In [1]:

```
import pandas as pd
import numpy as np
from bs4 import BeautifulSoup as bs
import requests

import string
from collections import Counter
import seaborn as sns
import matplotlib.pyplot as plt
from nltk.corpus import stopwords
from nltk.sentiment.vader import SentimentIntensityAnalyzer
from nltk.stem import WordNetLemmatizer
from nltk.tokenize import word_tokenize
import nltk
import warnings
warnings.filterwarnings('ignore')
```

In [42]:

```
!wget "https://s3.amazonaws.com/dl4j-distribution/GoogleNews-vectors-negative300.bin.gz"
```

```
--2022-03-27 14:21:50--  https://s3.amazonaws.com/dl4j-distribution/GoogleNews-vectors-negative300.bin.gz (htt
ps://s3.amazonaws.com/dl4j-distribution/GoogleNews-vectors-negative300.bin.gz)
Resolving s3.amazonaws.com (s3.amazonaws.com)... 52.216.88.13
Connecting to s3.amazonaws.com (s3.amazonaws.com)|52.216.88.13|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1647046227 (1.5G) [application/x-gzip]
Saving to: ‘GoogleNews-vectors-negative300.bin.gz’

GoogleNews-vectors- 100%[===================>]   1.53G  45.2MB/s    in 35s

2022-03-27 14:22:26 (44.5 MB/s) - ‘GoogleNews-vectors-negative300.bin.gz’ saved [1647046227/1647046227]
```

In [2]:

```
import tensorflow as tf
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np


import nltk
nltk.download('stopwords')
from nltk.corpus import stopwords
from nltk.stem import SnowballStemmer



from sklearn.model_selection import train_test_split
from sklearn.preprocessing import LabelEncoder


import re
from keras.preprocessing.sequence import pad_sequences
from keras.models import Sequential
from keras.layers import Dense, Embedding, LSTM, SpatialDropout1D
from sklearn.model_selection import train_test_split
from keras.utils.np_utils import to_categorical
from keras.callbacks import EarlyStopping
from keras.layers import Dropout
import re
from nltk.corpus import stopwords
from nltk import word_tokenize
STOPWORDS = set(stopwords.words('english'))
from bs4 import BeautifulSoup
import plotly.graph_objs as go

#import cufflinks
from IPython.core.interactiveshell import InteractiveShell
import plotly.figure_factory as ff
InteractiveShell.ast_node_interactivity = 'all'

print("Tensorflow Version",tf.__version__)
```

```
[nltk_data] Downloading package stopwords to /root/nltk_data...
[nltk_data]   Unzipping corpora/stopwords.zip.
Tensorflow Version 2.8.0
```

In [3]:
```
model_data = pd.read_csv("/content/model_data.csv")
model_data.head()
```

Out[3]:

	title	summary	anger	anticipation	disgust	fear	joy	negative	positive	sadness	surprise	trust	sentiment_class
0	The Hunger Games	Could you survive on your own in the wild, wit...	8	8	10	9	6	16	11	11	5	5	Negative
1	Harry Potter and the Order of the Phoenix	There is a door at the end of a silent corrido...	14	7	5	15	6	18	18	13	5	10	Neutral
2	To Kill a Mockingbird	The unforgettable novel of a childhood in a sl...	2	4	2	5	8	8	15	5	1	2	Positive
3	Pride and Prejudice	Alternate cover edition of ISBN 9780679783268S...	5	15	2	3	22	8	26	0	3	15	Positive
4	The Book Thief	Librarian's note: An alternate cover edition c...	3	5	3	7	3	9	11	4	4	11	Positive

