Sentiment Analysis Using Nueral Networks

Part I: Research Question

1. Research Question

Can positive or negative sentiment be predicted for future customers using a neural network and natural language processing (NLP)?

2. Goals

The goal of this analysis is to build a neural network that can predict positive or negative sentiment of future customers using previous customer reviews. This will lead to greater understanding of which products customers prefer and can help with future marketing decisions.

3. Neural Network Type

A recurrent neural network (RNN) will be used for this analysis. RNN considers that the next word depends on the previous words in the review. This is a many to one RNN. There are many inputs that lead to a single output, in this analysis, if the sentiment is positive or negative. (Saeed, 2021) The model will be built using a sequential neural network utilizing the TensorFlow and Keras libraries. A sequential model is used when the data is not 'independently and identically distributed' (Lendave, 2021). The data is not independent because the order of the words matter. If the order was changed, the meaning changes.

Part II: Data Preparation

1. Exploratory data analysis

Import packages

In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from tensorflow import keras
import warnings
warnings.filterwarnings('ignore')
```

Load Datasets

In [2]:

```
amazon_df = pd.read_csv('amazon_cells_labelled.txt', names = ['review', 'labe
yelp_df = pd.read_csv('yelp_labelled.txt', names = ['review', 'label'], sep =
imdb_df = pd.read_csv('imdb_labelled.csv',names = ['review', 'label'], sep =
```

Look at Dataframes and size

In [3]:

```
amazon_df.head()
```

Out[3]:

	review	label
0	So there is no way for me to plug it in here i...	0
1	Good case, Excellent value.	1
2	Great for the jawbone.	1
3	Tied to charger for conversations lasting more...	0
4	The mic is great.	1

In [4]:

```
amazon_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 2 columns):
 #   Column   Non-Null Count  Dtype 
---  ------   --------------  ----- 
 0   review   1000 non-null   object
 1   label    1000 non-null   int64 
dtypes: int64(1), object(1)
memory usage: 15.8+ KB
```

In [5]:

```
yelp_df.head()
```

Out[5]:

	review	label
0	Wow... Loved this place.	1
1	Crust is not good.	0
2	Not tasty and the texture was just nasty.	0
3	Stopped by during the late May bank holiday of...	1
4	The selection on the menu was great and so wer...	1

In [6]:

```
yelp_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 2 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   review  1000 non-null   object
 1   label   1000 non-null   int64
dtypes: int64(1), object(1)
memory usage: 15.8+ KB
```

In [7]:

```
imdb_df.head()
```

Out[7]:

	review	label
0	A very, very, very slow-moving, aimless movie ...	0
1	Not sure who was more lost - the flat characte...	0
2	Attempting artiness with black & white and cle...	0
3	Very little music or anything to speak of.	0
4	The best scene in the movie was when Gerardo i...	1

In [8]:

```
imdb_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 2 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   review  1000 non-null   object
 1   label   1000 non-null   int64
dtypes: int64(1), object(1)
memory usage: 15.8+ KB
```

Merge 3 dataframes into one.

code from: https://stackoverflow.com/questions/53877687/how-can-i-concat-multiple-dataframes-in-python

In [9]:

```
df_list = [amazon_df, yelp_df, imdb_df]
df = pd.concat(df_list, ignore_index = True)
df.head()
```

Out[9]:

	review	label
0	So there is no way for me to plug it in here i...	0
1	Good case, Excellent value.	1
2	Great for the jawbone.	1
3	Tied to charger for conversations lasting more...	0
4	The mic is great.	1

In [10]:

```
# Check size of new dataset. Should have two columns with 3000 rows.
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3000 entries, 0 to 2999
Data columns (total 2 columns):
 #   Column  Non-Null Count  Dtype 
---  ------  --------------  ----- 
 0   review  3000 non-null   object
 1   label   3000 non-null   int64 
dtypes: int64(1), object(1)
memory usage: 47.0+ KB
```

Get descriptive statistics to look at min and max. Should be between 0 and 1.

In [11]:

```
df.describe()
```

Out[11]:

	label
count	3000.000000
mean	0.499667
std	0.500083
min	0.000000
25%	0.000000
50%	0.000000
75%	1.000000
max	1.000000

Check for missing data

In [12]:

```
df.isnull().sum()
```

Out[12]:

```
review    0
label     0
dtype: int64
```

Make all words lower case

In [13]:

```
df['review'] = df['review'].str.lower()
df.head()
```

Out[13]:

	review	label
0	so there is no way for me to plug it in here i...	0
1	good case, excellent value.	1
2	great for the jawbone.	1
3	tied to charger for conversations lasting more...	0
4	the mic is great.	1

Remove all puncuation

In [14]:

```
df['review'] = df['review'].str.replace(r'[^\w\s]+', '')
df.head()
```

Out[14]:

	review	label
0	so there is no way for me to plug it in here i...	0
1	good case excellent value	1
2	great for the jawbone	1
3	tied to charger for conversations lasting more...	0
4	the mic is great	1

Remove special characters code from: https://towardsdatascience.com/simplify-your-dataset-cleaning-with-pandas-75951b23568e

In [15]:

