Sentiment_Analysis-binary-classification-BRNN-CuDNNGRU-Batchnormalization-AttentionLayer

January 25, 2020

1 Sentiment Analysis with an RNN

Run in Google Colab

View source on GitHub

http://www.polyvista.com/blog/wp-content/uploads/2015/06/sentiment-customer-exp-large.png

1.1 What is Sentiment Analysis?

Sentiment Analysis also know as opinion mining refers to the identification, extraction and study of sentiment states by using natural language processing, text analysis, computational linguistics and biometrics.

1.2 Sentiment Analysis with an Recurrent Neural Network

We will use a RNN for sentiment analysis because we care for the sequence in the data.

1.2.1 Imports

[1]:
```
import re
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt

from tensorflow.keras.models import Sequential, load_model
from tensorflow.compat.v1.keras.layers import CuDNNGRU, Embedding,␣
 ↪Dropout,Dense, Bidirectional, BatchNormalization
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.optimizers import RMSprop, Adamax , Adam

from attention.layers import AttentionLayer
```

```
# import keras
# from keras.models import Sequential, load_model
# from keras.layers import Dense, Embedding, Dropout
# from keras.preprocessing.text import Tokenizer
# from keras.preprocessing.sequence import pad_sequences
import tensorflow as tf
from tensorflow.python.client import device_lib
```

[2]:
```
from tensorflow.compat.v1 import ConfigProto
from tensorflow.compat.v1 import InteractiveSession

config = ConfigProto()
config.gpu_options.per_process_gpu_memory_fraction = 0.6
config.gpu_options.allow_growth = True
session = InteractiveSession(config=config)
```

[3]:
```
from IPython.core.interactiveshell import InteractiveShell
InteractiveShell.ast_node_interactivity = "all" #This is for multiple print␣
↪statements per cell
```

[4]:
```
value = tf.test.is_gpu_available(
    cuda_only=False,
    min_cuda_compute_capability=None
)
print ('***If TF can access GPU: ***\n\n',value) # MUST RETURN True IF IT CAN!!
```

```
WARNING:tensorflow:From <ipython-input-4-cb50da41978a>:3: is_gpu_available (from
tensorflow.python.framework.test_util) is deprecated and will be removed in a
future version.
Instructions for updating:
Use `tf.config.list_physical_devices('GPU')` instead.
***If TF can access GPU: ***

 True
```

[5]:
```
value = tf.config.list_physical_devices('GPU')
print(value)
```

```
[PhysicalDevice(name='/physical_device:GPU:0', device_type='GPU')]
```

[6]:
```
print(device_lib.list_local_devices())
```

```
[name: "/device:CPU:0"
device_type: "CPU"
memory_limit: 268435456
locality {
}
```

```
incarnation: 9181655214305204417
, name: "/device:XLA_CPU:0"
device_type: "XLA_CPU"
memory_limit: 17179869184
locality {
}
incarnation: 7914926322048032979
physical_device_desc: "device: XLA_CPU device"
, name: "/device:XLA_GPU:0"
device_type: "XLA_GPU"
memory_limit: 17179869184
locality {
}
incarnation: 10944215770640136862
physical_device_desc: "device: XLA_GPU device"
, name: "/device:GPU:0"
device_type: "GPU"
memory_limit: 1259942707
locality {
  bus_id: 1
  links {
  }
}
incarnation: 18196532749112552711
physical_device_desc: "device: 0, name: GeForce MX150, pci bus id: 0000:02:00.0,
compute capability: 6.1"
]
```

[7]:
```
tf.debugging.set_log_device_placement(True)
```

[8]:
```
 tf
print("Num GPUs Available: ", len(tf.config.experimental.
 ↪list_physical_devices('GPU')))
```

[8]:
```
<module 'tensorflow' from '/home/erolerten/anaconda3/envs/venv-
tensorflow/lib/python3.7/site-packages/tensorflow/__init__.py'>

Num GPUs Available:  1
```

2 Place tensors on the CPU

3 with tf.device(‘/GPU:0’):

a = tf.constant([[1.0, 2.0, 3.0], [4.0, 5.0, 6.0]]) b = tf.constant([[1.0, 2.0], [3.0, 4.0], [5.0, 6.0]])

c = tf.matmul(a, b) print(c)