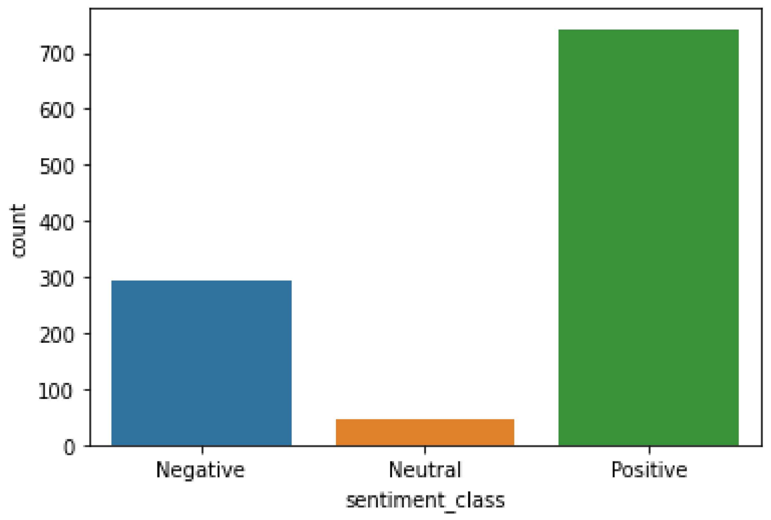
In [4]:
```
model_data.describe()
```

Out[4]:

	anger	anticipation	disgust	fear	joy	negative	positive	sadness	surprise	tru
count	1084.000000	1084.000000	1084.000000	1084.000000	1084.000000	1084.000000	1084.000000	1084.000000	1084.000000	1084.00000
mean	4.802583	7.273063	3.440037	7.455720	6.680812	10.226937	15.158672	5.087638	3.691882	8.29612
std	4.180568	4.835920	3.160102	5.472577	4.949567	6.611929	8.652238	4.011373	2.938126	5.39637
min	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.00000
25%	2.000000	4.000000	1.000000	3.000000	3.000000	5.000000	9.000000	2.000000	2.000000	4.00000
50%	4.000000	7.000000	3.000000	6.000000	6.000000	9.000000	14.000000	4.000000	3.000000	8.00000
75%	7.000000	10.000000	5.000000	11.000000	9.000000	14.000000	20.000000	7.000000	5.000000	11.00000
max	25.000000	46.000000	21.000000	31.000000	35.000000	39.000000	86.000000	25.000000	20.000000	58.00000

In [5]:
```
sns.countplot(x = 'sentiment_class', data = model_data)
```

Out[5]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f72f43e8e50>
```



Our data is imbalanced

In [6]:
```
from sklearn.metrics import classification_report
from sklearn.preprocessing import LabelEncoder
df_summary = model_data[["title","summary", "sentiment_class"]]
```

Multiclass text classification

In [29]:

```
import logging
import pandas as pd
import numpy as np
from numpy import random
import gensim
import nltk
from sklearn.model_selection import train_test_split
from sklearn.feature_extraction.text import CountVectorizer, TfidfVectorizer
from sklearn.metrics import accuracy_score, confusion_matrix
import matplotlib.pyplot as plt
from nltk.corpus import stopwords
import re
from bs4 import BeautifulSoup
%matplotlib inline
```

Naive Bayes Classifier for Multinomial Models

In [34]:

```
from sklearn.naive_bayes import MultinomialNB
from sklearn.pipeline import Pipeline
from sklearn.feature_extraction.text import TfidfTransformer
X = df_summary.summary
y = df_summary.sentiment_class
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state = 42)



nb = Pipeline([('vect', CountVectorizer()),
               ('tfidf', TfidfTransformer()),
               ('clf', MultinomialNB()),
              ])
nb.fit(X_train, y_train)


from sklearn.metrics import classification_report
y_pred = nb.predict(X_test)

print('accuracy %s' % accuracy_score(y_pred, y_test))
print(classification_report(y_test, y_pred,target_names=["Positive", "Negative", "Neutral"]))
```

Out[34]:

```
Pipeline(steps=[('vect', CountVectorizer()), ('tfidf', TfidfTransformer()),
                ('clf', MultinomialNB())])

accuracy 0.6748466257668712
              precision    recall  f1-score   support

    Positive       0.00      0.00      0.00        96
    Negative       0.00      0.00      0.00        10
     Neutral       0.67      1.00      0.81       220

    accuracy                           0.67       326
   macro avg       0.22      0.33      0.27       326
weighted avg       0.46      0.67      0.54       326
```

In [35]:

```
my_tags = ["Positive", "Negative", "Neutral"]
```

Linear Support Vector Machine

In [38]:
```
from sklearn.linear_model import SGDClassifier

sgd = Pipeline([('vect', CountVectorizer()),
                ('tfidf', TfidfTransformer()),
                ('clf', SGDClassifier(loss='hinge', penalty='l2',alpha=1e-3, random_state=42, max_iter=5, tol=No
               ])
sgd.fit(X_train, y_train)


y_pred = sgd.predict(X_test)

print('accuracy %s' % accuracy_score(y_pred, y_test))
print(classification_report(y_test, y_pred,target_names=my_tags))
```

Out[38]:
```
Pipeline(steps=[('vect', CountVectorizer()), ('tfidf', TfidfTransformer()),
                ('clf',
                 SGDClassifier(alpha=0.001, max_iter=5, random_state=42,
                               tol=None))])

accuracy 0.7239263803680982
              precision    recall  f1-score   support