```
spec_chars = ["!",'"',"#","%","&","'","(",")",
              "*","+",",","-",".","/",":",";","<",
              "=",">","?","@","[","\\","]","^","_",
              "`","{","|","}","~","–"]
for char in spec_chars:
    df['review'] = df['review'].str.replace(char, '')

df.head()
```

Out[15]:

	review	label
0	so there is no way for me to plug it in here i...	0
1	good case excellent value	1
2	great for the jawbone	1
3	tied to charger for conversations lasting more...	0
4	the mic is great	1

Remove digits from dataset

In [16]:

```
df['review'] = df['review'].str.replace('\d+', '')
```

Count number of words in each reviw and add count column

In [17]:

```
def word_count(string):
    words = string.split()
    return len (words)

df['count'] = df['review'].apply(word_count)
```

In [18]:

```
df.head()
```

Out[18]:

	review	label	count
0	so there is no way for me to plug it in here i...	0	21
1	good case excellent value	1	4
2	great for the jawbone	1	4
3	tied to charger for conversations lasting more...	0	10
4	the mic is great	1	4

Find total number of words

In [19]:

```
df['count'].sum()
```

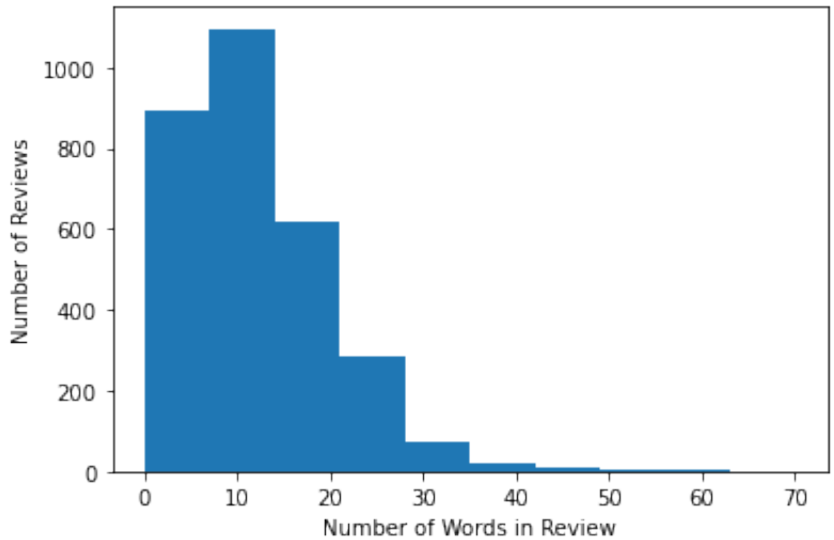
Out[19]:

```
35119
```

Historgram of review lengths

In [20]:

```
plt.hist(df['count'])
plt.xlabel('Number of Words in Review')
plt.ylabel('Number of Reviews')
plt.show()
```



Find length of longest review

In [21]:
```
df['count'].max()
```

Out[21]:
```
70
```

Remove stopwords

code from: https://towardsdatascience.com/how-to-clean-text-data-639375414a2f

In [22]:
```
import nltk

stopwords = nltk.corpus.stopwords.words('english')

df['review_nostop'] = df['review'].apply(lambda x: ' '.join([word for word in
                                                      word not in (stop

df.head()
```

Out[22]:

	review	label	count	review_nostop
0	so there is no way for me to plug it in here i...	0	21	way plug us unless go converter
1	good case excellent value	1	4	good case excellent value
2	great for the jawbone	1	4	great jawbone
3	tied to charger for conversations lasting more...	0	10	tied charger conversations lasting minutesmajo...
4	the mic is great	1	4	mic great

Count number of words in review_nostop and create new column

In [23]:

```
df['nostop_count'] = df['review_nostop'].apply(word_count)
df.head()
```

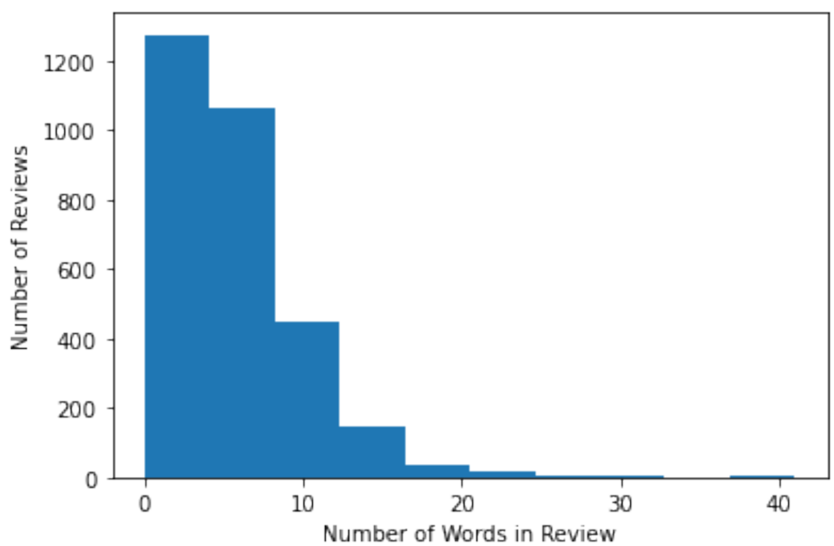
Out[23]:

	review	label	count	review_nostop	nostop_count
0	so there is no way for me to plug it in here i...	0	21	way plug us unless go converter	6
1	good case excellent value	1	4	good case excellent value	4
2	great for the jawbone	1	4	great jawbone	2
3	tied to charger for conversations lasting more...	0	10	tied charger conversations lasting minutesmajo...	6
4	the mic is great	1	4	mic great	2

Histogram of review length after stop word removal

In [24]:

```
plt.hist(df['nostop_count'])
plt.xlabel('Number of Words in Review')
plt.ylabel('Number of Reviews')
plt.show()
```



Length of longest review after removing stop words

In [25]:

```
df['nostop_count'].max()
```

Out[25]:

```
41
```

Find the size of the vocabulary

In [26]:

```
vocab = []
reviews = df['review_nostop'].tolist()

for review in reviews:
    for word in review.split(' '):
        if not word in vocab:
            vocab.append(word)
print(len(vocab))
```

```
5181
```

The proposed word embedding length was found using the formula: 4th root of the number of categories. (Introducting TensorFlow Feature Columns, 2017) In this analysis, every word in the vocabulary is its own category. Based on this formula, a word embedding length of 8 dimension will be used.

In [27]:

```
emb_size = len(vocab)**0.25
emb_size
```

Out[27]:

```
8.484053491799331
```

2. Tokenize the DataFrame

Tokenization is the process of separating text into smaller units known as tokens. For this analysis, the token size is word. These tokens are used to create the vocabulary, the set of unique tokens. Each of the words are then become an integer.(Aravindpai, 2020) This process is necessary because Keras cannot process text.

code from:https://towardsdatascience.com/a-complete-step-by-step-tutorial-on-sentiment-analysis-in-keras-and-tensorflow-ea420cc8913f

Set the tokenizer function

In [28]:

```
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences

tokenizer = Tokenizer(oov_token='<OOV>')
```

Splti the dataset into 70/30

In [29]:

```
split = round(len(df)*.7)
train_review = df['review_nostop'][:split]
train_label = df['label'][:split]
test_review = df['review_nostop'][split:]
test_label = df['label'][split:]
```

Convert the reviews to string format.

In [30]:

```python
training_reviews = []
training_labels = []
testing_reviews = []
testing_labels = []

for row in train_review:
    training_reviews.append(str(row))
for row in train_label:
    training_labels.append(row)
for row in test_review:
    testing_reviews.append(str(row))
for row in test_label:
    testing_labels.append(row)
```

Set terms for tokenize and padding

In [31]:

```python
vocab_size = 5180
embedding_dim = 8
max_length = 50
trunc_type = 'post'
oov_tok = '<OOV>'
padding_type = 'post'
```

Tokenize the words

In [32]:

```python
tokenizer = Tokenizer(num_words = vocab_size, oov_token = oov_tok)
tokenizer.fit_on_texts(training_reviews)
word_index = tokenizer.word_index
```

Print word_index

In [33]:

```python
print(word_index)
```


```
{'<OOV>': 1, 'good': 2, 'great': 3, 'phone': 4, 'food': 5, 'place': 6, 'servic
e': 7, 'like': 8, 'time': 9, 'back': 10, 'one': 11, 'really': 12, 'would': 13,
'quality': 14, 'dont': 15, 'well': 16, 'best': 17, 'product': 18, 'go': 19, 'i
ve': 20, 'also': 21, 'works': 22, 'ever': 23, 'nice': 24, 'headset': 25, 'batt
ery': 26, 'im': 27, 'get': 28, 'use': 29, 'sound': 30, 'even': 31, 'love': 32,
'excellent': 33, 'recommend': 34, 'work': 35, 'could': 36, 'never': 37, 'bette
r': 38, 'ear': 39, 'first': 40, 'made': 41, 'bad': 42, 'price': 43, 'much': 44
, 'pretty': 45, 'case': 46, 'disappointed': 47, 'got': 48, 'worst': 49, 'frien
dly': 50, 'think': 51, 'came': 52, 'way': 53, 'money': 54, 'going': 55, 'new':
56, 'enough': 57, 'still': 58, 'definitely': 59, 'minutes': 60, 'restaurant':
61, 'two': 62, 'experience': 63, 'amazing': 64, 'say': 65, 'poor': 66, 'happy'
: 67, 'delicious': 68, 'right': 69, 'didnt': 70, 'make': 71, 'thing': 72, 'won
t': 73, 'us': 74, 'far': 75, 'car': 76, 'terrible': 77, 'vegas': 78, 'movie':
79, 'waste': 80, 'little': 81, 'everything': 82, 'item': 83, 'worked': 84, 'al
ways': 85, 'charger': 86, 'comfortable': 87, 'long': 88, 'went': 89, 'people':
90, 'want': 91, 'buy': 92, 'used': 93, 'cant': 94, 'staff': 95, 'eat': 96, 'bo
ught': 97, 'piece': 98, 'times': 99, 'impressed': 100, 'bluetooth': 101, 'lot'
: 102, 'easy': 103, 'awesome': 104, 'ordered': 105, 'worth': 106, 'stars': 107
, 'doesnt': 108, 'fine': 109, 'since': 110, 'found': 111, 'know': 112, 'look':
```

113, 'quite': 114, 'wasnt': 115, 'chicken': 116, 'last': 117, 'problem': 118, 'couldnt': 119, 'life': 120, 'order': 121, 'tried': 122, 'reception': 123, 'fantastic': 124, 'slow': 125, 'every': 126, 'night': 127, 'horrible': 128, 'take': 129, 'menu': 130, 'fresh': 131, 'salad': 132, 'pizza': 133, 'charge': 134, 'sure': 135, 'purchase': 136, 'cell': 137, 'around': 138, 'small': 139, 'customer': 140, 'many': 141, 'give': 142, 'another': 143, 'feel': 144, 'wait': 145, 'steak': 146, 'highly': 147, 'talk': 148, 'camera': 149, 'calls': 150, 'cool': 151, 'device': 152, 'probably': 153, 'real': 154, 'low': 155, 'overall': 156, 'day': 157, 'come': 158, 'next': 159, 'taste': 160, 'server': 161, 'sushi': 162, 'flavor': 163, 'problems': 164, 'volume': 165, 'absolutely': 166, 'loved': 167, 'hear': 168, 'years': 169, 'clear': 170, 'phones': 171, 'using': 172, 'fit': 173, 'try': 174, 'bland': 175, 'nothing': 176, 'however': 177, 'said': 178, 'perfect': 179, 'burger': 180, 'buffet': 181, 'film': 182, 'plug': 183, 'several': 184, 'must': 185, 'design': 186, 'makes': 187, 'looks': 188, 'working': 189, 'motorola': 190, 'call': 191, 'fits': 192, 'getting': 193, 'cheap': 194, 'side': 195, 'bit': 196, 'family': 197, 'disappointing': 198, 'ill': 199, 'deal': 200, 'hard': 201, 'coming': 202, 'hour': 203, 'see': 204, 'tasty': 205, 'meal': 206, 'atmosphere': 207, 'without': 208, 'months': 209, 'left': 210, 'need': 211, 'find': 212, 'seriously': 213, 'big': 214, 'super': 215, 'expect': 216, 'area': 217, 'kind': 218, 'thought': 219, 'felt': 220, 'id': 221, 'year': 222, 'disappointment': 223, 'return': 224, 'either': 225, 'old': 226, 'hot': 227, 'looking': 228, 'away': 229, 'anyone': 230, 'took': 231, 'soon': 232, 'selection': 233, 'prices': 234, 'sauce': 235, 'waited': 236, 'days': 237, 'helpful': 238, 'kept': 239, 'end': 240, 'wear': 241, 'received': 242, 'black': 243, 'jabra': 244, 'high': 245, 'light': 246, 'fast': 247, 'completely': 248, 'job': 249, 'screen': 250, 'perfectly': 251, 'stay': 252, 'extremely': 253, 'company': 254, 'amazon': 255, 'unfortunately': 256, 'cannot': 257, 'friends': 258, 'bar': 259, 'inside': 260, 'fries': 261, 'table': 262, 'sandwich': 263, 'lunch': 264, 'meat': 265, 'breakfast': 266, 'dishes': 267, 'clean': 268, 'cold': 269, 'simple': 270, 'verizon': 271, 'dropped': 272, 'buttons': 273, 'different': 274, 'headsets': 275, 'gets': 276, 'home': 277, 'arrived': 278, 'quickly': 279, 'broke': 280, 'may': 281, 'pleased': 282, 'done': 283, 'avoid': 284, 'voice': 285, 'hours': 286, 'put': 287, 'tell': 288, 'junk': 289, 'anything': 290, 'couple': 291, 'others': 292, 'especially': 293, 'unit': 294, 'none': 295, 'barely': 296, 'awful': 297, 'overpriced': 298, 'waitress': 299, 'beer': 300, 'dish': 301, 'dining': 302, 'spicy': 303, 'spot': 304, 'rude': 305, 'tasted': 306, 'value': 307, 'decent': 308, 'started': 309, 'though': 310, 'everyone': 311, 'thats': 312, 'three': 313, 'hate': 314, 'picture': 315, 'priced': 316, 'audio': 317, 'seems': 318, 'actually': 319, 'week': 320, 'feels': 321, 'beautiful': 322, 'music': 323, 'pictures': 324, 'huge': 325, 'full': 326, 'software': 327, 'almost': 328, 'less': 329, 'check': 330, 'useless': 331, 'color': 332, 'part': 333, 'expected': 334, 'authentic': 335, 'hands': 336, 'nokia': 337, 'sucks': 338, 'ago': 339, 'average': 340, 'wanted': 341, 'waiting': 342, 'rather': 343, 'wrong': 344, 'given': 345, 'things': 346, 'enjoy': 347, 'quick': 348, 'pay': 349, 'mediocre': 350, 'easily': 351, 'waiter': 352, 'attentive': 353, 'cooked': 354, 'wonderful': 355, 'eating': 356, 'town': 357, 'ambiance': 358, 'chips': 359, 'half': 360, 'fun': 361, 'original': 362, 'yet': 363, 'bars': 364, 'ears': 365, 'least': 366, 'turn': 367, 'loud': 368, 'large': 369, 'reasonable': 370, 'headphones': 371, 'later': 372, 'within': 373, 'white': 374, 'wife': 375, 'ask': 376, 'signal': 377, 'house': 378, 'internet': 379, 'charm': 380, 'incredible': 381, 'lost': 382, 'hit': 383, 'thin': 384, 'mistake': 385, 'cable': 386, 'gave': 387, 'care': 388, 'lacking': 389, 'outside': 390, 'trying': 391, 'today': 392, 'plastic': 393, 'difficult': 394, 'liked': 395, 'review': 396, 'sucked': 397, 'zero': 398, 'needed': 399, 'plus': 400, 'cases': 401, 'extra': 402, 'guess': 403, 'something': 404, 'fact': 405, 'places': 406, 'pho': 407, 'warm': 408, 'shrimp': 409, 'tender': 410, 'fish': 411, 'potato': 412, 'served': 413, 'management': 414, 'special': 415, 'twice': 416, 'dinner': 417, 'bring': 4

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3329, 'horse': 3330, 'lifeoh': 3331, 'walk': 3332, 'theatre': 3333, 'relief':
3334, 'storyline': 3335}
```


