_df['airline_sentiment'] = tweets_df['airline_sentiment'].apply(lambda x: sentiment_ordering.index(x))
```

In [95]:
```
tweets_df
```

Out [95]:

	text	airline_sentiment
0	@VirginAmerica What @dhepburn said.	1
1	@VirginAmerica I didn't today... Must mean I need to take another trip!	1
2	@VirginAmerica it's really aggressive to blast obnoxious "entertainment" in your guests' faces & they have little recourse	0
3	@VirginAmerica and it's a really big bad thing about it	0
4	@VirginAmerica seriously would pay $30 a flight for seats that didn't have this playing.\nit's really the only bad thing about flying VA	0
...	...	...
13278	@AmericanAir thank you for doing the best you could to get me rebooked. Agent on phone & addtl resolution on DM was very much appreciated.	2
13279	@AmericanAir no email no phone call no nothing. You've screwed with my flight and my family/Friends flights. You Cancelled Flighted reservations for	0
13280	@AmericanAir If you care, could you have someone call me to explain what is going on.	0
13281	Hey @AmericanAir why automated call me and then hang up at 4:45 am!?! And why can't I reschedule Cancelled Flighted flights via web!?! Come on!!!	0
13282	@AmericanAir from a service rep but that hasn't happened	0

13283 rows × 2 columns

In [96]:
```
emoji.demojize('@AmericanAir right on cue with the delays👌')
```

Out [96]: '@AmericanAir right on cue with the delays:OK_hand:'

In [97]:
```
ps = PorterStemmer()

def process_tweet(tweet):
    new_tweet = tweet.lower()
    new_tweet = re.sub(r'@\w+', '', new_tweet) # Remove @s
    new_tweet = re.sub(r'#', '', new_tweet) # Remove hashtags
    new_tweet = re.sub(r':', ' ', emoji.demojize(new_tweet)) # Turn emojis into words
    new_tweet = re.sub(r'http\S+', '',new_tweet) # Remove URLs
    new_tweet = re.sub(r'\$\S+', 'dollar', new_tweet) # Change dollar amounts to dollar
    new_tweet = re.sub(r'[^a-z0-9\s]', '', new_tweet) # Remove punctuation
    new_tweet = re.sub(r'[0-9]+', 'number', new_tweet) # Change number values to number
    new_tweet = new_tweet.split(" ")
    new_tweet = list(map(lambda x: ps.stem(x), new_tweet)) # Stemming the words
    new_tweet = list(map(lambda x: x.strip(), new_tweet)) # Stripping whitespace from the words
    if '' in new_tweet:
        new_tweet.remove('')
    return new_tweet
```

In [98]:
```
tweets = tweets_df['text'].apply(process_tweet)

labels = np.array(tweets_df['airline_sentiment'])
```

In [99]:
```
tweets
```

Out [99]:
```
0
[what, , said]
1                                                                                              [i, didnt, today, must, mean, i, need, to,
take, anoth, trip]
2                                                [it, realli, aggress, to, blast, obnoxi, entertain, in, your, guest, face, amp, they,
have, littl, recours]
3                                                                                                          [and, it, a, realli, big,
bad, thing, about, it]
4                    [serious, would, pay, dollar, a, flight, for, seat, that, didnt, have, thi, playing\nit, realli, the, onli, bad,
thing, about, fli, va]
                                                                                           ...
13278             [thank, you, for, do, the, best, you, could, to, get, me, rebook, agent, on, phone, amp, addtl, resolut, on, dm, wa,
veri, much, appreci]
13279               [no, email, no, phone, call, no, noth, youv, screw, with, my, flight, and, my, familyfriend, flight, you, cancel,
flight, reserv, for]
13280                                                                    [if, you, care, could, you, have, someon, call, me, to,
explain, what, is, go, on]
13281     [hey, whi, autom, call, me, and, then, hang, up, at, number, number, am, and, whi, cant, i, reschedul, cancel, flight, flight,
via, web, come, on]
13282                                                                                                        [from, a, servic, rep, but,
that, hasnt, happen, ]
Name: text, Length: 13283, dtype: object
```

In [100]:
```
# Get size of vocabulary
vocabulary = set()

for tweet in tweets:
    for word in tweet:
        if word not in vocabulary:
            vocabulary.add(word)

vocab_length = len(vocabulary)

# Get max length of a sequence
max_seq_length = 0

for tweet in tweets:
    if len(tweet) > max_seq_length:
        max_seq_length = len(tweet)

# Print results
print("Vocab length:", vocab_length)
print("Max sequence length:", max_seq_length)
```

```
Vocab length: 10759
Max sequence length: 90
```

In [101]:
```
tokenizer = Tokenizer(num_words=vocab_length)
tokenizer.fit_on_texts(tweets)
sequences = tokenizer.texts_to_sequences(tweets)


word_index = tokenizer.word_index

model_inputs = pad_sequences(sequences, maxlen=max_seq_length, padding='post')
```

In [102]:
```
model_inputs
```

Out [102]:
```
array([[  49,    2,  209, ...,    0,    0,    0],
       [   5,  190,   99, ...,    0,    0,    0],
       [  15,  142, 2740, ...,    0,    0,    0],
       ...,
       [  69,    8,  234, ...,    0,    0,    0],
       [ 490,   70,  851, ...,    0,    0,    0],
       [  30,    7,   40, ...,    0,    0,    0]], dtype=int32)
```

In [103]:
```
model_inputs.shape
```

Out [103]:
```
(13283, 90)
```

In [104]:
```
X_train, X_test, y_train, y_test = train_test_split(model_inputs, labels, train_size=0.7, random_state=22)
```

In [105]:
```
embedding_dim = 32


inputs = tf.keras.Input(shape=(max_seq_length,))

embedding =
    tf.keras.layers.Embedding( input_di
    m=vocab_length,
    output_dim=embedding_dim,
    input_length=max_seq_length
)(inputs)


# Model A (just a Flatten layer)
flatten = tf.keras.layers.Flatten()(embedding)

# Model B (GRU with a Flatten layer)
gru = tf.keras.layers.GRU(units=embedding_dim)(embedding)
gru_flatten = tf.keras.layers.Flatten()(gru)

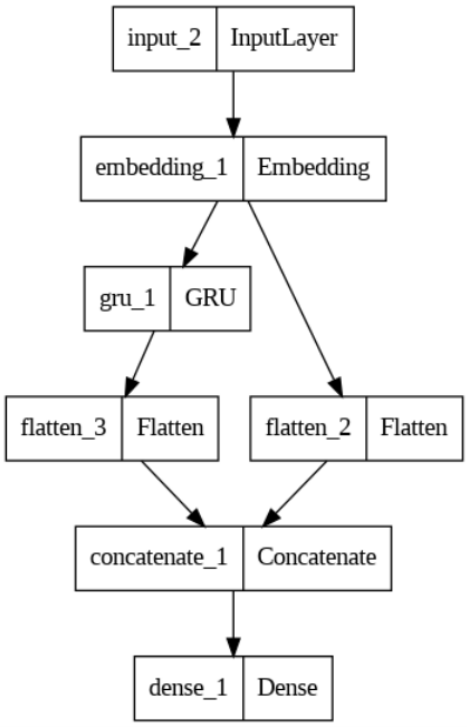
# Both A and B are fed into the output
concat = tf.keras.layers.concatenate([flatten, gru_flatten])

outputs = tf.keras.layers.Dense(3, activation='softmax')(concat)


model = tf.keras.Model(inputs, outputs)

tf.keras.utils.plot_model(model)
```

Out [105]:



In [106]:

```
    model.compile( opt
    imizer='adam',
    loss='sparse_categorical_crossentropy',
    metrics=['accuracy']
)


batch_size = 32
epochs = 100

history =
    model.fit( X_trai
    n,  y_train,
    validation_split=0.2,
    batch_size=batch_size,
    epochs=epochs,
    callbacks=[
        tf.keras.callbacks.EarlyStopping(
            monitor='val_loss', patience=3,
            restore_best_weights=True,
            verbose=1
        ),
        tf.keras.callbacks.ReduceLROnPlateau()
    ] )
```

```
Epoch 1/100
233/233 [==============================] - 26s 96ms/step - loss: 0.8076 - accuracy: 0.6530 - val_loss: 0.7008 - val_accuracy: 0.7054 - lr: 0.0
Epoch 2/100
233/233 [==============================] - 6s 27ms/step - loss: 0.5502 - accuracy: 0.7829 - val_loss: 0.5706 - val_accuracy: 0.7667 - lr: 0.00
Epoch 3/100
233/233 [==============================] - 7s 29ms/step - loss: 0.3929 - accuracy: 0.8630 - val_loss: 0.5230 - val_accuracy: 0.7925 - lr: 0.00
Epoch 4/100
233/233 [==============================] - 4s 18ms/step - loss: 0.2910 - accuracy: 0.9062 - val_loss: 0.5137 - val_accuracy: 0.7957 - lr: 0.00
Epoch 5/100
233/233 [==============================] - 6s 25ms/step - loss: 0.2163 - accuracy: 0.9360 - val_loss: 0.5246 - val_accuracy: 0.7898 - lr: 0.00
Epoch 6/100
233/233 [==============================] - 3s 13ms/step - loss: 0.1614 - accuracy: 0.9579 - val_loss: 0.5376 - val_accuracy: 0.7941 - lr: 0.00
Epoch 7/100
233/233 [==============================] - ETA: 0s - loss: 0.1209 - accuracy: 0.9715Restoring model weights from the end of the best epoch: 4.
233/233 [==============================] - 2s 11ms/step - loss: 0.1209 - accuracy: 0.9715 - val_loss: 0.5599 - val_accuracy: 0.7914 - lr: 0.00
Epoch 7: early stopping
```

In [107]:

```
model.evaluate(X_test, y_test)
```

```
125/125 [==============================] - 1s 5ms/step - loss: 0.4996 - accuracy: 0.8018
```

Out [107]: [0.49962925910949707, 0.8017565608024597]

In [107]:

In [108]:
```
# IMPORT BERT AS NLP
```

In [109]:
```
from transformers.models.bert.modeling_bert import BertModel
# Import BERT pretrained module
from transformers import BertModel

#Download uncased bert base model
bert=BertModel.from_pretrained('bert-base-uncased')
```

In [110]:
```
# Print BERT arcitecture
print(bert)
```

```
BertModel(
  (embeddings): BertEmbeddings(
    (word_embeddings): Embedding(30522, 768, padding_idx=0)
    (position_embeddings): Embedding(512, 768)
    (token_type_embeddings): Embedding(2, 768)
    (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
    (dropout): Dropout(p=0.1, inplace=False)
  )
  (encoder):
    BertEncoder( (layer):
    ModuleList(
      (0-11): 12 x
        BertLayer( (attention):
        BertAttention(
          (self): BertSelfAttention(
            (query): Linear(in_features=768, out_features=768, bias=True)
            (key): Linear(in_features=768, out_features=768, bias=True)
            (value): Linear(in_features=768, out_features=768, bias=True)
            (dropout): Dropout(p=0.1, inplace=False)
          )
          (output): BertSelfOutput(
            (dense): Linear(in_features=768, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          ) )
        (intermediate): BertIntermediate(
          (dense): Linear(in_features=768, out_features=3072, bias=True)
          (intermediate_act_fn): GELUActivation()
        )
        (output): BertOutput(
          (dense): Linear(in_features=3072, out_features=768, bias=True)
          (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
          (dropout): Dropout(p=0.1, inplace=False)
        ) )
    ) )
  (pooler): BertPooler(
    (dense): Linear(in_features=768, out_features=768, bias=True)
    (activation): Tanh()
  ) )
```

In [111]:
```
from transformers.models.bert.tokenization_bert_fast import BertTokenizerFast
# importing BERT tokenizer
tokenizer=BertTokenizerFast.from_pretrained('bert-base-uncased',do_lower_case=True)
```

In [112]:
```
text='Jim Henson was a puppeteer'
sentence_id=tokenizer.encode(text,
                             # add special character tokens
                             add_special_tokens=True,
                             # Specifying maximum length for any input sequences
                             max_length=10,
                             # if exceeeding 10, then it will be truncated, if <10, then it will be padded.
                             truncation=True,
                             # add pad tokens to the right side of the sequence
                             pad_to_max_length='right'
                             )
print("Integer Sequence:{}".format(sentence_id))
```

```
Integer Sequence:[101, 3958, 27227, 2001, 1037, 13997, 11510, 102, 0, 0]
```

```
/usr/local/lib/python3.10/dist-packages/transformers/tokenization_utils_base.py:2606: FutureWarning: The `pad_to_max_length` argument
is deprecated and will be removed in a future version, use `padding=True` or `padding='longest'` to pad to the longest sequence in the
batch, or use `padding='max_length'` to pad to a max length. In this case, you can give a specific length with `max_length` (e.g.
`max_length=45`) or leave max_length to None to pad to the maximal input size of the model (e.g. 512 for Bert).
  warnings.warn(
```

In [113]:
```
# converting integers back to text
print("Tokenizer Text: ",tokenizer.convert_ids_to_tokens(sentence_id))
```

```
Tokenizer Text:  ['[CLS]', 'jim', 'henson', 'was', 'a', 'puppet', '##eer', '[SEP]', '[PAD]', '[PAD]']
```

In [114]:
```
decoded=tokenizer.decode(sentence_id)
print('Decoded String:{}'.format(decoded))
```

```
Decoded String:[CLS] jim henson was a puppeteer [SEP] [PAD] [PAD]
```

In [115]:
```
att_mask=[int(tok>0) for tok in sentence_id]
print(att_mask)
```

```
[1, 1, 1, 1, 1, 1, 1, 1, 0, 0]
```

In [116]:
```
# convert lists to tensors
# torch.tensor creates a tensor of given data
sent_id=torch.tensor(sentence_id)
attn_mask=torch.tensor(att_mask)
print('Shape of sentence_id before reshaping is: {}'.format(sent_id.shape))
print('Shape of sentence_id before reshaping is: {}'.format(attn_mask.shape))
print('\n')
# reshaping tensor in form of batch,text length
sent_id=sent_id.unsqueeze(0)
attn_mask=attn_mask.unsqueeze(0)
print('Shape of sentence_id after reshaping is: {}'.format(sent_id.shape))
print('Shape of sentence_id after reshaping is: {}'.format(attn_mask.shape))
print('\n')
# reshaped tensor
print(sent_id)
```

```
Shape of sentence_id before reshaping is: torch.Size([10])
Shape of sentence_id before reshaping is: torch.Size([10])