    Positive       0.74      0.26      0.38        96
    Negative       0.00      0.00      0.00        10
     Neutral       0.72      0.96      0.82       220

    accuracy                           0.72       326
   macro avg       0.49      0.41      0.40       326
weighted avg       0.70      0.72      0.67       326
```

Logistic Regression

In [40]:
```
from sklearn.linear_model import LogisticRegression

logreg = Pipeline([('vect', CountVectorizer()),
                ('tfidf', TfidfTransformer()),
                ('clf', LogisticRegression(n_jobs=1, C=1e5)),
               ])
logreg.fit(X_train, y_train)



y_pred = logreg.predict(X_test)

print('accuracy %s' % accuracy_score(y_pred, y_test))
print(classification_report(y_test, y_pred,target_names=my_tags))
```

Out[40]:
```
Pipeline(steps=[('vect', CountVectorizer()), ('tfidf', TfidfTransformer()),
                ('clf', LogisticRegression(C=100000.0, n_jobs=1))])

accuracy 0.7331288343558282
              precision    recall  f1-score   support

    Positive       0.71      0.31      0.43        96
    Negative       0.00      0.00      0.00        10
     Neutral       0.74      0.95      0.83       220

    accuracy                           0.73       326
   macro avg       0.48      0.42      0.42       326
weighted avg       0.71      0.73      0.69       326
```

Word2vec and Logistic Regression

In [43]:
```
from gensim.models import Word2Vec
wv = gensim.models.KeyedVectors.load_word2vec_format("/content/GoogleNews-vectors-negative300.bin.gz", binary=Tr
wv.init_sims(replace=True)
```

In [44]:
```
def word_averaging(wv, words):
    all_words, mean = set(), []

    for word in words:
        if isinstance(word, np.ndarray):
            mean.append(word)
        elif word in wv.vocab:
            mean.append(wv.syn0norm[wv.vocab[word].index])
            all_words.add(wv.vocab[word].index)

    if not mean:
        logging.warning("cannot compute similarity with no input %s", words)
        # FIXME: remove these examples in pre-processing
        return np.zeros(wv.vector_size,)

    mean = gensim.matutils.unitvec(np.array(mean).mean(axis=0)).astype(np.float32)
    return mean

def  word_averaging_list(wv, text_list):
    return np.vstack([word_averaging(wv, post) for post in text_list ])
```

In [48]:
```
import nltk
nltk.download('punkt')
```

```
[nltk_data] Downloading package punkt to /root/nltk_data...
[nltk_data]   Unzipping tokenizers/punkt.zip.
```

Out[48]:
```
True
```

In [49]:
```
def w2v_tokenize_text(text):
    tokens = []
    for sent in nltk.sent_tokenize(text, language='english'):
        for word in nltk.word_tokenize(sent, language='english'):
            if len(word) < 2:
                continue
            tokens.append(word)
    return tokens

train, test = train_test_split(df_summary, test_size=0.3, random_state = 42)

test_tokenized = test.apply(lambda r: w2v_tokenize_text(r['summary']), axis=1).values
train_tokenized = train.apply(lambda r: w2v_tokenize_text(r['summary']), axis=1).values

X_train_word_average = word_averaging_list(wv,train_tokenized)
X_test_word_average = word_averaging_list(wv,test_tokenized)
```

In [53]:
```
from sklearn.linear_model import LogisticRegression
logreg = LogisticRegression(n_jobs=1, C=1e5)
logreg = logreg.fit(X_train_word_average, train['sentiment_class'])
y_pred = logreg.predict(X_test_word_average)
print('accuracy %s' % accuracy_score(y_pred, test.sentiment_class))
print(classification_report(test.sentiment_class, y_pred,target_names=my_tags))
```

```
accuracy 0.7239263803680982
              precision    recall  f1-score   support