3. Padding Process

Neural networks requires that all inputs be the same size and shapes. This is accomplished by adding zeros to the beginning or ending of the sequence. (Caner, 2020) Here, zeroes are added to the end of the sequence.

In [34]:

```
sequences = tokenizer.texts_to_sequences(training_reviews)
padded = pad_sequences(sequences, maxlen = max_length, truncating=trunc_type,
                       padding = 'post')
testing_reviews = tokenizer.texts_to_sequences(testing_reviews)
testing_padded = pad_sequences(testing_reviews, maxlen = max_length, padding
```

In [35]:

```
padded[0]
```

Out[35]:

```
array([  53,  183,   74,  420,   19, 1335,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
          0,    0,    0,    0,    0,    0], dtype=int32)
```

4. Categories of Sentiment and Activation Function

There are two categories of sentiment: 1 – positive, 2 – negative. The sigmoid activation function will be used in the final dense layer because the outputs are binary.

5. Steps to Prepare Data

The steps used to prepare the data are as follows:

- Import packages
- Load datasets
- Inspect datasets size
- Merge the datasets into one DataFrame
- Remove special characters and digits
- Remove stop words
- Create a vocabulary
- Find the embedding size
- Split the data into training and test sets using a 70/30 split
- Tokenize the DataFrame
- Pad the reviews to standardize the lengths

6. Copy of prepared data

In [36]:

```
df.to_csv('prepared_sentiment_data.csv')
```

Part III: Network Architecture

code from:https://towardsdatascience.com/a-complete-step-by-step-tutorial-on-sentiment-analysis-in-keras-and-tensorflow-ea420cc8913f

Build the model

In [37]:

```
model = keras.Sequential([keras.layers.Embedding(vocab_size, embedding_dim, \
                                                  input_length = max_len
                            keras.layers.GlobalAveragePooling1D(),\
                            keras.layers.Dense(10, activation = 'relu'),\
                            keras.layers.Dense(5, activation = 'relu'),\
                            keras.layers.Dense(1, activation = 'sigmoid')])
```

```
2022-03-14 11:33:44.329186: I tensorflow/core/platform/cpu_feature_guard.cc:14
5] This TensorFlow binary is optimized with Intel(R) MKL-DNN to use the follow
ing CPU instructions in performance critical operations:  SSE4.1 SSE4.2 AVX AV
X2 FMA
To enable them in non-MKL-DNN operations, rebuild TensorFlow with the appropri
ate compiler flags.
2022-03-14 11:33:44.329542: I tensorflow/core/common_runtime/process_util.cc:1
15] Creating new thread pool with default inter op setting: 12. Tune using int
er_op_parallelism_threads for best performance.
```

Compile the model

In [38]:

```
model.compile(loss='binary_crossentropy', optimizer = 'adam', metrics = ['acc
```

1. Summary of model

In [39]:

```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
embedding (Embedding)        (None, 50, 8)             41440     
_________________________________________________________________
global_average_pooling1d (Gl (None, 8)                 0         
_________________________________________________________________
dense (Dense)                (None, 10)                90        
_________________________________________________________________
dense_1 (Dense)              (None, 5)                 55        
_________________________________________________________________
dense_2 (Dense)              (None, 1)                 6         
=================================================================
Total params: 41,591
Trainable params: 41,591
Non-trainable params: 0
_________________________________________________________________
```

2. Discuss the number of layers, the type of layers, and the total number of parameters

The first layer is the Embedding layer. This layer converts each word to a fixed length vector of a stated size. The parameters used in the layer are the vocabulary size, embedding dimension, and the maximum length of each review. The second layer is GlobalAveragePooling1D() which flattens the vector from three dimensions to two dimension. The third layer is a Dense layer with 10 nodes and the activation function relu. The fourth layer has 5 nodes and uses the relu activation function. The final layer is a Dense layer with 1 node and activation function sigmoid. The sigmoid activation function was chosen because the output is binary.