Shape of sentence_id after reshaping is: torch.Size([1, 10])
Shape of sentence_id after reshaping is: torch.Size([1, 10])


tensor([[  101,  3958, 27227,  2001,  1037, 13997, 11510,   102,     0,     0]])
```

In [117]:
```
# passing integer sequence and attention mask tensor to BERT model
outputs=bert(sent_id,attention_mask=attn_mask)
```

In [118]:
```
# Unpacking the output of BERT model

# all_hidden_states is a collection of all the output vectors/ hidden states (of encoder) at each timestamps or
all_hidden_states=outputs[0]

print(all_hidden_states.shape)
print(all_hidden_states)
```

```
torch.Size([1, 10, 768])
tensor([[[-0.2531,  0.2038, -0.3862,  ..., -0.3034,  0.6197,  0.2373],
         [-0.2323, -0.0044, -0.5479,  ...,  0.0765,  0.8122, -0.4710],
         [ 0.2590,  0.7140, -0.5438,  ..., -0.3774,  0.9987,
         0.5400], ...,
         [ 0.7873,  0.3299, -0.0351,  ...,  0.2932, -0.5141,  0.0308],
         [-0.5547, -0.3669, -0.1106,  ...,  0.2593,  0.5321, -0.3871],
         [-0.5461, -0.2414, -0.2111,  ...,  0.3100,  0.5863, -0.3467]]],
       grad_fn=<NativeLayerNormBackward0>)
```

In [119]:
```
# this output contains output vector against the CLS token only (at the first position of BERT model)
# this output vector encodes the entire input sequence

cls_hidden_state=outputs[1]

print(cls_hidden_state.shape)
print(cls_hidden_state)
```

```
torch.Size([1, 768])
tensor([[-0.8767, -0.4109, -0.1220,  0.4494,  0.1945, -0.2698,  0.8316,  0.3127,
          0.1178, -1.0000, -0.1561,  0.6677,  0.9891, -0.3451,  0.8812, -0.6753,
         -0.3079, -0.5580,  0.4380, -0.4588,  0.5831,  0.9956,  0.4467,  0.2863,
          0.3924,  0.6864, -0.7513,  0.9043,  0.9436,  0.8207, -0.6493,  0.3524,
```