    Positive       0.60      0.58      0.59        96
    Negative       0.00      0.00      0.00        10
     Neutral       0.82      0.82      0.82       220

    accuracy                           0.72       326
   macro avg       0.47      0.47      0.47       326
weighted avg       0.73      0.72      0.73       326
```

Doc2vec and Logistic Regression

In [57]:

```
from tqdm import tqdm
tqdm.pandas(desc="progress-bar")
from gensim.models import Doc2Vec
from sklearn import utils
import gensim
#from gensim.models.doc2vec import TaggedDocument
import re

from gensim.models import Doc2Vec
import gensim
from gensim.models.doc2vec import TaggedDocument

def label_sentences(corpus, label_type):
    """
    Gensim's Doc2Vec implementation requires each document/paragraph to have a label associated with it.
    We do this by using the TaggedDocument method. The format will be "TRAIN_i" or "TEST_i" where "i" is
    a dummy index of the post.
    """
    labeled = []
    for i, v in enumerate(corpus):
        label = label_type + '_' + str(i)
        labeled.append(TaggedDocument(v.split(), [label]))
    return labeled
X_train, X_test, y_train, y_test = train_test_split(df_summary.summary, df_summary.sentiment_class, random_state
X_train = label_sentences(X_train, 'Train')
X_test = label_sentences(X_test, 'Test')
all_data = X_train + X_test
```

In [58]:

```
model_dbow = Doc2Vec(dm=0, vector_size=300, negative=5, min_count=1, alpha=0.065, min_alpha=0.065)
model_dbow.build_vocab([x for x in tqdm(all_data)])

for epoch in range(30):
    model_dbow.train(utils.shuffle([x for x in tqdm(all_data)]), total_examples=len(all_data), epochs=1)
    model_dbow.alpha -= 0.002
    model_dbow.min_alpha = model_dbow.alpha
```

```
100%|██████████| 1084/1084 [00:00<00:00, 906966.99it/s]
100%|██████████| 1084/1084 [00:00<00:00, 700342.81it/s]
100%|██████████| 1084/1084 [00:00<00:00, 284217.39it/s]
100%|██████████| 1084/1084 [00:00<00:00, 324457.68it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1062792.32it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1214376.48it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1149298.67it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1800643.78it/s]
100%|██████████| 1084/1084 [00:00<00:00, 254271.32it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1810683.21it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1144092.99it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1848221.76it/s]
100%|██████████| 1084/1084 [00:00<00:00, 232837.89it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1071306.68it/s]
100%|██████████| 1084/1084 [00:00<00:00, 743398.55it/s]
100%|██████████| 1084/1084 [00:00<00:00, 535969.06it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1226166.54it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1168798.34it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1924090.37it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1931446.70it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1168197.72it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1172717.45it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1185251.70it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1180328.54it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1950504.31it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1214052.21it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1133821.83it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1970795.64it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1915175.04it/s]
100%|██████████| 1084/1084 [00:00<00:00, 736414.89it/s]
100%|██████████| 1084/1084 [00:00<00:00, 1182785.00it/s]
```

In [59]:

```

def get_vectors(model, corpus_size, vectors_size, vectors_type):
    """
    Get vectors from trained doc2vec model
    :param doc2vec_model: Trained Doc2Vec model
    :param corpus_size: Size of the data
    :param vectors_size: Size of the embedding vectors
    :param vectors_type: Training or Testing vectors
    :return: list of vectors
    """
    vectors = np.zeros((corpus_size, vectors_size))
    for i in range(0, corpus_size):
        prefix = vectors_type + '_' + str(i)
        vectors[i] = model.docvecs[prefix]
    return vectors

train_vectors_dbow = get_vectors(model_dbow, len(X_train), 300, 'Train')
test_vectors_dbow = get_vectors(model_dbow, len(X_test), 300, 'Test')
```

In [60]:

```
logreg = LogisticRegression(n_jobs=1, C=1e5)
logreg.fit(train_vectors_dbow, y_train)
logreg = logreg.fit(train_vectors_dbow, y_train)
y_pred = logreg.predict(test_vectors_dbow)
print('accuracy %s' % accuracy_score(y_pred, y_test))
print(classification_report(y_test, y_pred,target_names=my_tags))
```

Out[60]:

```
LogisticRegression(C=100000.0, n_jobs=1)

accuracy 0.6809815950920245
              precision    recall  f1-score   support