Convert labels to arrays

In [40]:
```
training_labels_final = np.array(training_labels)
testing_labels_final = np.array(testing_labels)
```

3. Justify the choice of hyperparameters

Activation Functions: relu – chosen because it only returns positive numbers or 0. Sigmoid – chosen because the outcome is binary.

Number of Nodes per Layer – The nodes of the first layer are equal to the number of words in the vocabulary. The second node of 10 is a number that is between the first layer and the last layer. The third node of 5 was chosen because it reduces the number of nodes from the previous layer but is more than the final layer. The last layer has 1 node since the output of the model is binary.

Loss Function – The loss function used in the model was Binary Crossentropy. It was chosen because there are two possible outputs.

Optimizer – the Adaptive Moment Estimation, Adam, optimizer was chosen because it is efficient and requires less memory. The Adam optimizer combines the strength of gradient descent with momentum and root means square propagation. (Intuition of Adam Optimizer, 2020)

Stopping Criteria – Early stopping is used during the fitting of the model. The model will stop based on validation loss. Validation loss shows how well the model fits new data.

Evaluation Metric – Accuracy is the percent of correct predictions to the set of targets. It was chosen because of its ease of interpretation.

Part IV: Model Evaluation

Fit the model with 25 epochs

In [41]:
```
history_ns = model.fit(padded, training_labels_final, epochs = 25,\
                       validation_data = (testing_padded, testing_labels_fina
```

```
Train on 2100 samples, validate on 900 samples
Epoch 1/25
2100/2100 [==============================] - 1s 708us/sample - loss: 0.6932 -
accuracy: 0.5038 - val_loss: 0.6931 - val_accuracy: 0.4944
Epoch 2/25
2100/2100 [==============================] - 0s 132us/sample - loss: 0.6929 -
accuracy: 0.5629 - val_loss: 0.6925 - val_accuracy: 0.6489
Epoch 3/25
2100/2100 [==============================] - 0s 133us/sample - loss: 0.6912 -
accuracy: 0.6686 - val_loss: 0.6910 - val_accuracy: 0.7122
Epoch 4/25
2100/2100 [==============================] - 0s 130us/sample - loss: 0.6864 -
accuracy: 0.7600 - val_loss: 0.6864 - val_accuracy: 0.7422
Epoch 5/25
2100/2100 [==============================] - 0s 129us/sample - loss: 0.6715 -
accuracy: 0.8186 - val_loss: 0.6755 - val_accuracy: 0.7378
```

```
Epoch 6/25
2100/2100 [==============================] - 0s 127us/sample - loss: 0.6412 -
accuracy: 0.8586 - val_loss: 0.6566 - val_accuracy: 0.6800
Epoch 7/25
2100/2100 [==============================] - 0s 123us/sample - loss: 0.5935 -
accuracy: 0.8657 - val_loss: 0.6310 - val_accuracy: 0.7256
Epoch 8/25
2100/2100 [==============================] - 0s 116us/sample - loss: 0.5273 -
accuracy: 0.9000 - val_loss: 0.5959 - val_accuracy: 0.7489
Epoch 9/25
2100/2100 [==============================] - 0s 129us/sample - loss: 0.4577 -
accuracy: 0.9114 - val_loss: 0.5687 - val_accuracy: 0.7444
Epoch 10/25
2100/2100 [==============================] - 0s 118us/sample - loss: 0.3862 -
accuracy: 0.9219 - val_loss: 0.5432 - val_accuracy: 0.7444
Epoch 11/25
2100/2100 [==============================] - 0s 121us/sample - loss: 0.3290 -
accuracy: 0.9305 - val_loss: 0.5280 - val_accuracy: 0.7444
Epoch 12/25
2100/2100 [==============================] - 0s 123us/sample - loss: 0.2846 -
accuracy: 0.9295 - val_loss: 0.5209 - val_accuracy: 0.7511
Epoch 13/25
2100/2100 [==============================] - 0s 116us/sample - loss: 0.2408 -
accuracy: 0.9433 - val_loss: 0.5063 - val_accuracy: 0.7611
Epoch 14/25
2100/2100 [==============================] - 0s 163us/sample - loss: 0.2143 -
accuracy: 0.9448 - val_loss: 0.5107 - val_accuracy: 0.7533
Epoch 15/25
2100/2100 [==============================] - 0s 162us/sample - loss: 0.1881 -
accuracy: 0.9538 - val_loss: 0.5056 - val_accuracy: 0.7644
Epoch 16/25
2100/2100 [==============================] - 0s 157us/sample - loss: 0.1727 -
accuracy: 0.9533 - val_loss: 0.5237 - val_accuracy: 0.7600
Epoch 17/25
2100/2100 [==============================] - 0s 121us/sample - loss: 0.1524 -
accuracy: 0.9652 - val_loss: 0.5211 - val_accuracy: 0.7611
Epoch 18/25
2100/2100 [==============================] - 0s 122us/sample - loss: 0.1391 -
accuracy: 0.9657 - val_loss: 0.5249 - val_accuracy: 0.7667
Epoch 19/25
2100/2100 [==============================] - 0s 116us/sample - loss: 0.1255 -
accuracy: 0.9671 - val_loss: 0.5355 - val_accuracy: 0.7611
Epoch 20/25
2100/2100 [==============================] - 0s 119us/sample - loss: 0.1172 -
accuracy: 0.9695 - val_loss: 0.5360 - val_accuracy: 0.7578
Epoch 21/25
2100/2100 [==============================] - 0s 118us/sample - loss: 0.1076 -
accuracy: 0.9729 - val_loss: 0.5512 - val_accuracy: 0.7633
Epoch 22/25
2100/2100 [==============================] - 0s 121us/sample - loss: 0.1017 -
accuracy: 0.9738 - val_loss: 0.5528 - val_accuracy: 0.7600
Epoch 23/25
2100/2100 [==============================] - 0s 165us/sample - loss: 0.0972 -
accuracy: 0.9719 - val_loss: 0.5627 - val_accuracy: 0.7556
Epoch 24/25
2100/2100 [==============================] - 0s 172us/sample - loss: 0.0877 -
accuracy: 0.9757 - val_loss: 0.5810 - val_accuracy: 0.7700
```

```
Epoch 25/25
2100/2100 [==============================] - 0s 169us/sample - loss: 0.0827 - accuracy: 0.9771 - val_loss: 0.5808 - val_accuracy: 0.7667
```