```
        -0.9919, -0.2295, -0.0742, -0.9936,  0.3698, -0.7558,  0.0792, -0.2218,
        -0.8637,  0.4711,  0.9997, -0.4368,  0.0404, -0.3498, -1.0000,  0.2663,
        -0.8711,  0.0508,  0.0505, -0.1634,  0.1716,  0.4363,  0.4330, -0.0333,
        -0.0416,  0.2206, -0.2568, -0.6122, -0.5916,  0.2569, -0.2622, -0.9041,
         0.3221, -0.2394, -0.2634, -0.3454, -0.0723,  0.0081,  0.8297,  0.2279,
         0.1614, -0.6555, -0.2062,  0.3280, -0.4016,  1.0000, -0.0952, -0.9874,
        -0.0400,  0.0717,  0.3675,  0.3373, -0.3710, -1.0000,  0.4479, -0.1722,
        -0.9917,  0.2677,  0.4844, -0.2207, -0.3207,  0.3715, -0.2171, -0.2522,
        -0.3071, -0.3161, -0.1988, -0.0860, -0.0114, -0.1982, -0.1799, -0.3221,
         0.1751, -0.4442, -0.1570, -0.0434, -0.0893,  0.5717,  0.3112, -0.2900,
         0.3305, -0.9430,  0.6061, -0.2984, -0.9873, -0.3956, -0.9926,  0.7857,
        -0.1692, -0.2719,  0.9505,  0.5628,  0.2904, -0.1693,  0.1619, -1.0000,
        -0.1697, -0.1534,  0.2513, -0.2857, -0.9846, -0.9638,  0.5565,  0.9200,
         0.1805,  0.9995, -0.2122,  0.9391,  0.3246, -0.3937, -0.1248, -0.5209,
         0.0519,  0.1141, -0.6463,  0.3529, -0.0322, -0.3837, -0.3796, -0.2830,
         0.1280, -0.9191, -0.4201,  0.9145,  0.0713, -0.2455,  0.5212, -0.2642,
        -0.3675,  0.8082,  0.2577,  0.2755, -0.0157,  0.3675, -0.3107,  0.4502,
        -0.8224,  0.2841,  0.4360, -0.3193,  0.2164, -0.9851, -0.4444,  0.5759,
         0.9878,  0.7531,  0.3384,  0.2003, -0.2602,  0.4695, -0.9561,  0.9855,
        -0.1712,  0.2295,  0.1220, -0.1386, -0.8436, -0.3783,  0.8371, -0.3204,
        -0.8457, -0.0473, -0.4219, -0.3593, -0.2187,  0.5282, -0.3149, -0.4375,
        -0.0440,  0.9242,  0.9296,  0.7735, -0.3733,  0.3945, -0.9049, -0.2898,
         0.2695,  0.2910,  0.1695,  0.9932, -0.3069, -0.1611, -0.8349, -0.9827,
         0.1299, -0.8555, -0.0531, -0.6830,  0.3926,  0.2873, -0.1899,  0.2598,
        -0.9201, -0.7455,  0.3943, -0.3955,  0.4015, -0.2341,  0.7593,  0.3421,
        -0.6143,  0.5170,  0.8987,  0.1072, -0.6858,  0.6481, -0.2454,  0.8712,
        -0.5958,  0.9936,  0.3404,  0.4972, -0.9452, -0.2347, -0.8748, -0.0154,
        -0.1293, -0.5265,  0.4235,  0.4206,  0.3663,  0.7488, -0.4650,  0.9900,
        -0.8695, -0.9701, -0.5203, -0.0900, -0.9914,  0.0978,  0.2844, -0.0424,
        -0.4649, -0.4546, -0.9620,  0.8035,  0.2177,  0.9705, -0.0793, -0.7985,
        -0.3436, -0.9537, -0.0035, -0.0945,  0.4291,  0.0391, -0.9602,  0.4497,
         0.5135,  0.4913,  0.0608,  0.9948,  1.0000,  0.9810,  0.8865,  0.7961,
        -0.9894, -0.5122,  1.0000, -0.8521, -1.0000, -0.9412, -0.6633,  0.3110,
        -1.0000, -0.1468, -0.1235, -0.9465, -0.0891,  0.9796,  0.9700, -1.0000,
         0.9324,  0.9259, -0.4503,  0.4591, -0.1785,  0.9819,  0.2285,  0.4423,
        -0.2615,  0.4124, -0.5252, -0.8534,  0.0365, -0.0670,  0.8944,  0.1913,
        -0.4782, -0.9402,  0.2293, -0.1581, -0.2440, -0.9604, -0.1924, -0.0555,
         0.5484,  0.1915,  0.2038, -0.7367,  0.2698, -0.7307,  0.3715,  0.5640,
        -0.9386, -0.5717,  0.3818, -0.2775,  0.1536, -0.9608,  0.9702, -0.3502,
         0.1524,  1.0000,  0.3876, -0.9001,  0.2547,  0.1857,  0.0832,  1.0000,
         0.3811, -0.9852, -0.4053,  0.2576, -0.3923, -0.4125,  0.9994, -0.1463,
        -0.0428,  0.2818,  0.9899, -0.9923,  0.8351, -0.8563, -0.9634,  0.9617,
         0.9268, -0.4225, -0.7369,  0.1318,  0.1107,  0.2294, -0.8914,  0.6082,
         0.4665, -0.0720,  0.8555, -0.7973, -0.3478,  0.4201, -0.1762,  0.0761,
         0.2823,  0.4571, -0.1350,  0.1190, -0.3509, -0.4039, -0.9556,  0.0262,
         1.0000, -0.2164,  0.0569, -0.2296, -0.1003, -0.1827,  0.4036,  0.4715,
        -0.3293, -0.8471, -0.0518, -0.8453, -0.9935,  0.6732,  0.2284, -0.1968,
         0.9998,  0.5194,  0.2326,  0.1718,  0.7497, -0.0192,  0.4518, -0.0327,
         0.9765, -0.3259,  0.3491,  0.7471, -0.3186, -0.3019, -0.5725,  0.0563,
        -0.9206,  0.0572, -0.9589,  0.9565,  0.3109,  0.3348,  0.1635, -0.0619,
         1.0000, -0.6020,  0.5309, -0.3723,  0.6636, -0.9851, -0.6789, -0.4312,
        -0.1435, -0.0827, -0.2497,  0.1323, -0.9786, -0.0474, -0.0304, -0.9444,
        -0.9927,  0.2508,  0.6172,  0.1679, -0.7980, -0.6078, -0.4906,  0.4646,
        -0.1934, -0.9396,  0.5453, -0.3000,  0.4329, -0.3340,  0.4408, -0.2058,
         0.8344,  0.1265, -0.0307, -0.2098, -0.8340,  0.7114, -0.7410,  0.0518,
        -0.1481,  1.0000, -0.3100,  0.1461,  0.7011,  0.6334, -0.2857,  0.1618,
         0.0966,  0.2955, -0.0981, -0.1832, -0.6208, -0.3013,  0.4337,  0.0283,
        -0.2959,  0.7579,  0.4711,  0.3666, -0.0531,  0.0914,  0.9969, -0.2267,
        -0.1165, -0.5533, -0.1262, -0.3575, -0.2124,  1.0000,  0.3679,  0.0604,
        -0.9936, -0.2000, -0.9208,  0.9999,  0.8511, -0.8783,  0.5650,  0.2405,
        -0.2859,  0.6935, -0.2598, -0.2655,  0.2893,  0.2862,  0.9774, -0.4575,
        -0.9764, -0.5964,  0.3966, -0.9575,  0.9939, -0.5326, -0.2349, -0.4376,
        -0.0250,  0.2574,  0.0274, -0.9762, -0.1582,  0.1821,  0.9811,  0.3014,
        -0.3820, -0.9007, -0.1151,  0.3936, -0.0680, -0.9449,  0.9809, -0.9313,
         0.2600,  1.0000,  0.3860, -0.5243,  0.2401, -0.4410,  0.3253, -0.1413,
         0.5428, -0.9466, -0.2817, -0.3262,  0.4330, -0.2120, -0.2457,  0.7247,
         0.2134, -0.3430, -0.6305, -0.1214,  0.4871,  0.7498, -0.2957, -0.1829,
         0.1699, -0.1391, -0.9264, -0.4167, -0.2995, -0.9991,  0.6411, -1.0000,
        -0.1510, -0.5473, -0.2219,  0.8075,  0.3862, -0.1392, -0.7206, -0.0710,
         0.6995,  0.6656, -0.2889,  0.2902, -0.6951,  0.1622, -0.1298,  0.3182,
         0.1694,  0.6526, -0.2735,  1.0000,  0.1370, -0.3043, -0.9189,  0.3041,
        -0.2604,  1.0000, -0.7969, -0.9715,  0.2110, -0.5773, -0.7218,  0.2477,
        -0.0304, -0.7015, -0.6577,  0.9111,  0.8219, -0.3693,  0.4537, -0.3062,
        -0.3671,  0.0856,  0.1595,  0.9903,  0.2790,  0.8213, -0.2885, -0.0724,
         0.9636,  0.2213,  0.6892,  0.2070,  1.0000,  0.3249, -0.8999,  0.2644,
        -0.9700, -0.2610, -0.9228,  0.4016,  0.1170,  0.8570, -0.3587,  0.9672,
         0.0667,  0.1108, -0.1840,  0.4711,  0.3127, -0.9391, -0.9892, -0.9908,
         0.3962, -0.5013, -0.0640,  0.3811,  0.1530,  0.4712,  0.3781, -1.0000,
         0.9466,  0.3529,  0.2077,  0.9735,  0.2019,  0.4726,  0.4248, -0.9892,
        -0.9203, -0.3418, -0.2910,  0.6572,  0.5584,  0.8190,  0.4319, -0.4171,
        -0.4697,  0.4653, -0.8583, -0.9940,  0.4802,  0.0740, -0.8986,  0.9559,
        -0.4745, -0.1616,  0.4457,  0.1412,  0.8933,  0.8280,  0.4313,  0.2437,
         0.6787,  0.9043,  0.8940,  0.9903, -0.2561,  0.6986, -0.0055,  0.3281,
         0.6809, -0.9586,  0.1583,  0.0033, -0.2711,  0.3025, -0.1928, -0.9207,
         0.5260, -0.2139,  0.5709, -0.2302,  0.1593, -0.4779, -0.1577, -0.7036,
        -0.5208,  0.4676,  0.2335,  0.9372,  0.4775, -0.1995, -0.5655, -0.2336,
         0.0798, -0.9315,  0.8288, -0.0946,  0.5294,  0.0223, -0.0744,  0.7821,
         0.1236, -0.3705, -0.3959, -0.7528,  0.8145, -0.3204, -0.4786, -0.5135,
         0.7306,  0.3208,  0.9981, -0.3959, -0.3492, -0.1118, -0.2872,  0.3596,
        -0.1345, -1.0000,  0.2896,  0.2262,  0.1702, -0.3530,  0.1111, -0.0755,
        -0.9565, -0.2658,  0.2530, -0.0490, -0.5834, -0.4616,  0.3937,  0.2329,
         0.5620,  0.8138, -0.0288,  0.5621,  0.3811,  0.0852, -0.6049,  0.8452]],
      grad_fn=<TanhBackward0>)
```

In [120]:
```
data.shape
```

Out [120]: (13283, 15)

In [121]:
```
df=tweets_df
```

In [122]:
```
# Sabing value counts to a list
class_counts=df['airline_sentiment'].value_counts().to_list()
```

In [122]:
```

```

In [123]:
```
#TEXT CLEANING
```

In [124]:
```
def preprocess(text):
  # converting text tolower case
  text=text.lower()
  # remove user mentions
  text=re.sub(r'@[A-Za-z0-9]+','',text)
  # remove hashtags if needed keep for now
  #text=re.sub(r'#[A-Za-z0-9]+','',text)