3.0.1 Loading in Dataset

[9]:
```
data1 = pd.read_csv('Tweets.csv')
data2 = pd.read_csv('stanford-tweets.csv',sep=',')
# data1 = data1.sample(frac=1).reset_index(drop=True)
# data2 = data2.sample(frac=1).reset_index(drop=True)
print(data1.shape)
print(data2.shape)

data1.head()
data2.head()
```

```
(14640, 15)
(1600000, 2)
```

[9]:

	tweet_id	airline_sentiment	airline_sentiment_confidence	negativereason	negativereason_confidence	airline	airline_sentiment_gold	name	negativereason_gold	retweet_count	text	tweet_coord	tweet_created	tweet_location	user_timezone
0	570306133677760513	neutral	1.0000	NaN	NaN	Virgin America	NaN	cairdin	NaN	0	@VirginAmerica What @dhepburn said.	NaN	2015-02-24 11:35:52 -0800	NaN	Eastern Time (US & Canada)
1	570301130888122368	positive	0.3486	NaN	0.0000	Virgin America	NaN	jnardino	NaN	0	@VirginAmerica plus you've added commercials t…	NaN	2015-02-24 11:15:59 -0800	NaN	Pacific Time (US & Canada)
2	570301083672813571	neutral	0.6837	NaN	NaN	Virgin America	NaN	yvonnalynn	NaN	0	@VirginAmerica I didn't today… Must mean I n…	NaN	2015-02-24 11:15:48 -0800	Lets Play	Central Time (US & Canada)
3	570301031407624196	negative	1.0000	Bad Flight	0.7033	Virgin America	NaN	jnardino	NaN	0	@VirginAmerica it's really aggressive to blast…	NaN			
4	570300817074462722	negative	1.0000	Can't Tell	1.0000	Virgin America	NaN	jnardino	NaN	0	@VirginAmerica and it's a really big bad thing…	NaN			

```
3  2015-02-24 11:15:36 -0800            NaN  Pacific Time (US & Canada)
4  2015-02-24 11:14:45 -0800            NaN  Pacific Time (US & Canada)
```

[9]:

	sentiment	text
0	negative	@switchfoot http://twitpic.com/2y1zl - Awww, t…
1	negative	is upset that he can't update his Facebook by …
2	negative	@Kenichan I dived many times for the ball. Man…
3	negative	my whole body feels itchy and like its on fire
4	negative	@nationwideclass no, it's not behaving at all…

Removing all columns except the airline_sentiment and text column.

[10]:
```
data1 = data1[['airline_sentiment', 'text']]
new_columns = ['sentiment','text']
data1.columns = new_columns
data1.head()
```

[10]:

	sentiment	text
0	neutral	@VirginAmerica What @dhepburn said.
1	positive	@VirginAmerica plus you've added commercials t…
2	neutral	@VirginAmerica I didn't today… Must mean I n…
3	negative	@VirginAmerica it's really aggressive to blast…
4	negative	@VirginAmerica and it's a really big bad thing…

[11]:
```
df = data1.append(data2, ignore_index = True)
print(df.shape)
df
```

```
(1614640, 2)
```

[11]:

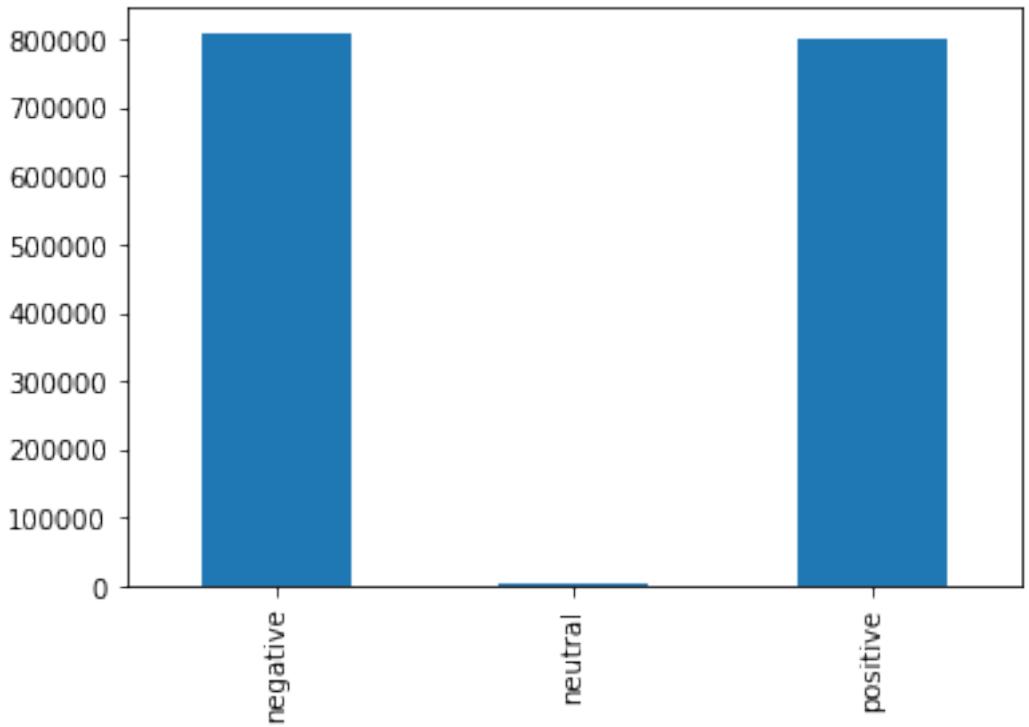
	sentiment	text
0	neutral	@VirginAmerica What @dhepburn said.
1	positive	@VirginAmerica plus you've added commercials t…
2	neutral	@VirginAmerica I didn't today… Must mean I n…
3	negative	@VirginAmerica it's really aggressive to blast…
4	negative	@VirginAmerica and it's a really big bad thing…
…	…	…
1614635	positive	Just woke up. Having no school is the best fee…
1614636	positive	TheWDB.com - Very cool to hear old Walt interv…
1614637	positive	Are you ready for your MoJo Makeover? Ask me f…
1614638	positive	Happy 38th Birthday to my boo of alll time!!! …
1614639	positive	happy #charitytuesday @theNSPCC @SparksCharity…

[1614640 rows x 2 columns]

3.0.2 Data exploration

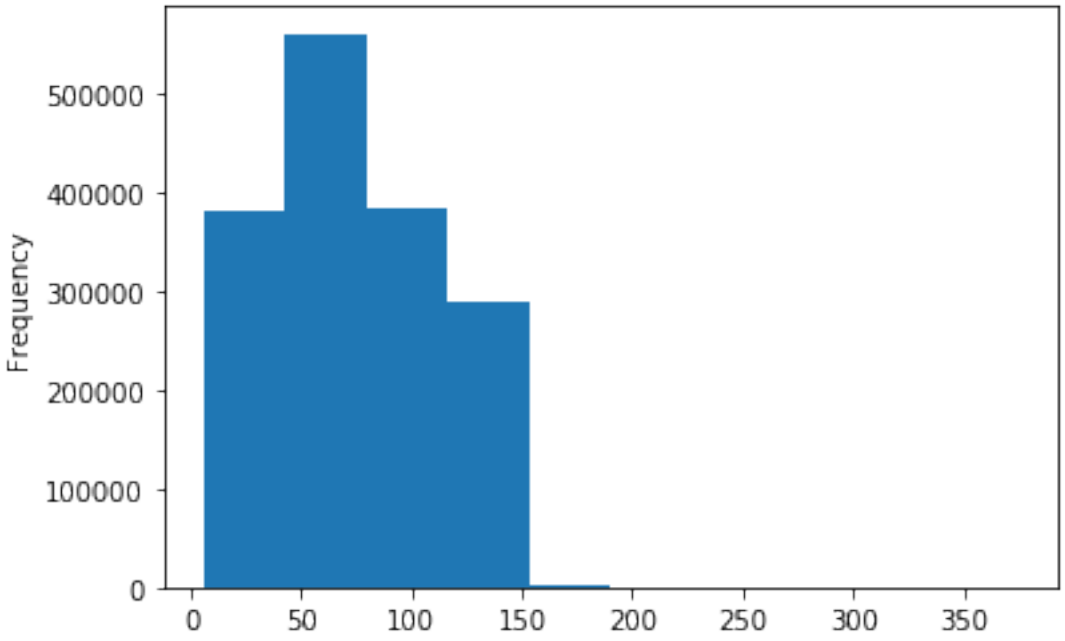
[12]:
```
df['sentiment'].value_counts().sort_index().plot.bar()
```