1. Stopping Criteria

Stopping criteria is used to prevent overfitting. It does this by stopping the training of the model as soon as the validation error reaches a minimum. The patience parameter is used to ensure that the training does not stop at a local minimum but reaches the true minimum.

code from: https://towardsdatascience.com/a-practical-introduction-to-early-stopping-in-machine-learning-550ac88bc8fd

In [42]:

```
from tensorflow.keras.callbacks import EarlyStopping

early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5, mode = 'mi
```

In [43]:

```
history = model.fit(padded, training_labels_final, epochs = 25,\
                    validation_data = (testing_padded, testing_labels_final),
```

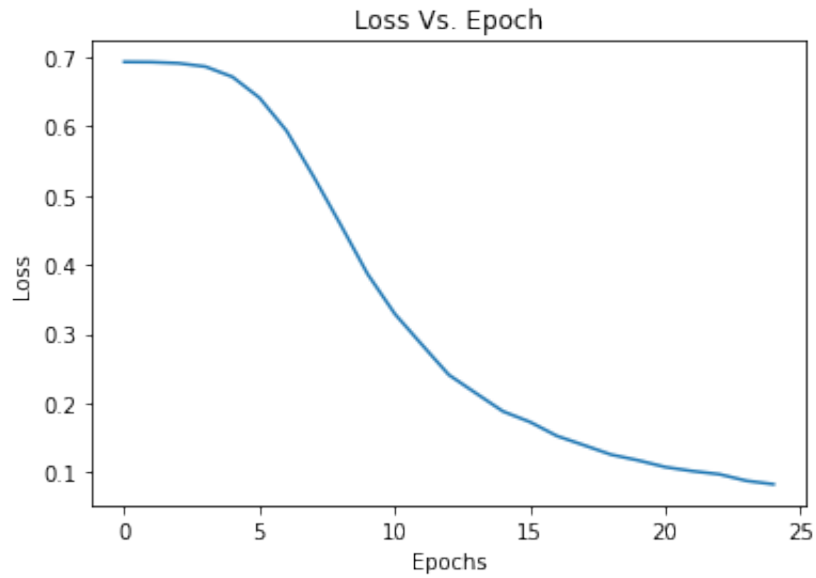
```
Train on 2100 samples, validate on 900 samples
Epoch 1/25
2100/2100 [==============================] - 0s 195us/sample - loss: 0.0781 - accuracy: 0.9795 - val_loss: 0.5912 - val_accuracy: 0.7678
Epoch 2/25
2100/2100 [==============================] - 0s 181us/sample - loss: 0.0727 - accuracy: 0.9810 - val_loss: 0.6254 - val_accuracy: 0.7589
Epoch 3/25
2100/2100 [==============================] - 0s 175us/sample - loss: 0.0702 - accuracy: 0.9790 - val_loss: 0.6092 - val_accuracy: 0.7611
Epoch 4/25
2100/2100 [==============================] - 0s 169us/sample - loss: 0.0655 - accuracy: 0.9805 - val_loss: 0.6202 - val_accuracy: 0.7489
Epoch 5/25
2100/2100 [==============================] - 0s 179us/sample - loss: 0.0647 - accuracy: 0.9795 - val_loss: 0.6318 - val_accuracy: 0.7511
Epoch 6/25
2100/2100 [==============================] - 0s 172us/sample - loss: 0.0618 - accuracy: 0.9795 - val_loss: 0.6366 - val_accuracy: 0.7600
```