  # remove links
  text=re.sub(r'http\S+','',text)

  # Split tokens so that extra spaces which were added due to above substitution are removed
  tokens=text.split()

  # join tokens by space
  return ' '.join(tokens)
```

In [125]:
```
# using apply function to apply this preprocess function on each row of the text column
data['cleaned_text']=data['text'].apply(preprocess)
```

In [126]:
```
data.head()[['airline_sentiment','text','cleaned_text']]
```

Out [126]:

	airline_sentiment	text	cleaned_text
0	neutral	@VirginAmerica What @dhepburn said.	what said.
1	neutral	@VirginAmerica I didn't today... Must mean I need to take another trip!	i didn't today... must mean i need to take another trip!
2	negative	@VirginAmerica it's really aggressive to blast obnoxious "entertainment" in your guests' faces & they have little recourse	it's really aggressive to blast obnoxious "entertainment" in your guests' faces & they have little recourse
3	negative	@VirginAmerica and it's a really big bad thing about it	and it's a really big bad thing about it
4	negative	@VirginAmerica seriously would pay $30 a flight for seats that didn't have this playing.\nit's really the only bad thing about flying VA	seriously would pay $30 a flight for seats that didn't have this playing. it's really the only bad thing about flying va

In [127]:
```
# Saving cleaned text and labels to variables
text=data['cleaned_text'].values
labels=data['airline_sentiment'].values
```

In [127]:
```

```

In [128]:
```
#PREPARING INPUT AND OUTPUT
```

In [129]:
```
from sklearn.preprocessing import LabelEncoder
le = LabelEncoder()
```

In [130]:
```
# Using label encoder, convert textual labels (positive, negative, neutral) into numners
le=LabelEncoder()

#fit and transform target strings to a number
labels=le.fit_transform(labels)
```

In [131]:
```
le.classes_
```

Out [131]:
```
array(['negative', 'neutral', 'positive'], dtype=object)
```

In [132]:
```
labels
```

Out [132]:
```
array([1, 1, 0, ..., 0, 0, 0])
```

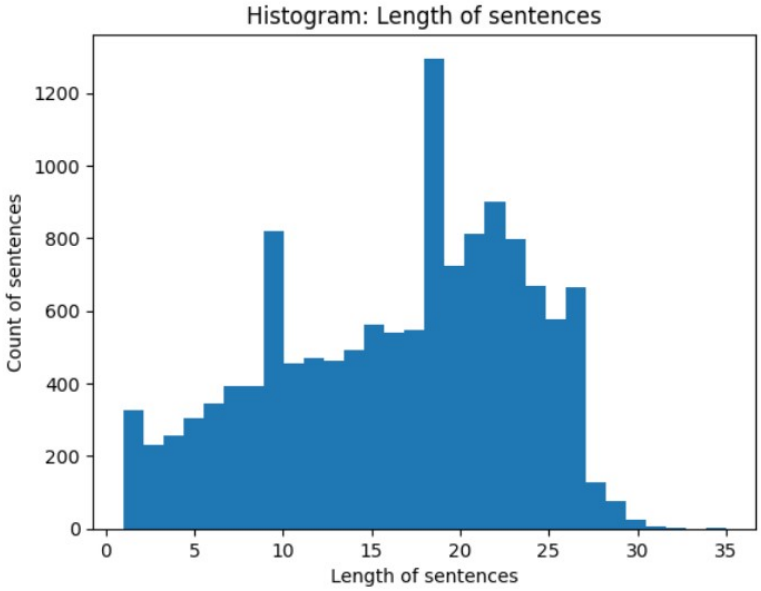
In [133]:
```
len(labels)
```

Out [133]:
```
13283
```

In [134]:
```
#VISUALIZATION
```

In [135]:
```
num=[len(i.split()) for i in text]
plt.hist(num,bins=30)
plt.title('Histogram: Length of sentences')
plt.xlabel('Length of sentences')
plt.ylabel('Count of sentences')
```

Out [135]:
```
Text(0, 0.5, 'Count of sentences')
```



In [136]:
```
max_len=28 # This is a hyper parameter which can be tuned
```

In [137]:
```
# Create an empty list to save integer sequence
sent_id=[]

# iterate over each tweet and encode it using bert tokenizer
for i in notebook.tqdm(range(len(text))):
  encoded_sent=tokenizer.encode(text[i],
                                add_special_tokens=True,
                                max_length= max_len,
                                truncation=True,
                                pad_to_max_length='right' )

  # save integer sequence to a list
  sent_id.append(encoded_sent)
```

```
  0%|          | 0/13283 [00:00<?, ?it/s]

/usr/local/lib/python3.10/dist-packages/transformers/tokenization_utils_base.py:2606: FutureWarning: The `pad_to_max_length` argument is deprecated and will be removed in a future version, use `padding=True` or `padding='longest'` to pad to the longest sequence in the batch, or use `padding='max_length'` to pad to a max length. In this case, you can give a specific length with `max_length` (e.g. `max_length=45`) or leave max_length to None to pad to the maximal input size of the model (e.g. 512 for Bert).
  warnings.warn(
```

In [138]:
```
print(text[0])
```

```
what said.
```

In [139]:
```
print(sent_id[0])
```

```
[101, 2054, 2056, 1012, 102, 0, 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 [140]:
```
len(sent_id)
```

Out [140]: 13283

In [141]:
```
attention_mask=[]

for sent in sent_id:
  attn_mask=[int(token_id>0) for token_id in sent]
  attention_mask.append(attn_mask)
```

In [142]:
```
len(attention_mask)
```

Out [142]: 13283

In [142]:
```

```

In [143]:
```
#Training and Validation Data
```

In [144]:
```
# Splitting input data
train_inputs,validation_inputs, train_labels,validation_labels=train_test_split(sent_id,labels,random_state=201
# Splitting masks
train_mask,validation_mask,_,_= train_test_split(attention_mask,labels,random_state=2018,test_size=0.1,stratify
```

In [145]:
```
# Converting all inputs and labels into torch tensors which is the required datatype for the BERT model

train_inputs=torch.tensor(train_inputs)
train_labels=torch.tensor(train_labels)
train_mask=torch.tensor(train_mask)

validation_inputs=torch.tensor(validation_inputs)
validation_labels=torch.tensor(validation_labels)
validation_mask=torch.tensor(validation_mask)
```

In [146]:
```
validation_inputs
```

Out [146]:
```
tensor([[ 101, 2061, 2008,  ...,     2138,     1997,
          101, 2821, 1012,  102], ...,    0,    0,
          101, 2339,                0], ...,    0,
         2052, ...,                 0,    0],
          101, 4283, 2005,
          101, 7632, 2045,  ...,    0,    0,
          101, 2059, 2339,           0],  ...,  1018,
                             2847,   102], ...,  2572,
                             1045,   102]])
```

In [147]:
```
# batch size
batch_size=64

# Creating Tensor Dataset for training data
train_data=TensorDataset(train_inputs,train_mask,train_labels)

# Defining a random sampler during training
train_sampler=RandomSampler(train_data)

# Creating iterator using DataLoader. This iterator supports batching, customized data loading order
train_dataloader=DataLoader(train_data,sampler=train_sampler,batch_size=batch_size )

# Creating tensor dataset for validation data
validation_data=TensorDataset(validation_inputs,validation_mask,validation_labels)

# Defining a sequential sampler during validation, bcz there is no need to shuffle the data. We just need to va
validation_sampler=SequentialSampler(validation_data)
# Create an iterator over validation dataset
validation_dataloader=DataLoader(validation_data,sampler=validation_sampler,batch_size=batch_size)
```

In [148]:
```
# Create an iterator object
iterator=iter(train_dataloader)

# loads batch data
sent_id,mask,target=iterator.__next__()
```