    Positive       0.57      0.53      0.55        92
    Negative       0.05      0.07      0.06        15
     Neutral       0.79      0.79      0.79       219

    accuracy                           0.68       326
   macro avg       0.47      0.46      0.46       326
weighted avg       0.69      0.68      0.69       326
```

Deep learning

In [74]:

```

import itertools
import os

%matplotlib inline
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow.keras.utils import to_categorical

from sklearn.preprocessing import LabelBinarizer, LabelEncoder
from sklearn.metrics import confusion_matrix

from tensorflow import keras
from keras.models import Sequential
from keras.layers import Dense, Activation, Dropout
from keras.preprocessing import text, sequence
from keras import utils

train_size = int(len(df_summary) * .7)
train_posts = df_summary['summary'][:train_size]
train_tags = df_summary['sentiment_class'][:train_size]

test_posts = df_summary['summary'][train_size:]
test_tags = df_summary['sentiment_class'][train_size:]

max_words = 15000
tokenize = text.Tokenizer(num_words=max_words, char_level=False)
tokenize.fit_on_texts(train_posts) # only fit on train

x_train = tokenize.texts_to_matrix(train_posts)
x_test = tokenize.texts_to_matrix(test_posts)

encoder = LabelEncoder()
encoder.fit(train_tags)
y_train = encoder.transform(train_tags)
y_test = encoder.transform(test_tags)

num_classes = np.max(y_train) + 1
y_train = to_categorical(y_train, num_classes)
y_test = to_categorical(y_test, num_classes)

batch_size = 32
```

Out[74]:

```
LabelEncoder()
```

In [95]:

```
# Build the model
model = Sequential()
model.add(Dense(512, input_shape=(max_words,)))
model.add(Activation('relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes))
model.add(Activation('softmax'))

model.compile(loss='categorical_crossentropy',
              optimizer='adam',
              metrics=['accuracy'])

history = model.fit(x_train, y_train,
                    batch_size=batch_size,
                    epochs=10,
                    verbose=1,
                    validation_split=0.1)
```

```
Epoch 1/10
22/22 [==============================] - 3s 108ms/step - loss: 0.7807 - accuracy: 0.6848 - val_loss: 0.6965 -
val_accuracy: 0.6711
Epoch 2/10
22/22 [==============================] - 2s 83ms/step - loss: 0.3244 - accuracy: 0.9282 - val_loss: 0.6900 - v
al_accuracy: 0.7105
Epoch 3/10
22/22 [==============================] - 1s 61ms/step - loss: 0.1276 - accuracy: 0.9677 - val_loss: 0.7257 - v
al_accuracy: 0.7368
Epoch 4/10
22/22 [==============================] - 1s 67ms/step - loss: 0.0467 - accuracy: 0.9985 - val_loss: 0.7872 - v
al_accuracy: 0.7368
Epoch 5/10
22/22 [==============================] - 1s 54ms/step - loss: 0.0201 - accuracy: 1.0000 - val_loss: 0.8534 - v
al_accuracy: 0.7237
Epoch 6/10
22/22 [==============================] - 1s 59ms/step - loss: 0.0116 - accuracy: 1.0000 - val_loss: 0.8843 - v
al_accuracy: 0.7237
Epoch 7/10
22/22 [==============================] - 1s 62ms/step - loss: 0.0063 - accuracy: 1.0000 - val_loss: 0.9093 - v
al_accuracy: 0.7368
Epoch 8/10
22/22 [==============================] - 1s 56ms/step - loss: 0.0044 - accuracy: 1.0000 - val_loss: 0.9295 - v
al_accuracy: 0.7368
Epoch 9/10
22/22 [==============================] - 1s 62ms/step - loss: 0.0034 - accuracy: 1.0000 - val_loss: 0.9477 - v
al_accuracy: 0.7368
Epoch 10/10
22/22 [==============================] - 1s 54ms/step - loss: 0.0025 - accuracy: 1.0000 - val_loss: 0.9634 - v
al_accuracy: 0.7368
```

In [96]:

```
score = model.evaluate(x_test, y_test,
                       batch_size=batch_size, verbose=1)
print('Test accuracy:', score[1])
```

```
11/11 [==============================] - 0s 18ms/step - loss: 1.0118 - accuracy: 0.7147
Test accuracy: 0.7147239446640015
```