[12]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fa8a02631d0>
```



[13]:
```
df['text'].str.len().plot.hist()
```

[13]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fa8a02c3e50>
```



3.0.3 Preprocessing

[14]:
```
# How much of Dataset to be used
frac = 0.2
```

[15]:
```
# data['text'] = data['text'].str.replace('@VirginAmerica', '')
# data.head()
df = df.sample(frac=frac).reset_index(drop=True)
df
```

[15]:

	sentiment	text
0	negative	@twinklybee one day lovely, one day no chan…
1	negative	Well my friend cancelled lunch.. she thinks sh…
2	positive	net surfing. oh yeah!
3	positive	@binxy yeah, you don't! While I am super-addic…
4	positive	getting ready to go read, pray, and go to bed…
…	…	…
322923	negative	it's 8:06am and i ate all the tostitos. http:…
322924	positive	@ryoswim But what you can do is smile and thi…
322925	positive	@Hedgewytch Great thanks.Well it *is* Friday! …
322926	positive	Just sobbing over Ty Penningtons Extreme Home …
322927	positive	Listening to the Best of 2008 songs on AIM and…

[322928 rows x 2 columns]

[16]:
```
df['text'].apply(lambda x: x.lower()) #transform text to lowercase
df['text'] = df['text'].apply(lambda x: re.sub('[^a-zA-z0-9\s]', '', x))
df['text'].head()
```

[16]:
```
0         @twinklybee  one day lovely, one day   no chan…
1         well my friend cancelled lunch.. she thinks sh…
2                                    net surfing. oh yeah!
3         @binxy yeah, you don't! while i am super-addic…
4         getting ready to go read, pray, and go to bed…
                               …
322923    it's 8:06am and i ate all the tostitos.  http:…
322924    @ryoswim  but what you can do is smile and thi…
322925    @hedgewytch great thanks.well it *is* friday! …
322926    just sobbing over ty penningtons extreme home …
322927    listening to the best of 2008 songs on aim and…
Name: text, Length: 322928, dtype: object
```

[16]:
```
0    twinklybee  one day lovely one day   no chance…
1    Well my friend cancelled lunch she thinks she …
2                                net surfing oh yeah
3       binxy yeah you dont While I am superaddicted
4    getting ready to go read pray and go to bed En…
Name: text, dtype: object
```

[17]:
```
df['sentiment']
```

[17]:
```
0         negative
1         negative
2         positive
3         positive
4         positive
            …
322923    negative
322924    positive
322925    positive
322926    positive
322927    positive
Name: sentiment, Length: 322928, dtype: object
```

[18]:
```
df = df[df['sentiment'] != 'neutral']
```

[19]:
```
df
```

[19]:
```
       sentiment                                              text
0       negative  twinklybee  one day lovely one day   no chance…
1       negative  Well my friend cancelled lunch she thinks she …
2       positive                                net surfing oh yeah
```

```
3       positive      binxy yeah you dont While I am superaddicted
4       positive  getting ready to go read pray and go to bed En…
…          …                                                   …
322923  negative  its 806am and i ate all the tostitos  httptiny…
322924  positive  ryoswim  But what you can do is smile and thin…
322925  positive    Hedgewytch Great thanksWell it is Friday   You
322926  positive  Just sobbing over Ty Penningtons Extreme Home …
322927  positive  Listening to the Best of 2008 songs on AIM and…

[322344 rows x 2 columns]
```