In [149]:
```
sent_id.shape
```

Out [149]:
```
torch.Size([64, 28])
```

In [150]:
```
outputs=bert(sent_id,attention_mask=mask)
```

In [151]:
```
hidden_states=outputs[0]
CLS_hidden_state=outputs[1]

print("Shape of Hidden States:",hidden_states.shape)
print("Shape of CLS Hidden State:",CLS_hidden_state.shape)
```

```
Shape of Hidden States: torch.Size([64, 28, 768])
Shape of CLS Hidden State: torch.Size([64, 768])
```

In [152]:
```
type(hidden_states)
```

Out [152]:
```
torch.Tensor
```

In [152]:
```

```

In [153]:
```
#Fine-Tuning BERT
```

In [154]:
```
# turn off the gradient of all parameters

for param in bert.parameters():
  param.requires_grad=False
```

In [155]:
```
class classifier(nn.Module):

    #define the layers and wrappers used by model
    def __init__(self, bert):

      #constructor
      super(classifier, self).__init__()

      #bert model
      self.bert = bert

      # dense layer 1
      self.fc1 = nn.Linear(768,512)

      #dense layer 2 (Output layer)
      self.fc2 = nn.Linear(512,3)

      #dropout layer
      self.dropout = nn.Dropout(0.1)

      #relu activation function
      self.relu =  nn.ReLU()

      #softmax activation function
      self.softmax = nn.LogSoftmax(dim=1)

    #define the forward pass
    def forward(self, sent_id, mask):

      #pass the inputs to the model
      all_hidden_states, cls_hidden_state = self.bert(sent_id, attention_mask=mask, return_dict=False)
```

```
        #pass CLS hidden state to dense layer
        x = self.fc1(cls_hidden_state)

        #Apply ReLU activation function
        x = self.relu(x)

        #Apply Dropout
        x = self.dropout(x)

        #pass input to the output layer
        x = self.fc2(x)

        #apply softmax activation
        x = self.softmax(x)

        return x
```

In [156]:
```
# create the model
model=classifier(bert)

# push the model to GPU, if available
model=model.to(device)
```

In [157]:
```
# model arcitecture
model
```

Out [157]:
```
classifier(
  (bert): BertModel(  (embeddings):
    BertEmbeddings(
      (word_embeddings): Embedding(30522, 768, padding_idx=0)
      (position_embeddings): Embedding(512, 768)
      (token_type_embeddings): Embedding(2, 768)
      (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
      (dropout): Dropout(p=0.1, inplace=False)
    )
    (encoder):
      BertEncoder( (layer):
      ModuleList(
        (0-11): 12 x
          BertLayer( (attention):
          BertAttention(
            (self): BertSelfAttention(
              (query): Linear(in_features=768, out_features=768, bias=True)
              (key): Linear(in_features=768, out_features=768, bias=True)
              (value): Linear(in_features=768, out_features=768, bias=True)
              (dropout): Dropout(p=0.1, inplace=False)
            )
            (output): BertSelfOutput(
              (dense): Linear(in_features=768, out_features=768, bias=True)
              (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
              (dropout): Dropout(p=0.1, inplace=False)
            ) )
          (intermediate): BertIntermediate(
            (dense): Linear(in_features=768, out_features=3072, bias=True)
            (intermediate_act_fn): GELUActivation()
          )
          (output): BertOutput(
            (dense): Linear(in_features=3072, out_features=768, bias=True)
            (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
            (dropout): Dropout(p=0.1, inplace=False)
          ) )
      ) )
    (pooler): BertPooler(
      (dense): Linear(in_features=768, out_features=768, bias=True)
      (activation): Tanh()
    ) )
  (fc1): Linear(in_features=768, out_features=512, bias=True)
  (fc2): Linear(in_features=512, out_features=3, bias=True)
  (dropout): Dropout(p=0.1, inplace=False)
  (relu): ReLU()
  (softmax): LogSoftmax(dim=1) )
```

In [158]:
```
type(sent_id)
```

Out [158]:
```
torch.Tensor
```

In [159]:
```
# push the tensors to GPU
sent_id=sent_id.to(device)
mask=mask.to(device)
target=target.to(device)
```

In [160]:
```
# pass inputs to the model
outputs=model(sent_id,mask)
```

In [161]:
```
outputs=outputs.to(device)
```

In [162]:
```
print(outputs)
```

```
tensor([[-1.2232, -1.0100, -1.0744],
        [-1.1630, -1.1001, -1.0368],
        [-1.2991, -0.9757, -1.0490],
        [-1.1139, -1.0148, -1.1737],
        [-1.2009, -1.0234, -1.0797],
        [-1.1697, -1.0318, -1.0991],
        [-1.0872, -1.0524, -1.1592],
        [-1.2265, -0.9934, -1.0895],
        [-1.1732, -1.0778, -1.0490],
        [-1.1801, -1.0813, -1.0397],
        [-1.1764, -1.0488, -1.0752],
        [-1.1602, -1.0256, -1.1148],
        [-1.2054, -1.0620, -1.0366],
        [-1.1465, -1.0620, -1.0892],
        [-1.2220, -1.0083, -1.0773],
        [-1.2599, -0.9961, -1.0584],
        [-1.2138, -1.0896, -1.0035],
        [-1.1712, -1.1177, -1.0134],
        [-1.2372, -1.0056, -1.0672],
        [-1.1331, -1.1503, -1.0178],
        [-1.2231, -1.0425, -1.0409],
        [-1.1484, -1.1201, -1.0311],
        [-1.2305, -0.9841, -1.0963],
        [-1.2644, -0.9668, -1.0868],
        [-1.1275, -1.0897, -1.0793],
        [-1.1852, -1.0842, -1.0324],
        [-1.1931, -1.0517, -1.0574],
        [-1.1857, -1.0545, -1.0611],
        [-1.2097, -1.0274, -1.0677],
        [-1.1815, -1.0492, -1.0701],
        [-1.1104, -1.0503, -1.1371],
        [-1.1696, -1.0490, -1.0811],
        [-1.2009, -1.0319, -1.0708],
        [-1.1560, -1.0016, -1.1458],
        [-1.2123, -1.0040, -1.0905],
        [-1.2090, -1.0525, -1.0428],
        [-1.2269, -1.0298, -1.0506],
        [-1.1871, -1.0303, -1.0846],
        [-1.1873, -1.0200, -1.0955],
        [-1.1152, -1.0546, -1.1275],
        [-1.1781, -1.0283, -1.0950],
        [-1.1709, -1.0207, -1.1099],
        [-1.1761, -1.0342, -1.0906],
        [-1.1532, -1.0311, -1.1154],
        [-1.0658, -1.0251, -1.2147],
        [-1.0293, -1.0305, -1.2521],
        [-1.2047, -1.0635, -1.0356],
        [-1.2065, -1.0597, -1.0379],
        [-1.1798, -1.0853, -1.0360],
        [-1.1391, -1.0284, -1.1323],
        [-1.2485, -1.0418, -1.0210],
        [-1.2462, -1.0245, -1.0401],
        [-1.1619, -1.0094, -1.1312],
        [-1.1140, -1.0380, -1.1470],
        [-1.1645, -1.0683, -1.0662],
        [-1.2286, -0.9953, -1.0856],
        [-1.1400, -1.0602, -1.0972],
        [-1.1500, -1.0331, -1.1164],
        [-1.1303, -1.0630, -1.1038],
        [-1.2427, -1.0062, -1.0619],
        [-1.1400, -1.0412, -1.1173],
        [-1.1931, -1.0781, -1.0315],
        [-1.1844, -1.0609, -1.0558],
        [-1.1058, -1.0606, -1.1307]], device='cuda:0',
       grad_fn=<LogSoftmaxBackward0>)
```