2. Visualizations of the model's training process

Graph of loss

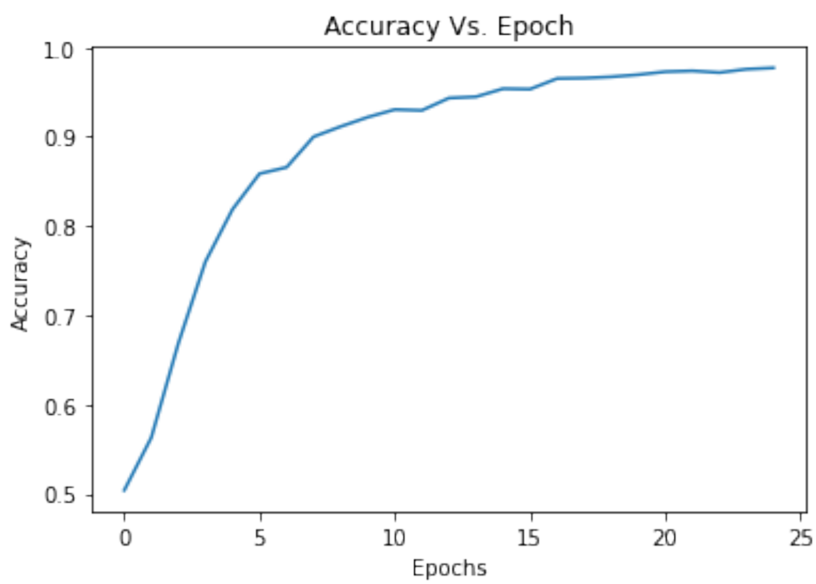
In [44]:

```
plt.plot(history_ns.history['loss'])
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.title('Loss Vs. Epoch')
plt.show()
```



Graph of accuracy

In [45]:
```
plt.plot(history_ns.history['accuracy'])
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.title('Accuracy Vs. Epoch')
plt.show()
```



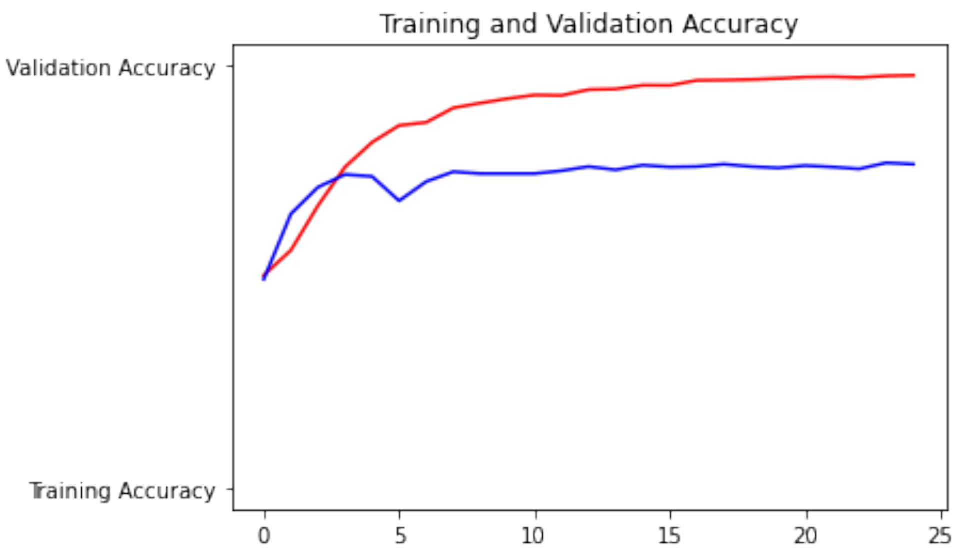
Graphs of training and validation

code from: https://towardsdatascience.com/a-complete-step-by-step-tutorial-on-sentiment-analysis-in-keras-and-tensorflow-ea420cc8913f

In [46]:

```
acc = history_ns.history['accuracy']
val_acc = history_ns.history['val_accuracy']
loss = history_ns.history['loss']
val_loss = history_ns.history['val_loss']
epochs = range(len(acc))
plt.plot(epochs, acc, 'r', 'Training Accuracy')
plt.plot(epochs, val_acc, 'b', 'Validation Accuracy')
plt.title('Training and Validation Accuracy')
plt.figure()
plt.plot(epochs, loss, 'r', 'Training Loss')
plt.plot(epochs, val_acc, 'b', 'Validation Loss')
plt.title('Training and Validation Loss')
plt.figure()
```

Out[46]: <Figure size 432x288 with 0 Axes>



<Figure size 432x288 with 0 Axes>

3. Model Fitness

The model accuracy improves over the first 6 epochs. After this point the model starts to overfit the training data. While having a large accuracy percentage may seem good, it can be a sign that the model will not handle new data well. To reduce the chance of overfitting, early stopping was used.

4. Predictive Accuracy

The predictive accuracy of the model is 76%. The model can predict customer sentiment about 76% of the time. This is fairly high accuracy.

Part V: Summary and Recommendations

E. Code to save trained model

code from: https://www.kdnuggets.com/2021/02/saving-loading-models-tensorflow.html

In [47]:
```
model.save('SentimentAmalysis.h5')
```

F. Functionality of neural network

This model is very functional. It has a high predictive accuracy. One recommendation would be to try the model with more layers. This might improve the accuracy.

G. Recommendations

A recommend course of action is to use the model to reach out to customers who are predicted to have poor sentiment towards the product. The company can use this opportunity to correct any problems with the product or gather feedback on how to improve. This will help to improve sentiments towards the company if not the product.

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In [ ]:

```
```

In [ ]:

```
```