[20]:
```
vocabulary_size = 20000
```

[21]:
```
tokenizer = Tokenizer(num_words=vocabulary_size, split=" ")
tokenizer.fit_on_texts(df['text'].values)

X = tokenizer.texts_to_sequences(df['text'].values)
X = pad_sequences(X) # padding our text vector so they all have the same length
X[:5]
```

[21]:
```
array([[    0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,    54,    32,   425,    54,    32,    37,   759,
           12,     4,   588, 12077,    99,     4,  6581,    10,     3,
        10460,    51,  1151,   496],
       [    0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,    66,     5,   256,   860,   351,
          138,   854,   138,     8,   179,    34,  2130,    30,     6,
           37,   202,     2,    38],
       [    0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,
         1604,  3823,    81,   140],
       [    0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,   140,     7,
           39,   245,     1,    61],
       [    0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,   127,   203,     2,
           38,   325,  1213,     6,    38,     2,   142,   379,     3,
          470,    12,     3,    75]], dtype=int32)
```

3.0.4 Creating model

[22]:
```
model = Sequential()
model.add(Embedding(vocabulary_size, 256, input_length=X.shape[1]))
model.add(Dropout(0.3))
model.add(Bidirectional(CuDNNGRU(256, return_sequences=True)))
model.add(Dropout(0.3))
model.add(Bidirectional(CuDNNGRU(256, return_sequences=True)))
model.add(AttentionLayer(name='attention'))
model.add(BatchNormalization())
model.add(Dense(2, activation='sigmoid'))
```

```
Executing op RandomUniform in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op Sub in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op Mul in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op Add in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op VarIsInitializedOp in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op LogicalNot in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op Assert in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op AssignVariableOp in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op RandomUniform in device
/job:localhost/replica:0/task:0/device:GPU:0
Executing op Sub in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op Mul in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op Add in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarIsInitializedOp in device
/job:localhost/replica:0/task:0/device:GPU:0
Executing op LogicalNot in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op Assert in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op AssignVariableOp in device
/job:localhost/replica:0/task:0/device:GPU:0
Executing op RandomStandardNormal in device
/job:localhost/replica:0/task:0/device:GPU:0
Executing op Qr in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op DiagPart in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op Sign in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op Transpose in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op Reshape in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op Fill in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
```

```
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
```

[23]:
```
model.compile(loss='binary_crossentropy', optimizer='adam',␣
↪metrics=['accuracy'])
model.summary()
```

```
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding (Embedding)        (None, 40, 256)           5120000
_________________________________________________________________
dropout (Dropout)            (None, 40, 256)           0
_________________________________________________________________
bidirectional (Bidirectional (None, 40, 512)           789504
_________________________________________________________________
dropout_1 (Dropout)          (None, 40, 512)           0
_________________________________________________________________
bidirectional_1 (Bidirection (None, 40, 512)           1182720
_________________________________________________________________
attention (AttentionLayer)   (None, 512)               263168
_________________________________________________________________
batch_normalization (BatchNo (None, 512)               2048
_________________________________________________________________
dense (Dense)                (None, 2)                 1026
=================================================================
Total params: 7,358,466
Trainable params: 7,357,442
Non-trainable params: 1,024
_________________________________________________________________
```

[24]:
```
y = pd.get_dummies(df['sentiment']).values
[print(df['sentiment'][i], y[i]) for i in range(0,5)]
```

```
negative [1 0]
negative [1 0]
positive [0 1]
positive [0 1]
positive [0 1]
```

[24]:
```
[None, None, None, None, None]
```

[25]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,␣
↪random_state=0)
```

3.0.5 Training model

[ ]:
```
batch_size = 32
epochs = 8
import time
from datetime import datetime
datetime = str(datetime.now())
csv_logger = tf.keras.callbacks.CSVLogger('training'+datetime+'.log')
start = time.time()
history = model.fit(X_train, y_train, epochs=epochs, batch_size=batch_size,␣
 ↪verbose=2, callbacks=[csv_logger])
end = time.time()
elapsed = end - start
print(elapsed/60," minutes")
```