In [163]:
```
# no. of trainable parameters
def count_parameters(model):
  return sum(p.numel() for p in model.parameters() if p.requires_grad)

print(f'The model has {count_parameters(model):,} trainable parameters')
```

```
The model has 395,267 trainable parameters
```

In [164]:
```
# Adam optmizer
optimizer=torch.optim.Adam(model.parameters(),lr=0.0005)
```

In [165]:
```
# Understnding class distribution

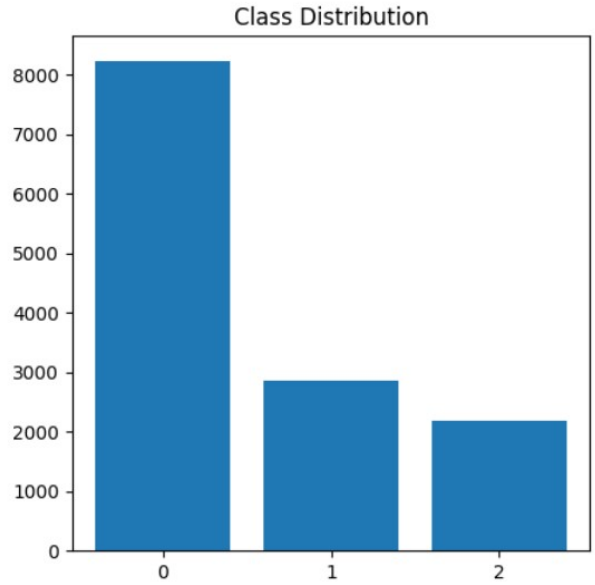
keys=['0','1','2']
```

```
# set figure size
plt.figure(figsize=(5,5))

# plot bar chart
plt.bar(keys,class_counts)

# set title
plt.title('Class Distribution')
```

Out [165]: Text(0.5, 1.0, 'Class Distribution')



In [166]:
```
# library for array processing
import numpy as np

# computing the class weights
class_weights=compute_class_weight(class_weight='balanced',classes=np.unique(labels),y=labels)
print("Class Weights:",class_weights)
```

```
Class Weights: [0.53746864 1.55302233 2.01807961]
```

In [167]:
```
# Converting a list of class weights into a tensor
weights=torch.tensor(class_weights, dtype=torch.float)

# transferring weights to GPU
weights=weights.to(device)

# define the loss function
cross_entropy=nn.NLLLoss(weight=weights)
```

In [168]:
```
# Computing the loss
print(target)
#print(outputs)
loss=cross_entropy(outputs,target)
print('Loss: ',loss)
```

```
tensor([0, 1, 2, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 2, 0, 1, 0, 2, 0, 0,
        0, 0, 0, 1, 0, 0, 2, 1, 0, 0, 0, 0, 0, 0, 2, 2, 1, 0, 0, 1, 2, 1, 0, 1,
        0, 2, 1, 2, 0, 2, 2, 0, 2, 2, 0, 0, 0, 1, 0, 2], device='cuda:0')
Loss:  tensor(1.1130, device='cuda:0', grad_fn=<NllLossBackward0>)
```

In [169]:
```
# Function for computing time in hh:mm:ss

def format_time(elapsed):

  elapsed_rounded=int(round(elapsed))

  # format intp hh:mm:ss
  return str(datetime.timedelta(seconds=elapsed_rounded))
```

In [170]:

```
# Defining a training function for the model:

def train():
  print('\n Training')

  # set the model on training phase- Dropout layers are activated
  model.train()
  # recording current time
  t0=time.time()
  # initialize the loss and accuracy to 0
  total_loss,total_accuracy=0,0

  # Create an empty list to save the model prediction
  total_preds=[]

  # for every batch
  for step, batch in enumerate(train_dataloader):
    #Progress update after every 40 batches
    if step % 40==0 and not step==0:
      elapsed=format_time(time.time()-t0)         # Calculate elapsed time in minutes
      print(' Batch{:>5,} of {:>5,}. Elapsed: {:}.'.format(step,len(train_dataloader),elapsed)) # Print progres
    batch=tuple(t.to(device) for t in batch)      # push the batch to GPU

    # batch is a part of all the records in train_dataloader. It contains 3 pytorch tensors:
    # [0]: input ids
    # [1]: attention masks
    # [2]: labels

    sent_id,mask,labels=batch

    #Pytorch doesn't automatically clear previously calculated gradients, hence before performing a backward pa
    model.zero_grad()

    # Perform a forward pass. This returns the model predictions
    preds=model(sent_id,mask)

    # Compute the loss between actual and predicted values
    loss=cross_entropy(preds,labels)

    #Accumulate training loss over all the batches, so that we can calculate the average loss at the end
    # loss is a tensor containing a single value.
    # .itme() method just returns the Python value from the tensor

    total_loss=total_loss+loss.item()

    # Perform backward pass to calculate the gradients
    loss.backward()
    # During backward pass, information about parameter changes flows backwards, from the output to the hidden

    optimizer.step()
    # Update parameters and take a step using the computed gradient.
    # Here, the optimizer dictates the update rule = how the parameters are modified based on their gradients,

    # The model predictions are stored on GPU, so push it to CPU
    preds=preds.detach().cpu().numpy()

    # Accumulate model predicitons of each batch
    total_preds.append(preds)



    # Compute the training loss of an epoch
  avg_loss=total_loss/len(train_dataloader)

  # The prediction are in the form of (no. of batches, size of batch, no. of classes)
  # So we need to resahpe the predictions in the form of number of samples x number of classes
```

```
  total_preds=np.concatenate(total_preds, axis=0)

  return avg_loss,total_preds
```

In [170]:

In [171]:
```
#EVALUATION
```

In [172]:
```
# define a function for evaluating the model

def evaluate():
  print("'n Evaluating....")

  # set the model on validation phase. Here dropout layers are deactivated
  model.eval()

  # record the current time
  t0=time.time()

  # initialize loss and accuracy to 0
  total_loss, total_accuracy=0,0

  # Create an empty list to save model predicitons
  total_preds=[]

  # for each batch

  for step, batch in enumerate(validation_dataloader):
    if step%40==0 and not step ==0:
      elapsed=format_time(time.time()-t0)
      print('  Batch {:>5,}  of  {:>5,}.    Elapsed: {:}.'.format(step, len(validation_dataloader), elapsed))

    batch=tuple(t.to(device) for t in batch)
    sent_id,mask,labels=batch

    #deactivate autograd
    with torch.no_grad():

      preds=model(sent_id,mask)
      loss=cross_entropy(preds,labels)
      total_loss=total_loss+loss.item()
      preds=preds.detach().cpu().numpy()
      total_preds.append(preds)

    avg_loss=total_loss/len(validation_dataloader)

    total_preds=np.concatenate(total_preds,axis=0)

    return avg_loss,total_preds
```

In [173]:
```
#define a function for evaluating the model
def evaluate():

  print("\nEvaluating.....")

  #set the model on training phase - Dropout layers are deactivated
  model.eval()

  #record the current time
  t0 = time.time()

  #initialize the loss and accuracy to 0
  total_loss, total_accuracy = 0, 0

  #Create a empty list to save the model predictions
  total_preds = []
```

```
  #for each batch
  for step,batch in enumerate(validation_dataloader):

    # Progress update every 40 batches.
    if step % 40 == 0 and not step == 0:

      # Calculate elapsed time in minutes.
      elapsed = format_time(time.time() - t0)

      # Report progress.
      print('  Batch {:>5,}  of  {:>5,}.    Elapsed: {:}.'.format(step, len(validation_dataloader), elapsed))

    #push the batch to gpu
    batch = tuple(t.to(device) for t in batch)

    #unpack the batch into separate variables
    # `batch` contains three pytorch tensors:
    #   [0]: input ids
    #   [1]: attention masks
    #   [2]: labels
    sent_id, mask, labels = batch

    #deactivates autograd
    with torch.no_grad():

      # Perform a forward pass. This returns the model predictions
      preds = model(sent_id, mask)

      #compute the validation loss between actual and predicted values
      loss = cross_entropy(preds,labels)

      # Accumulate the validation loss over all of the batches so that we can
      # calculate the average loss at the end. `loss` is a Tensor containing a
      # single value; the `.item()` function just returns the Python value
      # from the tensor.
      total_loss = total_loss + loss.item()

      #The model predictions are stored on GPU. So, push it to CPU
      preds=preds.detach().cpu().numpy()

      #Accumulate the model predictions of each batch
      total_preds.append(preds)

  #compute the validation loss of a epoch
  avg_loss = total_loss / len(validation_dataloader)

  #The predictions are in the form of (no. of batches, size of batch, no. of classes).
  #So, reshaping the predictions in form of (number of samples, no. of classes)
  total_preds  = np.concatenate(total_preds, axis=0)

  return avg_loss, total_preds
```

In [173]:

In [174]:
```
#TRAIN MODEL
```

In [175]:
```
# Assign the initial loss to infinite
best_valid_loss=float('inf')

# Create an empty list to store training and validation loss of each epoch
train_losses=[]
valid_losses=[]

epochs=5

#for each epoch repeat call the train() method
```

```
for epoch in range(epochs):
  print('\n .............epoch {:} / {:} .......'.format(epoch + 1, epochs))

  #train model
  train_loss,_ =train()

  #evaluate model
  valid_loss,_=evaluate()

  # save the best model
  if valid_loss<best_valid_loss:
    best_valid_loss=valid_loss
    torch.save(model.state_dict(),'Saved_weights.pt')

  # Accumulate training and validaion loss
  train_losses.append(train_loss)
  valid_losses.append(valid_loss)

  print(f'\nTraining Loss: {train_loss:.3f}')
  print(f'Validation Loss: {valid_loss:.3f}')

print("")
print("Training complete!")
```

```
 .............epoch 1 / 5 .......

 Training
 Batch   40 of   187. Elapsed: 0:00:04.
 Batch   80 of   187. Elapsed: 0:00:08.
 Batch  120 of   187. Elapsed: 0:00:12.
 Batch  160 of   187. Elapsed: 0:00:16.

Evaluating.....

Training Loss: 0.990
Validation Loss: 0.910

 .............epoch 2 / 5 .......

 Training
 Batch   40 of   187. Elapsed: 0:00:04.
 Batch   80 of   187. Elapsed: 0:00:09.
 Batch  120 of   187. Elapsed: 0:00:13.
 Batch  160 of   187. Elapsed: 0:00:17.

Evaluating.....

Training Loss: 0.824
Validation Loss: 0.775

 .............epoch 3 / 5 .......

 Training
 Batch   40 of   187. Elapsed: 0:00:04.
 Batch   80 of   187. Elapsed: 0:00:09.
 Batch  120 of   187. Elapsed: 0:00:14.
 Batch  160 of   187. Elapsed: 0:00:18.

Evaluating.....

Training Loss: 0.774
Validation Loss: 0.722

 .............epoch 4 / 5 .......

 Training
 Batch   40 of   187. Elapsed: 0:00:04.
 Batch   80 of   187. Elapsed: 0:00:09.
 Batch  120 of   187. Elapsed: 0:00:14.
 Batch  160 of   187. Elapsed: 0:00:18.

Evaluating.....

Training Loss: 0.746
Validation Loss: 0.771

 .............epoch 5 / 5 .......

 Training
 Batch   40 of   187. Elapsed: 0:00:04.
 Batch   80 of   187. Elapsed: 0:00:09.
 Batch  120 of   187. Elapsed: 0:00:13.
 Batch  160 of   187. Elapsed: 0:00:18.

Evaluating.....

Training Loss: 0.744
Validation Loss: 0.698

Training complete!
```

In [175]:

In [176]:
```
#EVALUATE MODEL
```

In [177]:
```
  # load weights of best model
path='Saved_weights.pt'
model.load_state_dict(torch.load(path))
```

Out [177]: <All keys matched successfully>

In [178]:
```
# get the model prediction on the validation data
valid_loss, preds=evaluate()
# this returns 2 elements- Validation loss and prediction
print(valid_loss)
```

```
Evaluating.....
0.698055747009459
```

In [179]:
```
# Converting the log(probabilities) into class & then choosing index of maximum value as class
y_pred=np.argmax(preds,axis=1)

# actual labels
y_true=validation_labels
```

In [180]:
```
print(classification_report(y_true,y_pred))
```

```
              Precision    recall  f1-score   support

           0       0.88      0.77      0.82       824
           1       0.51      0.55      0.53       285
           2       0.57      0.80      0.66       220

    accuracy                           0.72      1329
   macro avg       0.65      0.70      0.67      1329
weighted avg       0.75      0.72      0.73      1329
```

CONCLUSION

In this initial phase of our sentiment analysis project, we've made significant progress by successfully loading and preprocessing the dataset and using nlp {BERT} . This foundational step is crucial for the success of our entire project, as the quality and structure of our data will directly impact the accuracy and reliability of our sentiment analysis models. By loading the dataset, we've bridged the gap between raw data and actionable insights, making it accessible for further analysis. Our preprocessing efforts, which included tasks such as text cleaning, tokenization, and handling missing values, have improved the data's quality, making it ready for more advanced natural language processing techniques.

Loading the dataset was more than just a technical task; it marked the beginning of our journey towards understanding and predicting sentiment in text. The dataset, comprised of text data from various sources, holds the potential to reveal valuable insights about people's opinions, emotions, and attitudes. By ensuring it is correctly structured and prepared, we are one step closer to extracting meaningful information. Our diligent preprocessing work ensures that the data is consistent and free from common issues that could otherwise lead to biased or inaccurate results in our sentiment analysis.

As we move forward in this sentiment analysis project, we can build upon this solid foundation. The loaded and preprocessed dataset serves as the cornerstone for our data-driven insights, allowing us to explore different natural language processing techniques, sentiment analysis algorithms, and model development. With this groundwork in place, we are now better equipped to delve into the fascinating world of sentiment analysis and ultimately provide valuable insights that can inform decision-making, marketing strategies, and much more. Our commitment to data quality and preprocessing sets the stage for the success of our sentiment analysis solution.