```
Executing op RangeDataset in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op RepeatDataset in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op MapDataset in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op PrefetchDataset in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op FlatMapDataset in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op TensorDataset in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op RepeatDataset in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op ZipDataset in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op ParallelMapDataset in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op DatasetCardinality in device
/job:localhost/replica:0/task:0/device:CPU:0
Train on 257875 samples
Epoch 1/8
Executing op ModelDataset in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op AnonymousIteratorV2 in device
/job:localhost/replica:0/task:0/device:CPU:0
Executing op MakeIterator in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op AssignVariableOp in device
/job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
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Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:CPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
```

```
Executing op LogicalNot in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op Assert in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
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Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
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Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:GPU:0
Executing op VarHandleOp in device /job:localhost/replica:0/task:0/device:CPU:0
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/job:localhost/replica:0/task:0/device:GPU:0
257875/257875 - 626s - loss: 0.4617 - accuracy: 0.7826
Epoch 2/8
257875/257875 - 610s - loss: 0.3984 - accuracy: 0.8220
Epoch 3/8
257875/257875 - 603s - loss: 0.3578 - accuracy: 0.8445
Epoch 4/8
```

```
257875/257875 - 604s - loss: 0.3210 - accuracy: 0.8639
Epoch 5/8
257875/257875 - 614s - loss: 0.2860 - accuracy: 0.8809
Epoch 6/8
257875/257875 - 609s - loss: 0.2579 - accuracy: 0.8946
Epoch 7/8
257875/257875 - 611s - loss: 0.2371 - accuracy: 0.9042
Epoch 8/8
```

3.0.6 Plotting Training History

[ ]:
```
# print(history)
```

[ ]:
```
import matplotlib.pyplot as plt

# Plot training & validation accuracy values
plt.plot(history.history['accuracy'])
# plt.plot(history.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()

# Plot training & validation loss values
plt.plot(history.history['loss'])
# plt.plot(history.history['val_loss'])
plt.title('Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()
```

3.0.7 Testing model

[ ]:
```
predictions = model.predict(X_test)

[print(df['text'][i], predictions[i], y_test[i]) for i in range(0, 5)]
```

[ ]:
```
accurate_prediction_count, inaccurate_prediction_count = 0, 0
for i, prediction in enumerate(predictions):
    if np.argmax(prediction)==np.argmax(y_test[i]):
        accurate_prediction_count += 1
    else:
        inaccurate_prediction_count += 1
```

```
total_predictions = accurate_prediction_count + inaccurate_prediction_count
print('Number of predictions: ', total_predictions)
print('Number of accurate predictions: ', accurate_prediction_count)
print('Number of false predictions: ', inaccurate_prediction_count)
print('Accuracy: ', accurate_prediction_count/total_predictions)
```

[ ]:
```
name =␣
↪'Sentiment_Analysis-binary-classification-BRNN-CuDNNGRU-Batchnormalization-AttentionLayer-8
```

[ ]:
```
model.save(name+'.h5')
```

[ ]:
```
# pos_count, neu_count, neg_count = 0, 0, 0
# real_pos, real_neu, real_neg = 0, 0, 0
# for i, prediction in enumerate(predictions):
#     if np.argmax(prediction)==2:
#         pos_count += 1
#     elif np.argmax(prediction)==1:
#         neu_count += 1
#     else:
#         neg_count += 1

#     if np.argmax(y_test[i])==2:
#         real_pos += 1
#     elif np.argmax(y_test[i])==1:
#         real_neu += 1
#     else:
#         real_neg +=1

# print('Positive predictions:', pos_count)
# print('Neutral predictions:', neu_count)
# print('Negative predictions:', neg_count)
# print('Real positive:', real_pos)
# print('Real neutral:', real_neu)
# print('Real negative:', real_neg)
```

[ ]:
```
!jupyter nbconvert␣
↪Sentiment_Analysis-binary-classification-BRNN-CuDNNGRU-Batchnormalization-AttentionLayer.
↪ipynb --to pdf
```

3.1 Improvements we could implement

Weight classes (because data is skew)

Train more epochs

Use bigger network

Try other word number

3.2 Resources

Recurrent Neural Networks Explained (my own post and video)

Sentiment Analysis (Wikipedia)

What is the best way to do sentiment analysis with Python? (Quora)

How to Do Sentiment Analysis (Siraj Raval)